

Appendix A

Glossary

Term	Definition
10-Year Comprehensive Review	A detailed evaluation of habitat conservation plan (HCP) implementation every decade to inform future planning and assess systemic changes needed to meet conservation objectives.
5-Year Mid-Point Check-in	A periodic review conducted halfway through each 10-year implementation cycle to assess progress toward biological goals and determine if adaptive management is needed.
Activities Not Covered	Actions not authorized under the HCP, including public recreation, herbicide application, and third-party land use not under ODF control.
Activity Center (NSO)	Specific geographic location within a northern spotted owl's core use area that is typically identified by the most biologically significant detection (known nest site or daytime location of individuals) and contains features essential for the conservation of the species and may require special management or protection.
Adaptive Management	A flexible decision-making process that adjusts conservation actions based on monitoring results and new scientific information to improve outcomes for wildlife and habitat.
Alternatives to Take	Options considered in an HCP that aim to reduce or eliminate the incidental take of federally listed species, as required under the Endangered Species Act (ESA).
Ameliorate	To improve, moderate, or reduce the severity of adverse thermal conditions, particularly extreme heat or rapid, unnatural flow fluctuations that could stress aquatic life.
Anadromous	Fish that hatch in freshwater, migrate to and spend most of their adult lives in the ocean, and then return to freshwater to spawn.
Annual Report	A yearly summary submitted by ODF to USFWS and NOAA Fisheries detailing HCP compliance, habitat changes, conservation actions, and monitoring results.
Anthropogenic	Environmental changes, pollution, or impacts caused or influenced by human activity.
Aquatic Habitat Restoration	Conservation actions aimed at improving aquatic ecosystems including, but not limited to, the placement of logs in streams, fish passage improvements, road/trail improvements or vacating, and sediment source stabilization.
Aquatic Invasive Plant Species	Nonnative plant species that colonize streamside or aquatic habitats, potentially displacing native vegetation and degrading habitat quality for native aquatic species.
Aquatic Inventories Project (AIP)	A long-term monitoring program by ODFW that assesses stream habitat conditions to support salmon and watershed conservation.
Aquatic Zone	Stream channel(s) and associated aquatic habitat features including beaver ponds, stream-associated wetlands, side channels, and channel migration zone.
Artificial Fish Passage Barrier	Human-made structures (e.g., culverts, dams) that preclude or prevent the migration of migratory aquatic species.
Barred Owl Management	Strategic removal of barred owls to reduce competition and improve survival and reproduction of northern spotted owls, conducted under a regional strategy coordinated with USFWS.

Term	Definition
Barred Owl Management Strategy	A USFWS framework to mitigate the impact of invasive barred owls on northern spotted owl populations.
Beaver Management	Conservation strategy promoting natural recolonization of beavers to enhance stream complexity and salmonid habitat.
Best Available Science	The most reliable, valid, up-to-date, and relevant, empirical knowledge that maximizes data quality and objectivity, often relying on peer-reviewed, publicly available research to inform regulatory decisions
Best Management Practices	Operational standards and techniques designed to minimize environmental impacts of land management activities, such as sediment control, timing restrictions, and equipment limitations.
Biennial Budget	A 2-year financial plan submitted by ODF to the Oregon Legislature, including funding for HCP implementation.
Biological Goals and Objectives	Required components of an HCP that define conservation targets and measurable outcomes for covered species, guiding habitat management and monitoring.
Biological Opinion	A document issued by USFWS or NOAA Fisheries that evaluates whether a federal action will harm listed species or their critical habitat.
Board Feet	A unit of measurement for the volume of lumber, sawlogs, and veneer representing a piece of wood that is 12 inches wide, 12 inches long, and 1 inch thick (144 cubic inches)
Board of Forestry (BOF)	Oregon's governing body responsible for forest policy and oversight of state forest lands, including decisions related to conservation planning.
Board of Forestry Lands (BOFL)	State-owned forest lands managed by ODF to provide long-term ecological, economic, and social benefits under the Greatest Permanent Value rule.
Borrow Site	A location where native soil or rock is extracted for use in road or landing construction, managed to prevent hydrological impacts.
Breast Height	A standard vertical reference point on a tree trunk used to measure diameter consistency across different trees, sites, and time periods.
Broadcast Burning	A controlled fire applied across a forest area to reduce fuel loads and emulate natural disturbance, used for site preparation and wildfire risk reduction.
Cable Corridors	A narrow, cleared linear path cut through a forest stand to allow for the installation and operation of cables (such as a skyline) used to transport harvested logs from the cutting area to a landing.
Candidate Conservation Agreement with Assurances	A voluntary agreement between nonfederal landowners and USFWS that provides assurances against additional regulatory requirements if a species becomes listed under the ESA.
Candidate Species	Species being considered for listing under the ESA due to threats to their survival but not yet officially listed.
Carrying Capacity	The maximum population size of a species that a specific environment can sustainably support over the long term without degrading the habitat.
Changed Circumstances	Events or conditions that can be reasonably anticipated during the permit term and for which the permittee must plan and respond with mitigation measures as outlined in the HCP.

Term	Definition
Channel Migration Zone	Area where the active channel of a stream or river is prone to move, and the movement results in a potential near-term loss of riparian function and associated habitat adjacent to the stream
Clearcut	A regeneration harvest method that removes nearly all trees in a stand, retaining minimal live trees, snags, and downed wood as required by Oregon Forest Practices Act.
Common School Forest Lands (CSFL)	Lands owned by the Oregon Department of State Lands and managed by ODF, with revenue supporting public education.
Compensatory Mitigation	The restoration, establishment, enhancement, or preservation of resources to offset remaining, unavoidable adverse impacts on species or their habitats after all appropriate and practicable avoidance and minimization measures have been applied.
Complex Forest Structure	The diverse arrangement of a forest stand characterized by multi-layered canopies with a range of species, vertical and horizontal variation, and the presence of stand elements such as gaps, snags, and downed woody material.
Compliance Monitoring	Ensure whether ODF is adhering to HCP implementation and management standards following the terms of the HCP and incidental take permits in the permit area.
Conservation Fund	A dedicated funding mechanism to support habitat restoration, species monitoring, and strategic conservation actions beyond routine forest management.
Conservation Strategy	A set of actions designed to avoid, minimize, and mitigate the impacts of covered activities on listed species, including aquatic and terrestrial restoration and enhancement projects.
Conservation Strategy Implementation Activities	Actions required under the HCP to achieve conservation goals, including habitat restoration, monitoring, and adaptive management.
Conserve	To protect from harm and destruction.
Contract Administration	Agreements between ODF and contractors for timber sales and project work that include requirements to implement conservation measures consistent with the HCP.
Covered Activity	Forest management action authorized under the HCP that may result in incidental take of listed species, such as timber harvest and road maintenance.
Covered Species	Species for which ODF seeks incidental take authorization under the ESA, selected based on range, status, impact, and data availability. Require monitoring and conservation actions to ensure their protection.
Covered Species	Species included in an HCP for which incidental take permits are sought under the ESA.
Critical Habitat	Specific geographic areas designated under the ESA that contain features essential for the conservation of a listed species and may require special management or protection.
Data Criterion	One of the four criteria used to select covered species, requiring sufficient scientific information to assess impacts and develop conservation measures.
Dispersal Habitat	Forest areas that support movement of species between habitat patches, critical for maintaining genetic diversity and population connectivity.

Term	Definition
Distinct Population Segment	A vertebrate population or group of populations that is both discrete from other populations of the species and significant in relation to the entire species.
Domestic Water Use (Type D)	A stream that has domestic water use, but no fish use.
Downed Wood Retention	Conservation practice of retaining logs and woody debris on the forest floor to support microhabitats for species like salamanders and voles.
Drainage Structure	Infrastructure such as culverts and bridges used to manage water flow across forest roads, installed and maintained to protect aquatic habitats.
EarlySeral Forest	Forest stands with little legacy structure, low tree species diversity, little shrub or herbaceous vegetation, and little downed wood.
Ecological Processes	The fundamental physical, biological, and chemical actions and interactions that drive ecosystem function.
Ecoregion	A geographically distinct area defined by ecological factors such as climate, geology, vegetation, and wildlife communities.
Ectothermic	Organisms that rely on external environmental sources to regulate their body temperature, rather than producing their own internal heat.
Edge Effects	Ecological changes that occur at the boundary between different habitat types, often resulting in increased predation, competition, or microclimate changes that degrade habitat quality for specific listed species.
Effectiveness Monitoring	Evaluate whether conservation actions are achieving biological goals and objectives for covered species and their habitats in the permit area.
Effects Pathway	A conceptual model used to trace the causal chain from a covered activity to its biological impact on a species, including stressors, behavioral responses, and population-level effects.
Endangered Species Act (ESA)	Federal law that protects species at risk of extinction and the ecosystems they depend on, enforced by USFWS and NOAA Fisheries.
Enhance	Describes actions, both active and passive, that are implemented or allowed to persist in suitable habitat for a covered species that improve quality of certain habitat features.
Environmental Deoxyribonucleic Acid (eDNA) Sampling	Environmental DNA collection from water or soil to detect the presence of species without direct observation.
Environmental Setting	The physical, biological, and ecological characteristics of a geographic area, including climate, geology, soils, hydrology, vegetation, and land use.
Environmental Variability	The natural, shifting conditions that directly influence a species habitat, demographic, and evolutionary needs over time
Equipment Restriction Zone (ERZ)	A 35-foot buffer within RCAs where ground disturbance and vegetation removal are minimized to protect streambanks and aquatic habitat.
ESA Compliance Strategies	The approaches used by ODF to meet ESA requirements in the HCP, including take avoidance, mitigation, and conservation measures for listed and sensitive species.
Essential Fish Habitat (EFH)	Waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.

Term	Definition
Evolutionary Significant Units (ESUs)	A pacific salmon population or group of populations that is substantially reproductively isolated from other conspecific populations and that represents an important component of the evolutionary legacy of the species.
Fish Passage	The ability of native migratory fish to move freely (upstream/downstream) past artificial obstructions, with minimal stress or injury, focusing on the weakest species/life stage.
Fish Salvage	The nonlethal, physical removal of fish and other aquatic organisms from an isolated in-water work area to avoid or minimize mortality during construction, repair, or hazardous environmental conditions.
Fish-Bearing Stream (Type F)	A stream with fish use, or both fish use and domestic water use.
Floodplain	A portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regime of the stream and which is covered with water when the waterway overflows its banks at flood stage.
Floodplain Connectivity	The dynamic, functional interaction between a river channel and its adjacent, low-lying land, allowing for the natural exchange of water, sediment, nutrients, and organisms
Forest Age	The time elapsed since the last major disturbance that eliminated much of the previous forest and allowed regeneration of a new stand
Forest Inventory	Data collection on forest stand characteristics such as age, species composition, and structure, used to model habitat conditions for wildlife.
Forest Management Activities	Actions such as timber harvest, road construction, and recreational infrastructure development that may result in habitat modification and incidental take of listed species.
Forest Management Plan (FMP)	An ODF regulatory document guiding forest operations, including timber harvest, road management, and conservation actions, aligned with the HCP.
Forest Structure	The vertical and horizontal arrangement of vegetation in a forest, including canopy layers, snags, downed wood, and understory diversity.
Funding Assurances	Commitments by ODF to secure and allocate sufficient funding through biennial budget requests to implement the HCP over its permit term.
Greatest Permanent Value Rule	A statutory requirement that state forests to be managed for a full range of long-term benefits, including ecological, economic, and social values to the people of Oregon.
Habitat Conservation Area (HCA)	Designated forest areas managed to conserve, maintain, and enhance habitat for terrestrial covered species within the permit area under the HCP.
Habitat Conservation Plan (HCP)	A regulatory document required under ESA Section 10 that outlines how ODF will minimize and mitigate impacts on listed species from lawful activities.
Habitat Enhancement	Actions taken to improve the quality or quantity of habitat for wildlife, often used to offset impacts from forest operations.
Habitat Fragmentation	The process whereby a continuous habitat is transformed into a series of disconnected fragments or sites, often resulting in a decrease in biodiversity, particularly for species with limited dispersal abilities.

Term	Definition
Habitat Loss	The reduction, degradation, and destruction of natural environments that eliminates essential food, water, and shelter for species.
Habitat Management	The active process of conserving, protecting, and enhancing fish, wildlife, plants, and their habitats to support species life history needs.
Habitat Metrics	Quantitative measures of habitat quality and quantity used to assess progress toward biological goals and objectives.
Habitat Quality	An ecosystem's capacity to provide the necessary resources and environmental conditions to support the survival, growth, and successful reproduction of specific species.
Habitat Quantity	The relative abundance of a habitat with regard to its ability to influence species presence and support life-history requirements of the species that use it.
Habitat Suitability Index (HSI)	A model-derived score indicating the predicted quality of habitat for a specific species, used to prioritize management actions within HCAs.
Harm (ESA Definition)	A form of take under the ESA that includes significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.
Harvest Unit	A specifically designated, delineated, and managed area, or operational boundary, of forest land where timber harvesting operations are planned and executed
Hazard Tree Removal	The selective removal of trees that pose safety risks to people or infrastructure, conducted with minimal environmental disturbance.
HCP Modification	A minor change to the HCP (e.g., correcting errors, clarifying language) that does not alter the scope or impact of the plan and is acknowledged through formal correspondence.
High-Energy (HE) Reaches	Stream segments with steep gradients and high flow velocities, often requiring wider buffers due to increased erosion and sediment transport risks.
Horizontal Distance	The linear distance between two points measured along a level, horizontal plane, rather than along the slope of the ground.
Hydrologic Unit Code (HUC)	A standardized system used by USGS to classify and identify watersheds and subwatersheds across the United States.
Hydrologically Connected	A segment of a road and/or trail where surface runoff discharges into a stream without first filtering through the forest floor.
Hydrologically Connected and Mitigated	A segment of a road and/or trail that has a direct pathway for surface water to enter a stream, but best management practices or engineering solutions have been implemented to reduce, filter, or control delivery to minimize impacts.
Hydrologically Disconnected	A segment of a road and/or trail where surface runoff does not discharge directly into a stream by first filtering surface runoff through the forest floor.
Impact Criterion	A selection criterion for covered species, requiring that the species or its habitat could be affected by covered activities.

Term	Definition
Implementation Plans	A district-level strategic document translating high-level FMPs into actionable, long-term operational goals, covering timber harvest, habitat improvement, and forest road maintenance.
Incidental Take	Unintentional take of a listed species resulting from lawful activities, authorized under ESA Section 10 through an approved HCP.
Incidental Take Permit (ITP)	A permit under ESA Section 10 issued by USFWS or NOAA Fisheries that allows ODF to conduct covered activities resulting in incidental take, contingent on HCP implementation.
Ingrowth Habitat	Forest stands that are not currently suitable habitat but are projected to develop into suitable habitat during the permit term.
Intrinsic Potential	A measure of a stream's capacity to provide high-quality habitat and support fish populations based on geomorphic and hydrologic characteristics. Used to prioritize restoration projects.
Land Acquisition and Exchange Plans	ODF planning documents identifying parcels for potential acquisition or exchange to improve forest management and conservation outcomes.
Landing	A cleared, stable area where logs are collected and loaded for transport during harvest operations, constructed and maintained under Oregon FPA standards.
Large Wood Recruitment	The natural process by which large trees fall into streams, contributing to habitat complexity, sediment retention, and fish refuge areas.
Late-Seral Forest	Forest stands begin to move into this condition between 80 and 120 years old and are characterized by complex structure, large trees, snags, and downed wood.
Limiting Factors	Environmental conditions that restrict the growth, abundance, or distribution of a species, such as water temperature, sedimentation, or habitat fragmentation.
Magnuson-Stevens Act	Federal law requiring consultation with NOAA Fisheries when federal actions may affect essential fish habitat.
Marbled Murrelet Conservation Zones	Geographic zones defined in the USFWS recovery plan to guide conservation efforts for marbled murrelet populations.
Microhabitat	A small, specific, and localized area within a larger ecosystem or habitat that possesses its own unique environmental conditions that differ from the surrounding environment.
Mid-Seral Forest	Forest stands generally 30 to 80 years old, with developing structural complexity and potential for habitat enhancement through management.
Monitoring	Systematic and repeated collection of data to track habitat conditions and species responses over time, used to assess compliance and effectiveness of conservation actions.
Mountain Beaver Control	Management of mountain beaver populations to protect young seedlings, using trapping and protective tubing.
National Environmental Policy Act (NEPA)	Federal law requiring environmental review of major actions, including ITP issuance, to assess impacts on the human and natural environment.
Native Migratory Fish	Species that migrate for their life history needs and that are listed in the rules of the State Fish and Wildlife Director.

Term	Definition
Natural Disturbance	Events caused by environmental factors that disrupt the structure and function of ecosystems, leading to change in species composition and community dynamics.
Nephelometric Turbidity Units	The standard unit used to measure the cloudiness or haziness (turbidity) of a fluid, such as water, caused by suspended particles.
No Surprises Rule	A federal regulation providing assurances to HCP permit holders that no additional mitigation will be required for unforeseen circumstances without the permittee's consent, provided the HCP is properly implemented.
No Take Alternative	A proposed approach where no forest management activities would result in take of covered species, thereby eliminating the need for an ITP. Rejected due to impracticality and conflict with ODF's mission.
Non-Fish-Bearing Stream (Type N)	All perennial or seasonal streams or reaches that are not Type SSBT or Type F streams.
North Oregon Coast Distinct Population Segment (DPS)	A genetically and geographically distinct population of red tree voles considered for conservation under the ESA.
NorWeSt Database	A regional stream temperature database and modeling tool used to predict future stream temperature scenarios based on climate change projections.
Occupied Behavior (Marbled Murrelet)	Observations indicating nesting or nesting-related activity, used as a surrogate for nest site identification in conservation planning.
One-End Suspension Cable Logging	A specialized cable yarding technique where the leading end of a log is lifted completely off the ground while the trailing end drags.
Operating Fund Balance	ODF's reserve fund used to maintain operations and HCP implementation during fluctuations in timber revenue or economic downturns.
Operational Restrictions	Seasonal or spatial limitations on forest activities to avoid disturbing nesting, denning, or breeding behaviors of covered species.
Operationally Limited Areas	Stands that are currently deemed not harvestable because they occur in areas where access is limited, or are otherwise retained in the landscape (e.g., visual barriers, geologically sensitive areas, campgrounds).
Oregon Department of Fish and Wildlife (ODFW)	The state agency that collaborates with ODF on species protection and regulatory compliance under the Oregon ESA.
Oregon Department of Forestry (ODF)	The state agency responsible for regulating Oregon's forestlands, protecting them from fire, and implementing conservation and forest management policies on State managed forestlands.
Oregon Endangered Species Act	A state law that protects listed species on state-managed lands and requires coordination with ODFW and other agencies.
Oregon Forest Practices Act (FPA)	A state law regulating commercial forest operations to ensure sustainable practices and protection of forest resources.
Oregon Plan for Salmon and Watersheds	A cooperative initiative to restore native fish populations and improve watershed health through regulatory and voluntary actions.
Oregon Scenic Waterway	A river, lake, or segment thereof, that has been designated to possess outstanding scenic, fish, wildlife, geological, botanical, historic, archaeological, and outdoor recreation values, where activities cannot affect the free-flowing character or values of present and future benefit to the public.

Term	Definition
Partial Cut Harvest	A silvicultural method that retains at least 80 square feet of basal area per acre, used to manage stand density and structure without full regeneration.
Perennial Stream	Streams that have flow year-round and may have spatially intermittent dry reaches downstream of perennial flow.
Permit Amendment	A substantial change to the HCP or ITP that affects covered species, conservation outcomes, or the scope of authorized take, requiring formal review and approval.
Permit Area	The geographic area where ODF is authorized to conduct covered activities under the HCP and where incidental take is permitted.
Permit Suspension or Revocation	Legal action by USFWS or NOAA Fisheries to suspend or revoke an ITP if the permittee fails to comply with the HCP or if continued activities threaten the survival or recovery of covered species.
Permittee	The entity authorized under an ITP to conduct covered activities in compliance with the HCP.
Persist	To continue in existence.
Physiographic Province	A region defined by its physical geography and geology, used in species recovery planning to tailor conservation strategies.
Pile Burning	Burning of machine-piled slash following harvest, conducted outside riparian conservation areas to reduce fuel loads.
Plan Area	The broader area analyzed in the HCP, including current and potential future ODF-managed lands.
Potential Debris Flow Tracks (PDFTs)	Seasonal stream reaches identified as having high potential for debris flows, requiring enhanced riparian protections.
Precommercial Thinning	The removal of excess young trees to improve stand health and growth, typically performed once in a stand's life cycle.
Process Protection Zones (PPZs)	Specialized buffer zones upstream of fish-bearing streams to mitigate temperature increases and sedimentation from upstream non-fish-bearing streams.
Process-Based Restoration (PBR)	A silvicultural technique used in RCAs to accelerate late-seral forest development by thinning overstocked young stands to improve habitat quality.
Quarry	A site where rock is extracted for road surfacing and other uses, operated under environmental regulations and reclaimed when no longer active.
Range Criterion	A selection criterion for covered species, requiring that the species occurs or is expected to occur in the plan area.
Recovery Plan	A document outlining actions necessary to recover and conserve a listed species, including habitat protection, monitoring, and threat mitigation.
Reduced Covered Activities Alternative	An alternative that excludes certain activities (e.g., road and recreational infrastructure construction/maintenance) from the HCP to reduce take. Rejected due to operational necessity and limited conservation benefit.
Reduced Covered Species Alternative	An alternative that limits HCP coverage to currently listed species, excluding those expected to be listed during the permit term. Rejected due to reduced conservation benefits and increased future regulatory burden.

Term	Definition
Reduced Habitat Loss from Timber Harvest Alternative	An alternative involving reduced timber harvest to minimize habitat loss and incidental take. Rejected due to economic infeasibility and reduced long-term habitat quality.
Reforestation	The planting of trees following harvest to meet stocking standards and promote forest regeneration, including initial planting and interplanting.
Regeneration Harvest	A silvicultural treatment that removes all or a significant portion of a mature stand to create a new, young forest.
Relative Density/Stand Density Index (SDI)	A metric used to guide thinning prescriptions based on tree density and size, influencing forest structure and habitat quality.
Remedial Measures	Actions taken by the permittee to address changed circumstances, including habitat restoration, harvest deferral, or other management adjustments to maintain compliance with HCP commitments.
Resilient	An ecosystem's ability to withstand disturbances and rapidly adapt and recover to maintain its essential functions, structure, and processes rather than collapsing into a degraded state.
Riparian Area	The ground along a water of the state where the vegetation and microclimate are influenced by year-round or seasonal water, associated with high water tables, and soils which exhibit some wetness characteristics.
Riparian Conservation Area (RCA)	A designated, protected buffer zone along streams, rivers, and lakes that vary in width based on stream type and slope designed to maintain or restore aquatic and riparian-dependent species habitat.
Riparian Reserve	A designated area adjacent to streams and rivers managed to protect aquatic habitats and species, often part of federal conservation plans.
Road System Management	Activities related to the construction, maintenance, use, and vacating of forest roads, conducted to minimize environmental impacts.
Safe Harbor Agreement (SHA)	A voluntary agreement between USFWS and other nonfederal or private property owners that provides regulatory assurances to landowners who contribute to the recovery of listed species.
Salmon, Steelhead, Bull Trout (Type SSBT)	A stream that is classified as a Type F stream and has SSBT use.
Salvage Harvest	Timber removal following disturbance events, conducted to recover value and support reforestation, with restrictions in RCAs and HCAs.
Salvage Logging	The removal of dead, damaged, or dying trees from a forest following natural disturbances to recover economic value, manage safety, or reduce fuel loads
Scoping Team	A group of technical experts from state and federal agencies who advised ODF during HCP development by providing scientific and regulatory input, guidance, and provided recommendations to the Steering Committee to consider.
Seasonal Stream	Streams that do not have surface flow during at least some portion of the year.
Section 10 (ESA)	Allows nonfederal entities to obtain incidental take authorization through development of an HCP.
Section 7 (ESA)	Requires federal agencies to consult with USFWS or NOAA Fisheries to ensure actions do not jeopardize listed species or critical habitat.

Term	Definition
Seral Stage	A phase in forest development following disturbance, ranging from early seral (young stands) to late seral (old growth conditions).
Significant Observations (MAMU)	Observations indicating nesting or nesting-related activity, used as a surrogate for nest site identification in conservation planning.
Silvicultural Prescription	A forest management plan detailing thinning, regeneration, or other treatments to achieve desired habitat conditions for covered species.
Site Preparation	Treatments applied to harvested areas to improve conditions for seedling establishment, including mechanical and pile burning methods.
Slash Piling	A forestry practice of gathering residual woody debris (branches, tops, limbs, stumps) left after logging and piling it into heaps to reduce fire hazards and clear the land for replanting. Piles are often burned during winter or wet conditions.
Slope Distance	The actual length measured along the surface of the ground, rather than the horizontal distance between two points.
Snag Retention	Conservation practice of preserving standing dead trees (snags) to provide nesting, roosting, and foraging habitat for birds and mammals.
Solar Radiation	Energy radiated from the sun in the form of electromagnetic waves, including visible and ultraviolet light and infrared radiation.
Species Distribution Model (SDM)	A predictive tool used to estimate the geographic distribution of a species based on habitat characteristics and occurrence data.
Species Listing Forecasting	The process of identifying species likely to be listed under the ESA during the HCP permit term, to proactively include them in conservation planning.
Species Monitoring	Surveys conducted to assess the presence, abundance, and habitat use of covered wildlife species.
Species Occupancy	The presence of a species in a specific habitat area, used to assess conservation success and guide management decisions.
Species of Conservation Concern	Fish or wildlife species at risk of long-term decline or extinction, requiring targeted management to ensure their persistence.
Species Selection Criteria	Scientific and regulatory standards used to determine which species are eligible for HCP coverage, including range, status, impact, and data availability.
Stand Level Inventory (SLI)	Acquires and updates state forest vegetation information at the specific site level (forest stand). This information is used for tactical and operational decision-making. The SLI includes vegetation sampling protocols, forest stand data arranged in a database, computer programs for managing and using the information, and documentation of inventory elements.
Stand Management Activity	The control of tree density within a forest stand to optimize growth and productivity, balancing objectives such as individual tree size and total volume.
State Land Board	A constitutional body overseeing CSFL, composed of Oregon's Governor, Secretary of State, and Treasurer.
Stay-Ahead Provision	A regulatory requirement ensuring that habitat gains from conservation actions exceed habitat losses from covered activities over time.

Term	Definition
Steering Committee	A group of government agency and academic institution representatives who advised ODF on achieving a mutually acceptable HCP outcome that satisfies regulatory requirements under the Endangered Species Act while balancing stakeholder interests, and provided direction and support to the Scoping Team.
Stockpile Site	A location where rock or equipment is stored for future use, managed to prevent hydrological impacts and located outside RCAs.
Strategic Terrestrial Species Conservation Actions	Targeted conservation efforts for terrestrial species (e.g., barred owl management, research on red tree vole and coastal marten), funded through the Conservation Fund.
Stream Complexity	The structural diversity of stream channels, including pools, wood, floodplain connectivity, and sinuosity, which supports aquatic species habitat.
Stream Enhancement Projects	Restoration activities aimed at improving aquatic habitat conditions, such as adding large woody debris, improving fish passage, and stabilizing stream banks.
StreamNet	A cooperative data management project providing fish distribution and habitat data for conservation planning.
Stumpage Price	The price paid per 1,000 board feet (MBF) of timber sold, which influences the amount allocated to the Conservation Fund.
Suitable Habitat	An area characterized by specific environmental variables that meet the life-history requirements of fish and wildlife species, allowing for a species to survive and support a population long-term.
Swiss Needle Cast (SNC)	A foliage disease specific to Douglas fir caused by the fungal pathogen <i>Nothophaeocryptopus gaeumannii</i> . SNC symptoms include yellow needles and decreased needle retention, resulting in sparse crowns and reduced diameter and height growth.
Tailhold/Guyline Anchors	Logging equipment attachments that must be carefully placed to avoid damaging trees with nesting platforms or other critical habitat features.
Take	Under the ESA, refers to actions that harm, harass, kill, or otherwise negatively affect a listed species, including habitat modification.
Take Impact Assessment	An evaluation of the context, intensity, and duration of effects from covered activities on the survival, reproduction, and distribution of covered species.
Targeted Actions Outside HCAs and RCAs	Management activities conducted outside designated conservation areas to support habitat connectivity and species persistence.
Technical Assistance	Guidance provided by USFWS, NOAA Fisheries, or ODFW to help ODF interpret and implement the HCP, especially in situations not clearly defined by the plan.
Thermal Refugia	Specific, localized habitats such as deep pools, groundwater springs, or shady patches that maintain cooler temperatures than surrounding areas.
Thinning (Light, Moderate, Heavy, Variable Density)	Silvicultural treatments that reduce tree density to improve forest health and structure, with varying intensities and ecological outcomes.
Threatened Species	Species that are likely to become endangered in the near future and are protected under the ESA.

Term	Definition
Timber Sale Revenue	The primary funding source for ODF's State Forests Division, derived from the sale of timber harvested from state forestlands.
Tree Planting	The establishment of new forest stands through planting, with species selection and density tailored to site conditions and climate resilience goals.
Turbidity Monitoring	Tracking water quality to assess sediment levels in streams, which can affect aquatic species like salmon and salamanders.
Unauthorized Take	Any action, intentional or negligent, that results in take of a protected species or its habitat without a specific permit or authorization.
Underburning	A controlled fire beneath forest canopy used to reduce ladder fuels and improve forest health, with potential future expansion due to climate change.
Unforeseen Circumstances	Events that could not reasonably be anticipated during HCP development and result in substantial and adverse changes to the status of covered species.
Unmanned Aircraft System (UAS)	Drones used for forest monitoring, mapping, and operational support, including surveys and equipment deployment.
Upland Restoration Activities	Management of forest stands to improve habitat quality for terrestrial covered species, including reforestation and treatment of marginal stands.
Vacating Roads and Trails	The process of decommissioning roads or trails to prevent resource damage, including stabilization and removal of drainage structures.
Variable Density Thinning	A silvicultural technique combining multiple thinning intensities within a stand to mimic natural forest heterogeneity and improve habitat complexity.
Water Temperature Monitoring	Tracking stream temperatures to ensure compliance with water quality standards and suitability for cold-water aquatic species.
Watershed Restoration	Activities aimed at improving the health of a watershed to support aquatic and terrestrial species, often part of broader conservation plans.
Wetlands (NWI Classification)	Areas classified by the National Wetlands Inventory, including riverine, forested/shrub, and emergent wetlands, important for aquatic species and ecosystem services.
Wildfire Hazard	The likelihood of wildfire occurrence based on vegetation, climate, and topography, used in risk assessments and forest planning.
Windthrow	The uprooting or breaking of trees caused by the force of strong winds, typically when wind energy exceeds a tree's stem or anchor strength. Also known as blowdown.
Yarding Corridor	Pathways used during logging to transport felled trees; their placement within RCAs is regulated to minimize habitat disturbance.
Young Stand Management	Silvicultural practices designed to promote the growth, health, and quality of trees after the initial reforestation phase.

Appendix B

Stakeholder Engagement

Western Oregon State Forests Habitat Conservation Plan: Stakeholder and Public Engagement Report

as of August 2026

CONTEXT AND INTRODUCTION

The purpose of the Western Oregon State Forests Habitat Conservation Plan (HCP) process was to develop potential options for reaching mutually agreeable conservation, forest management and financial outcomes through incidental take permits from the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NOAA Fisheries). In October of 2020, the Board of Forestry (BOF) gave direction to the State Forests Division to continue the development of the HCP. The Administrative Draft HCP entered the National Environmental Policy Act (NEPA) process in March 2021 and a Public Draft HCP was shared with the public in March 2022. A key goal of the HCP process was to provide information and engage in dialogue with all Oregonians who wanted to weigh in on these important planning efforts.

The project team included Oregon Department of Forestry (ODF) staff, ICF, and Kearns & West. Kearns & West led the facilitation of committees and stakeholder and public outreach and ICF led the technical and HCP development work. Oregon Consensus was engaged in stakeholder coordination early in the HCP process. The project team developed and implemented a comprehensive stakeholder and public engagement process to ensure that interested parties had opportunities to provide meaningful input on the development of the HCP. Kearns & West developed a stakeholder engagement and communications plan that guided stakeholder and public involvement during the HCP development process.

The following report serves as a high-level summary of the stakeholder and public engagement efforts, including the engagement approach, goals, and activities.

STAKEHOLDER ENGAGEMENT APPROACH AND GOALS

Public engagement is critical for an effective HCP process. ODF worked closely with sister agencies and partners to develop the HCP as part of the Scoping Team (ST), a technical level working group, and the Steering Committee (SC), a policy level working group. To supplement the ST and SC, Kearns & West and Oregon Consensus worked directly with stakeholders from a range of interests to design a public engagement process responsive to stakeholder feedback.

The goals of the stakeholder engagement process included:

- Provide counties, stakeholders, and interested parties with opportunities to provide feedback at key points throughout the process.
- Engage counties as part of the Forest Trust Land Advisory Committee, and as part of the overall engagement effort.
- Keep interested parties informed at all major milestones through timely updates and information.
- Allow diverse interests to hear and learn from one another's perspectives.
- Provide clear expectations for how stakeholder and public input will be used and integrated into the Western Oregon State Forests HCP product.
- Build a common understanding of the expected results of HCP implementation.
- Align engagement and outreach opportunities with related processes, such as the Western Oregon State Forest Management Plan (FMP).

- Keep stakeholders informed to promote relevant comments during the Western Oregon State Forests HCP NEPA Process.

The engagement strategy also outlined a structure and process for stakeholder input and review of HCP elements. This structure was implemented throughout HCP development. Under the structure, the ST developed technical recommendations for the SC to consider when advising the ODF State Forests Division Chief. The SC provided overall guidance for the HCP process and provided direction and support to the ST.

After both the ST and SC reached alignment on key technical components and decision points for the HCP, the project team held large meetings open to the public to provide updates on the HCP process and present information on the development of the HCP. Follow-up meetings with stakeholder groups were scheduled upon request to further discuss the information presented during the meetings open to the public and to dive deeper into the details of the HCP.

Key stakeholder and public engagement activities are outlined below and include details on the convening interviews, SC and ST meetings, meetings open to the public, stakeholder meetings, and county engagement.

CONVENING INTERVIEWS

SC and ST Convening Interviews

To kick-off the HCP stakeholder engagement process, Kearns & West conducted interviews with each entity in the ST and SC to learn about agency roles and responsibilities, interests, and issues, as well as to hear any ideas and suggestions on how to provide a productive and constructive process. The goal of the interviews was to gather information to help ensure the process strives for a mutually satisfactory and successful outcome to development of a potential Western Oregon HCP. At the conclusion of the interview process, Kearns & West developed process recommendations for any future HCP process.

Kearns & West conducted 15 interviews with individuals of the following entities: NOAA Fisheries, Oregon Department of Fish and Wildlife, Oregon Department of Environmental Quality, Oregon Department of State Lands, United States Fish and Wildlife Service, Oregon Department of Forestry, , and Oregon State University.

Stakeholder Convening Interviews

Kearns & West also interviewed key stakeholders to learn about their interests and concerns as it relates to the development of a Western Oregon HCP as well as to hear any ideas and suggestions for how to provide a productive public engagement process. The goal of the interviews was to gather information to help ensure an open and transparent process to keep stakeholders engaged in the development of a potential Western Oregon HCP. At the conclusion of the interview process, Kearns & West developed recommendations for the future HCP public engagement processes.

Kearns & West conducted nine interviews with individual stakeholders and four small group interviews. Members of the following groups were invited to participate in the stakeholder interviews: Oregon Forests Conservation Coalition and Conservation Collaboration, Industry Adhoc, State Forests Advisory Committee, and the Forest Trust Land Advisory Committee. The invitation included over 80 stakeholders.

SC AND ST MEETINGS

ODF has continued to work with sister agencies and partners throughout the development of the HCP as part of the SC and ST. The SC consists of government agency representatives. Members voluntarily work together to provide advice on how ODF can achieve a mutually acceptable outcome that satisfies, to the greatest degree possible, the interests of all participants. The role of the SC is to provide overall guidance for the HCP process and to provide direction and support to the ST.

The HCP ST is comprised of terrestrial and aquatic biologists and technical specialists from state and federal agencies. Members provide the SC with technical information needed to evaluate potential policy options for ODF's consideration. The role of the ST is to provide technical expertise and to develop technical recommendations for the SC to consider when advising the Division Chief in the development of a potential HCP.

The SC and ST have met extensively throughout the project to develop the HCP and have worked collaboratively to develop the HCP since April 2018. By July 2026, the project team conducted 41 SC meetings and 72 ST meetings. The project team also conducted 12 joint SC and ST meetings to ensure there was agency alignment on the HCP. There were additional small group meetings with SC and ST members throughout the HCP development process to better understand agency interests, discuss specific technical topics, and seek alignment on key components of the HCP.

PUBLIC MEETINGS

The project team has conducted a total of twelve Western Oregon HCP meetings open to the public. The meetings open to the public included updates on the HCP process, presentations, and question and answer/discussion periods which were followed by informal discussion periods with meeting participants to discuss topics of most interest to participants. The first three meetings were held in-person in Salem and offered a livestream option. The final nine meetings were held via webinar due to COVID-19 concerns and safety precautions. ODF notification methods to inform stakeholders and the public about the meetings included:

- Email distributions to interested parties
- Posts on ODF social media including Facebook and X (formerly Twitter).
- Meeting notice via FlashAlert to media in areas that would be potentially covered in the HCP (including Portland media)
- Posts on the ODF news site
- Posts on the Western Oregon HCP project webpage
- Posts on the State of Oregon Transparency website
- Letter from ODF to specifically invite county commissioners

The meetings open to the public received strong participation and engagement. Attendance has ranged from approximately 15 to over 100 participants. The following is a list of the meetings that were open to the public and an overview of the number of attendees and the topics discussed.

- **March 21, 2019 Meeting Open to the Public**
 - Attendees: 24 individuals attended the public kick-off meeting and an additional 31 individuals participated in the livestream.
 - Meeting purpose:
 - To introduce the Western Oregon HCP Phase 2 process to a wide range of stakeholders.

- Present Phase 2 scope of work and schedule.
- Explain the process, including role of SC, ST, and stakeholder engagement.
- **June 12, 2019 Meeting Open to the Public**
 - Attendees: 26 individuals attended the meeting open to the public and an additional 21 individuals participated in the livestream.
 - Meeting purpose:
 - Provide updates on various elements of the HCP including: the permit and plan area, the covered species list, expected covered activities, existing conditions, and the data used in developing the HCP.
 - Present and discuss the proposed Mission, Vision and Goals that will help guide the direction and future of the HCP.
 - Present and discuss the overall HCP stakeholder engagement process.
- **October 15, 2019 Meeting Open to the Public**
 - Attendees: Seven individuals attended the meeting open to the public and an additional six people joined via livestream.
 - Meeting purpose:
 - Discuss the final draft of the Mission, Vision and Goals that will help guide the direction and future of the HCP.
 - Present and discuss the Western Oregon HCP conceptual Biological Goals and Objectives.
 - Share upcoming topics including: Conservation Actions, Impact Mechanisms, Effects Analysis, and Timber Modeling.
- **March 20, 2020 Meeting Open to the Public**
 - Attendees: Over 50 members of the public attended via webinar.
 - Meeting purpose:
 - Present the forest goals and objectives associated with the HCP.
 - Provide updates about the Western Oregon HCP's development and the status of conservation strategies, including:
 - A high-level overview of the methodology for habitat modeling and timber harvest modeling.
 - The conceptual framework of aquatic and terrestrial conservation strategies.
- **July 13, 2020 Meeting Open to the Public**
 - Attendees: Over 100 members of the public attended via webinar.
 - Meeting purpose:
 - Present the components of the aquatic and terrestrial conservation strategies.
 - Provide the results of the aquatic conservation strategy modeling and species habitat modeling.
 - Discuss policy-level forest management modeling.
- **September 16, 2020 Meeting Open to the Public**
 - Attendees: Over 100 members of the public attended via webinar.
 - Meeting purpose:

- Provide updates on the development of the draft HCP.
 - Discuss the HCP Conservation Strategy.
 - Share the information that will be presented to the Board of Forestry in October to help the Board make a decision whether to move forward with an HCP.
- **May 6, 2021 Meeting Open to the Public**
 - Attendees: Over 70 members of the public attended via webinar.
 - Meeting purpose:
 - Hear updates on the Draft Western Oregon State Forests HCP.
 - Hear updates on the HCP NEPA process.
 - **August 10, 2021 Meeting Open to the Public**
 - Attendees: Over 70 members of the public attended via webinar.
 - Meeting purpose:
 - Hear updates on the Draft Western Oregon State Forests Administrative Draft HCP.
 - Hear updates on the HCP NEPA process.
 - **October 12, 2021 Meeting Open to the Public**
 - Attendees: 40 members of the public attended via webinar.
 - Meeting purpose:
 - Hear updates on the Draft Western Oregon State Forests Administrative Draft HCP.
 - Hear updates on the HCP NEPA process.
 - **December 7, 2021 Meeting Open to the Public**
 - Attendees: Over 50 members of the public attended via webinar.
 - Meeting purpose:
 - Hear updates on the Draft Western Oregon State Forests Administrative Draft HCP.
 - Hear updates on the HCP NEPA process.
 - **February 7, 2023 Meeting Open to the Public**
 - Attendees: Close to 100 members of the public attended via webinar.
 - Meeting purpose:
 - Hear updates on the HCP NEPA process.
 - **August 23, 2023 Meeting Open to the Public**
 - Attendees: Close to 40 members of the public attended via webinar
 - Meeting purpose:
 - Hear updates on the HCP NEPA process.
 - Hear updates on the Draft Forest Management Plan (FMP), Draft Adaptive Management Plan (AMP), and Draft Performance Measures.

STAKEHOLDER MEETINGS

Following the meetings open to the public, the project team conducted stakeholder meetings with a cross-section of interests upon request from stakeholders. The purpose of these stakeholder meetings was to further discuss and provide additional details on the topics presented during the meetings open to the public as well as to have an open conversation with various interests to hear stakeholders' feedback, thoughts, concerns, and any additional information they would like the project team to

consider during the development of the HCP. The project team met with the following stakeholder groups: Conservation interests, industry representatives, recreation interests, and the State Forests Advisory Committee.

The following is a list of the focused stakeholder meetings and an overview of the number of attendees and the topics discussed.

Joint Stakeholder Meetings Representing Multiple Interests:

- April 8, 2020
 - Attendees: 21 stakeholders attended the meeting.
 - Meeting purpose:
 - Introduce the terrestrial species habitat modeling.
 - Introduce the riparian habitat modeling.
 - Introduce the timber harvest modeling.
- August 6, 2020
 - Attendees: 32 stakeholders attended the meeting.
 - Meeting purpose:
 - Present and discuss the conservation strategies and forest management approach including:
 - Overview of the approach to how Habitat Conservation Areas (HCAs) were designed and developed.
 - Management of the forest: Approach to management of forests on the landscape, both inside and outside of HCAs.
 - Policy-level forest management modeling update.
 - Next Steps: Expectations for information that will be available for the September 16 meeting open to the public.
 - Discussion on topics of most interest to participants.
- September 24, 2020
 - Attendees: 42 stakeholders attended the meeting.
 - Meeting purpose:
 - Further discuss topics presented during the September 16 meeting open to the public.
 - Discussion on topics of most interest to participants.
- December 3, 2020
 - Attendees: 32 stakeholders attended this meeting.
 - Meeting purpose:
 - Provide updates on the development of the HCP since the October 6 Board of Forestry meeting and share updates on the technical elements.
 - Discuss the processes, next steps, and timelines for the HCP, FMP, and NEPA.
 - Provide updates on the Santiam State Forest fire response and restoration efforts.
 - Discuss topics of most interests to participants.

Stakeholder Meetings with Conservation Interests:

- October 2, 2019
 - Attendees: Eight stakeholders attended the meeting.
 - Meeting purpose:

- Discuss Western Oregon State Forests HCP Mission, Vision and Goals.
- Present and discuss the conceptual Biological Goals and Objectives for species covered under the HCP.
- Learn overall interests for the Western Oregon HCP.
- Discuss future engagement with stakeholders.
- December 9, 2019
 - Attendees: 11 stakeholders attended the meeting.
 - Meeting purpose:
 - Overview of Western Oregon HCP current activities, including the terrestrial and riparian strategies.
 - Discussion on conservation groups' interest and inputs for the Western Oregon HCP.
- March 13, 2020
 - Attendees: Three stakeholders attended the meeting.
 - Meeting purpose:
 - Discuss the terrestrial species conservation strategy.
- January 21, 2021
 - Attendees: Eight stakeholders attended the meeting.
 - Meeting purpose:
 - Share updates on the development of the HCP.
 - Discuss and seek feedback on the draft HCP.
 - Discuss the HCP, FMP, and NEPA processes and timeline.
- June 24, 2021
 - Attendees: Two stakeholders attended the meeting.
 - Meeting purpose:
 - Share updates on the development of the HCP related to drinking water.
 - Discussion on the connection between drinking water and forest health.

Stakeholder Meetings with Industry Representatives:

- September 19, 2019
 - Attendees: Five stakeholders attended the meeting.
 - Meeting purpose:
 - Present the Western Oregon State Forests HCP Mission, Vision and Goals.
 - Present and discuss the conceptual Biological Goals and Objectives for species covered under the HCP.
 - Learn overall interests for the Western Oregon HCP.
 - Discuss future engagement with stakeholders.
- January 27, 2020
 - Attendees: Five stakeholders attended the meeting.
 - Meeting purpose:
 - Overview of Western Oregon HCP progress and products to date including:
 - HCP Timeline and Process
 - Biological Goals and Objectives
 - Terrestrial and Riparian Strategies
 - Discussion on industry groups' interest and inputs for the Western Oregon HCP.
- February 4, 2021
 - Attendees: Nine stakeholders attended the meeting.

- Meeting purpose:
 - Share updates on the development of the HCP.
 - Discuss and seek feedback on the draft HCP.
 - Discuss the HCP, FMP, and NEPA processes and timeline.

Stakeholder Meetings with Recreation Interests:

- December 19, 2019
 - Attendees: Five stakeholders attended the meeting.
 - Meeting purpose:
 - Review Western Oregon HCP products to date.
 - Overview of Western Oregon HCP process.
 - Discuss interests of recreation groups for the Western Oregon HCP.
- February 3, 2021
 - Attendees: Six stakeholders attended the meeting.
 - Meeting purpose:
 - Share updates on the development of the HCP.
 - Discuss and seek feedback on the draft HCP.
 - Discuss the HCP, FMP, and NEPA processes and timeline.

State Forests Advisory Committee Meetings:

ODF attended the following State Forests Advisory Committee meetings, provided updates on the development of the HCP, and sought SFAC feedback:

- 2019: October 25, December 9
- 2020: April 24, June 19, September 17, October 23
- 2021: April 23, June 11, October 29
- 2022: April 8, June 24, October 28
- 2023: April 7, June 2, October 27
- 2024: March 8
- 2025: May 16, October 24
- 2026: March 20, May 15

Forest Trust Land Advisory Committee Meetings

ODF attended the following Forest Trust Land Advisory Committee (FTLAC) Meetings, provided updates on the development of the HCP, and sought FTLAC feedback:

- 2018: October 26
- 2019: April 12, July 19, August 23
- 2020: None (all meetings cancelled)
- 2021: February 19, May 28, August 27, December 3
- 2022: February 18, April 29, August 12, November 4
- 2023: None (all meetings focused on the FMP)
- 2024: February 23
- 2025: February 21
- 2026: None (all meetings focused on the FMP)

Meetings with Individual Stakeholders:

ODF and the project team engaged in dozens of individual meetings and phone calls with individual

stakeholders throughout Phase 2 to check in on the development of the HCP and to understand their interests, concerns, feedback, and suggestions as it relates to the HCP.

COUNTY ENGAGEMENT

ODF and the project team engaged with the counties throughout Phase 2 of the process. ODF and the project team had several in-person meetings and phone calls with county representatives, members of the Forest Trust Land Advisory Committee, and members of the Association of Oregon Counties. ODF continues to engage with counties as the HCP moves forward into the NEPA process.

Appendix C

Species Accounts

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C1 Oregon Coast Coho (*Oncorhynchus kisutch*)

The Oregon Coast coho salmon evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Oregon Coast coho salmon ESU includes rivers and streams originating from the Oregon Coast range, except for the Umpqua River, which extends east through the Oregon Coast Range to originate from the Cascade Mountains.

Legal Status

State: Sensitive species

Federal: Threatened (National Marine Fisheries Service 2008, final rule 2011)

Critical Habitat: Designated (National Marine Fisheries Service 2008, reaffirmed 2011)

Recovery Planning: Recovery plan approved (National Marine Fisheries Service 2016a)

Status Review: 5-year status review (National Marine Fisheries Service 2016b)



Photo: Native Fish Society

Oregon Coast coho salmon are listed as a sensitive species under the Oregon State Sensitive Species List (OAR 635-100-0040) and are not listed under the Oregon Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135). Oregon developed the Oregon State Coast Coho Conservation Plan for the same populations as the federal listing to address the conservation concerns for the species. The Oregon Coast Coho Conservation Plan addresses legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The conservation plan was approved by the Oregon Fish and Wildlife Commission in March 2007.

Taxonomy

Coho salmon (*Oncorhynchus kisutch*) were first described by Walbaum in 1792. Coho are one of five recognized species of Pacific Salmon (*Oncorhynchus spp.*) that occur in North America.

Distribution

Coho salmon distribution is described for their entire range, the Oregon Coast ESU, and independent populations that intersect the HCP plan area and Oregon Department of Forestry (ODF) managed lands.

General

In North America, coho salmon originally ranged from Waddell and Scott creeks in Santa Cruz County, California, to Point Hope on the northwest corner of Alaska (Sandercock 1991). Botkin et al. (1995) estimated that coho salmon are no longer present (extirpated) from approximately 46% of their historic range in North America and 3.5% of their original range in Western Oregon and Northern California.

The Oregon Coast coho salmon ESU (Figure C1-1) includes the Pacific Ocean and the freshwater and estuarine habitat along the Oregon Coast from the Necanicum River on the north to the Sixes River on the south. Rivers in the ESU originate from the Oregon Coast Range, except for the Umpqua River, which extends east through the Oregon Coast Range to drain the Cascade Mountains.

The Oregon Department of Fish and Wildlife (ODFW) identified three gene conservation groups (GCGs) within the ESU: (1) North/Mid Coast to Siuslaw River, (2) Umpqua River, and (3) Mid/South Coast to Cape Blanco/Sixes River (Kostow 1995). A fourth, lake population group was subsequently identified, and the northern GCG was divided into two areas based on geographic diversity within this population group. The result is five biogeographic strata across the ESU (Lawson et al. 2007).

Across the five strata a total of 56 historical populations were identified and were classified as either Dependent or Independent (Lawson et al. 2007). Independent populations are those that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years. Across the five strata 21 independent populations were identified. Many of the identified dependent populations within the five biogeographic strata are in small coastal streams with limited freshwater habitat available for coho salmon spawning and rearing.

Historically adult coho salmon were widely distributed in streams across the ESU accessible to migrating adults and had favorable channel gradients for spawning. Burnett et al. (2007) reviewed several studies comparing reach gradient and juvenile coho salmon presence and no presence in streams greater than 7%.

The ESU recovery strategy calls for achieving sustainable independent populations within the ESU. NMFS set two recovery criteria for recovery of the Oregon Coast coho salmon ESU: (1) a majority of the independent populations in each stratum must be sustainable and (2) all five strata must be sustainable for the whole ESU to be sustainable (National Marine Fisheries Service 2016a).

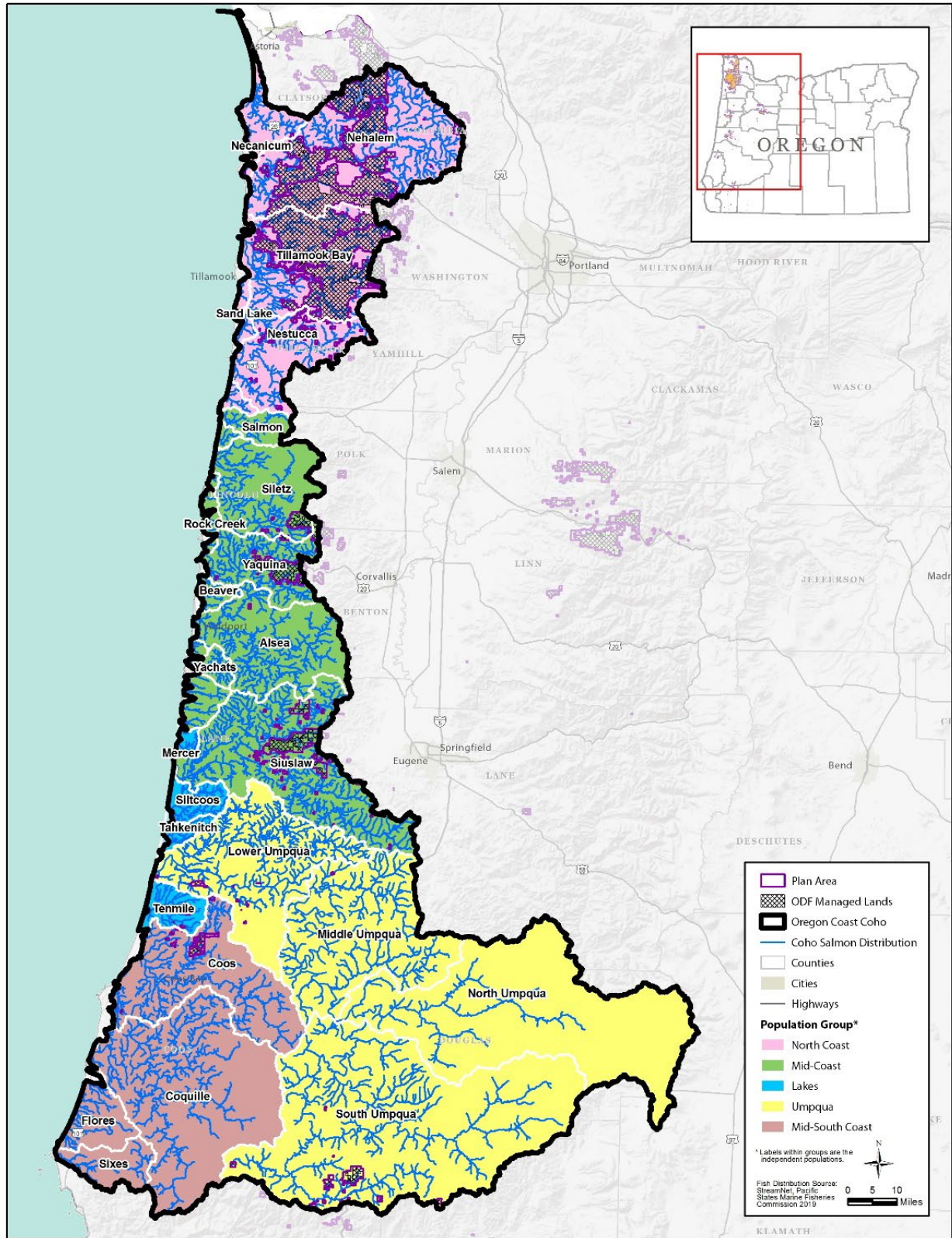


Figure C1-1. Oregon Coast Coho (*Oncorhynchus kisutch*) Biogeographic Strata and Independent Populations

Occurrences Within the Plan Area

Not all independent populations of coho salmon intersect or adjoin the plan area. However, across the entire ESU the following ten independent populations intersect portions of the plan area (Figure C1-1) (from north to south): (1) Necanicum, (2) Newhalem, (3) Tillamook Bay (includes Trask, Wilson, Tillamook, Miami, and Kilchis), (4) Nestucca, (5) Siletz, (6) Yaquina, (7) Siuslaw, (8) Tenmile, (9) South Umpqua, (10) Lower Umpqua, and (11) Coos.

Miles of streams with ODFW documented or assumed coho salmon presence within the plan area are summarized in Table C1-1. Stream miles are identified for independent populations by strata. The Newhalem and Tillamook Bay independent populations have the highest percentage of stream miles with coho salmon presence within the plan area.

Natural History

Oregon Coast Coho salmon typically have a 3-year life cycle. The typical freshwater period from the start of egg incubation to seaward migration is approximately 18 months. Adults return to fresh water and spawn between November and March after 18 months in the ocean. Each female deposits about 2,500 eggs into a redd formed in the stream. These eggs hatch in late winter, and alevins remain in the gravel until spring. In the spring the young coho salmon fry emerge from the gravel and begin to feed through spring, summer, and winter before migrating to sea the following spring.

Life History and Habitat Requirements

Coho salmon in North America inhabit small coastal streams as well as the largest rivers in western North America. Within larger river systems, coho salmon spawning is typically distributed in tributaries to the mainstem river. This pattern of spawning principally in smaller streams has given coho salmon a reputation of being primarily associated with small rivers and streams (Behnke 2002).

Sandercock (1991) described spawning distribution of coho salmon as follows:

Their success as a species may be partly attributed to their utilization of a myriad of small coastal streams and to their aggressiveness and apparent determination to reach the small headwater creeks and tributaries of larger rivers to spawn. In many cases, they overcome difficult obstructions to reach areas inaccessible to other salmon and then share these locations with only migrant steelhead or perhaps resident cutthroat trout. These small headwater streams generally provide cool, clear, well-oxygenated water, with stable flows that are ideal for incubation and subsequent rearing.

Table C1-1. Miles of Coho Salmon Known or Presumed Coho Salmon Presence

Biogeographic Stratum and Population	Stream Miles with Known or Presumed Coho Salmon Presence		
	Total Stream Miles	Miles Within Plan Area	Percent of Total Within Plan Area
North Coast Stratum	1,643	480	29%
Necanicum River	100	1	1%
Nehalem River	769	242	31%
Tillamook River	0	0	0%
Tillamook Bay	461	233	51%
Nestucca River	256	4	2%
Sand Lake	57	0	0%
North Coast Dependents	0	0	0%
Mid Coast Stratum	2,101	41	2%
Salmon River	58	0	0%
Siletz River	284	7	3%
Yaquina River	280	0	0%
Beaver Creek	56	0.6	1%
Alsea River	424	0	0%
Siuslaw River	841	34	4%
Siuslaw River	63	0	0%
Rock Creek	44	0	0%
Yachats River	52	0	0%
Mid Coast Dependents	0	0	0%
Lakes Stratum	262	0.8	0.3%
Siltcoos Lake	97	0	0%
Mercer Lake	24	0	0%
Tahkenitch Lake	53	0	0%
Tenmile Lake	90	0.8	1%
Umpqua Stratum	2,202	12	1%
Lower Umpqua River	610	2	0.4%
Middle Umpqua River	559	0.3	0.1%
North Umpqua River	216	0	0%
South Umpqua River	816	9	1%
Mid South Coast Stratum	1,273	14	1%
Coos River	483	14	3%
Coquille River	598	0	0%
Floras Creek	120	0	0%
Sixes River	72	0	0%
Mid South Coast Dependents	0	0	0%

Source: Streamnet 2019.

Spawning

Females typically construct redds at the head of a riffle or in a pool tailout over substrate sized less than 15 centimeters (Sandercock 1991). Redds are located to maximize water circulation and oxygenation of the egg pocket.

Incubation

The factors most often associated with poor incubation survival of coho salmon are fine sediment and bed scour. Fine sediment can affect water circulation through the gravel and oxygenation of the egg pocket, affect the ability of fry to move within the substrate, and may cover the egg pocket, impacting the ability of fry to emerge from the gravel. Tagart (1984) reported poor egg survival to emergence of coho salmon when the percent fines (particles less than 0.85 millimeters) exceed 15%. Peterson et al. (1992) suggest a target percent fine sediment of less than 11% for good egg incubation survival.

Bedload movement and scour of the egg pocket can also reduce fry survival to emergence. Coho salmon egg pocket depths range from 12 to 25 centimeters (Devries 1997).

Freshwater Juvenile Residence

Throughout their freshwater residence juvenile coho salmon are strongly associated with slow water and areas with high channel complexity and physical cover (in-channel wood, vegetated banks, and side channels). Newly emergent coho salmon fry move quickly to low-velocity waters, usually along the stream's margins or into backwaters where velocities are minimal (Sandercock 1991; Nickelson et al. 1992). Nickelson et al. (1992) reported the highest fry densities in calm backwater pools in small streams on the Oregon Coast.

Coho salmon exhibit multiple life history patterns during freshwater residence. This movement of coho salmon fry following emergence and colonization of suitable rearing habitat may be a result of intraspecific competition (Chapman 1962), high flow (Hartman et al. 1982), or the lack of shallow, low-velocity habitat suitable for colonization (Au 1972). Fry movement may disperse fry long distances downstream into larger streams and lakes for summer rearing. Coho salmon that disperse to larger downstream streams and rivers may subsequently move into off-channel habitats to seek out calm, low-velocity water (Peterson and Reid 1984).

The fall movement of coho salmon fingerlings to downstream habitats is likely in response to the onset of fall rains and cooler temperatures and a need to seek more suitable low-velocity overwinter habitats, particularly floodplain channels, wetlands, and ponds. Coho fingerlings may be swept downstream by fall and winter rains if suitable low-velocity habitats are not present in their natal stream.

Reach geomorphic features (i.e., wide valley width and moderate to low gradients), increase intrinsic potential, consistent with juvenile coho salmon affinity for slow water habitats and floodplain habitats (Burnett et al. 2007). This affinity for slow water habitats also means coho salmon are susceptible to loss of complex in-channel habitat structure and disconnected floodplain habitats.

Some studies have found evidence for life history patterns for coho salmon that include the use of estuarine habitat or direct seaward migration by juveniles after only 6 months in freshwater. Koski (2009) reviewed several studies to better understand the role that these "nomadic" juveniles play in

population resiliency, and suggests that estuarine habitats may have a significant role in the recovery of depressed coho salmon populations. Miller and Sadro (2003) reported spring movement of juveniles to downstream estuarine habitats for a coastal Oregon stream, where most fry resided through the summer and returned upstream to fresh water to overwinter. Roni et al. (2012) reported juvenile coho salmon leaving a Strait of Juan de Fuca stream (Washington) in the fall of their first year. They reported over 50% of the juveniles from a given brood year were fall migrants (migrated to saltwater between early October and end of December).

During the summer, juvenile coho salmon reside in a wide variety of stream types and sizes, including connected lakes where present (e.g., Tenmile Lake). The highest densities are found in natal streams, although a higher proportion of fry will move from higher gradient streams (Lestelle et al. 1993).

The affinity for calm, low-velocity habitats remains during summer rearing. Juvenile coho salmon are more closely associated with the shoreline or dense cover of woody debris than other salmonids. Juvenile coho salmon are most often found in pools (Nickelson et al. 1992), and densities in small Oregon coastal streams can be high, ranging from 0.31 juvenile fish per square meter to 0.68 juvenile fish per square meter (Jepsen and Rodgers 2004; Jepsen 2006). In addition to stream complexity affecting juvenile densities, density can be strongly affected by stream productivity (amount of food available) (Mason 1976; Ptolemy 1993; Ward et al. 2003). More productive streams tend to support higher densities of juvenile salmon.

The presence of wood in streams is loosely correlated to number of juvenile fish. Wood may have a more important role in pool formation and the quantity of pool habitat favorable for coho salmon and have less importance as cover in small streams (Lestelle 2007). However, high quantities of wood may be more important as cover in larger streams and rivers. Peters (1996) found that juvenile coho salmon rearing in the mainstem Clearwater River (Washington) was strongly associated with large wood. The study hypothesized that the attraction of wood during the summer in mainstem rivers is primarily because it provides refuge cover from predators rather than refuge from water velocity.

Lestelle (2007) summarized several studies on effects of water temperature on juvenile coho salmon. A study in the Mattole River (Northern California) reported coho were not found in streams that exceeded a maximum weekly temperature of 18°C (Welsh et al. 2001 in Lestelle 2007). Another study in the Sixes River (Southern Oregon) reported juvenile coho salmon to be absent or rare in stream segments where temperatures exceeded 21°C (Frissell 1992 in Lestelle 2007).

Juvenile coho salmon may seek sites of thermal refuge to avoid warm water temperatures. These sites may be at the confluence of cool-water tributaries entering a stream, springbrooks, and side channels, or at smaller scales of thermally stratified pools. At the reach scale and smaller, bedform topography may create vertical hydraulic gradients of exchange between the streambed and flowing channel (Torgersen et al. 2012) providing thermal variation longitudinally along the channel and across pool/riffle habitat units.

The quantity of summer rearing habitat can have a strong density-dependent effect on survival. Low late summer flows, few pools, and reduced food may reduce survival and limit population abundance. However, the effects of summer low flow on survival and freshwater smolt abundance may be less important than the quantity of overwinter habitat for coho salmon. Overwinter survival of juvenile fish is a major factor found to influence abundance in Oregon Coast streams. Limited overwinter habitat can create a population bottleneck during coho salmon freshwater residence.

Solazzi et al. (2000) reported a substantial increase in abundance of seaward migrating smolts following habitat modifications to increase the quantity of winter rearing habitat. They increased the amount of overwinter habitat through a combination of improvements of in-channel habitats and the creation of new off-channel habitats. They concluded critical elements to improving survival were increasing the quantity of slow-water habitat and the addition of large quantities of wood.

Ocean Life

Pacific salmon are anadromous fish; adults migrate from the ocean to spawn in freshwater lakes and streams where their offspring hatch and rear prior to migrating back to the ocean to forage until maturity. The physiological and behavioral changes required for the transition to saltwater results in a distinct smolt stage. Adult coho salmon begin migrating into coastal streams and rivers in the fall. Eggs hatch in the spring and fry grow rapidly to the parr stage by early summer or early fall. Parr then seek out areas protected from high flows and spend a second winter in freshwater before migrating to the ocean as smolts in March through June. Coho salmon, primarily male fish, mature and spawn after only several months in the ocean. About 20% of males mature at age 2 and return to freshwater as “jacks” in the same year they entered the ocean as adults. Although the production of jacks is a heritable trait in coho salmon, the proportion of jacks in a given coho salmon population is strongly influenced by environmental factors. The remainder of juveniles rear in the ocean for 18 months and return as 3-year-old adults in the fall. Habitat capacity for coho salmon on the Oregon Coast has significantly decreased from historical levels. During periods of poor ocean survival, high quality habitat is necessary to sustain coho populations. Disease and infection of juvenile coho salmon in the first few months of ocean residence is a key concern.

Ecological Relationships

Juvenile salmon migrate downstream through every riverine and estuarine corridor between their natal lake or stream and the ocean. On their journey, they develop behaviors such as predator avoidance, foraging, and competition that help ensure their survival. Salmon’s complex life cycle gives rise to complex habitat needs, particularly during the freshwater phase. Juveniles compete for abundant food sources, including insects, crustaceans, and other small fish. They need places to hide from predators (mostly birds and bigger fish), such as under logs, root wads, and boulders in the stream, as well as beneath overhanging vegetation. Returning adults also require cool waters and places to rest and hide from predators.

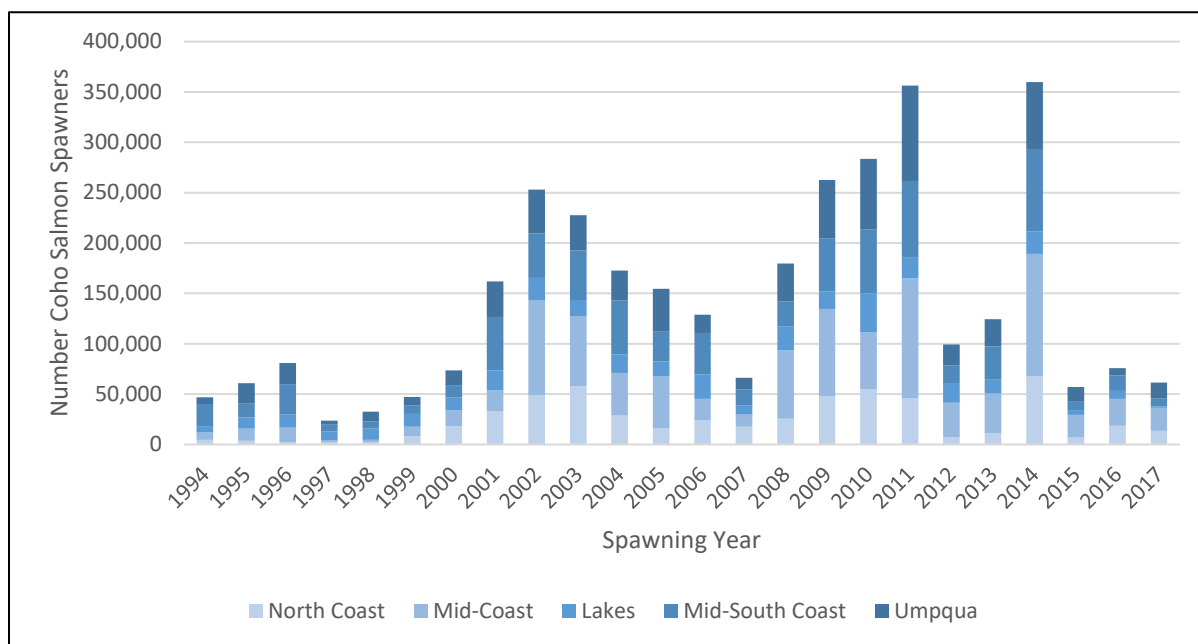
Population Status and Trends

The Oregon Coast Coho Conservation Plan assumes a historical (pre-development) coho salmon adult return to the Oregon Coast coho salmon ESU in the range of 1 to 2 million fish during periods of favorable ocean conditions (ODFW 2007).

Since 1994, coho salmon spawner abundance in the Oregon Coast coho salmon ESU has ranged from 23,661 to 359,692 coho salmon (Figure C1-2). Abundance during the early period was low, averaging 52,240 fish from 1994 to 2000. Coho salmon spawner abundance increased considerably from 2001 to 2014, due mostly to improved marine survival, combined with substantially reduced harvest on returning adults (National Marine Fisheries Service 2016b). From 2001 to 2017, the number of adult coho salmon averaged 177,920 fish. However, there has been a decline in abundance beginning in 2015; from 2015 to 2017 the number of coho salmon spawners across the

ESU has been less than 100,000 fish. The recent year decline is likely because of low ocean survival and possibly freshwater conditions during egg incubation and juvenile residence. However, many positive improvements to Oregon Coast coho salmon are described by ODFW, including positive long-term abundance trends and escapement. Increases in ESU scores for persistence and sustainability also clearly indicate the biological status of the ESU is improving, due in large part to management decisions (reduced harvest and hatchery releases) and favorable environmental variation such as high marine survival. Environmental conditions in both fresh and marine waters inhabited by Pacific Northwest salmon are also influenced by two ocean-basin scale drivers, the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO). Starting in late 2013, however, abnormally warm conditions in the Central Northeast Pacific Ocean known as the “warm blob” has also had a strong influence on both terrestrial and marine habitats (National Marine Fisheries Service 2016b).

Coho salmon spawner abundance from 2013 to 2017 by stratum and independent population are summarized in Table C1-2. The averages and ranges during this period include the high abundance in 2014 (359,692 adults). The Mid Coast stratum comprising six independent populations was on average 34% of the total ESU abundance during this period. The most abundant population in this stratum was the Siuslaw River with an average of almost 16,000 adults. The Mid South Coast stratum comprising four independent populations was on average 22% of the total ESU abundance during this period. The most abundant population in this stratum was the Coquille River with an average of approximately 16,500 adults. As shown in Table C1-1 the plan area has the largest overlap with the North Coast stratum, specifically the Nehalem and Tillamook independent populations. These two populations comprise, on average, 13% of the total ESU abundance during this period (Table C1-2).



Source: Oregon Department of Fish and Wildlife 2019.

Figure C1-2. Trends Abundance Adult Spawning Coho Salmon

Table C1-2. Adult Coho Salmon Abundance

Biogeographic Stratum and Population	Coho Salmon Adult Abundance	
	Recent 5-year Average and Range (2013–2017)	Percent of Total ESU Abundance
Oregon Coast Coho ESU	135,702 (57,125/359,692)	
North Coast Stratum	23,481 (6,740/67,370)	17%
<i>Necanicum River</i>	1,767 (529/5,727)	1%
<i>Nehalem River</i>	10,246 (3,079/30,577)	8%
<i>Tillamook River</i>	7,173 (1,345/20,090)	5%
<i>Nestucca River</i>	3,050 (946/6,369)	2%
North Coast Dependents	1,245 (206/4,607)	<1%
Mid Coast Stratum	46,739 (22,673/121,963)	34%
Salmon River	1,336 (332/3,680)	1%
<i>Siletz River</i>	7,518 (2,216/19,496)	6%
Yaquina River	7,551 (2,400/25,582)	6%
<i>Beaver Creek</i>	2,435 (332/6,564)	2%
Alsea River	10,566 (4,288/25,733)	8%
<i>Siuslaw River</i>	15,927 (7,129/38,896)	12%
Mid Coast Dependents	1,406 (473/2,012)	1%
Lakes Stratum	9,949 (1,302/22,010)	7%
Siltcoos Lake	3,134 (715/7,178)	2%
Tahkenitch Lake	1,941 (269/3,691)	1%
<i>Tenmile Lake</i>	4,874 (318/11,141)	4%
Umpqua Stratum	26,227 (7,494/66,272)	19%
<i>Lower Umpqua River</i>	12,746 (3,725/36,942)	9%
<i>Middle Umpqua River</i>	4,681 (1,159/13,939)	3%
North Umpqua River	2,537 (1,148/3,979)	2%
<i>South Umpqua River</i>	6,263 (765/12,178)	5%
Mid South Coast Stratum	29,309 (8,092/82,077)	22%
<i>Coos River</i>	11,221 (2,689/38,880)	8%
Coquille River	16,558 (3,357/41,660)	12%
Floras Creek	1,236 (693/1,936)	1%
Sixes River	267 (69/567)	0%
Mid South Coast Dependents	27 (0/105)	<1%

Source: ODFW 2019.

Note: *italics* = populations occur in the plan area.

Threats

A federal recovery plan for the Oregon Coast coho salmon ESU was finalized in December 2016 (81 FR 90780). The plan provides guidance to improve the viability of the species to the point that it meets the delisting criteria and no longer requires ESA protection. The primary threat identified in the recovery plan is deteriorating freshwater habitat conditions and a concern that existing

voluntary and regulatory mechanisms are inadequate to protect and recover Oregon Coast coho salmon (National Marine Fisheries Service 2016a).

The Oregon State Coast Coho Conservation Plan (Oregon Coho Plan) was approved by the Oregon Fish and Wildlife Commission in 2007 prior to final listing under the ESA (ODFW 2007). The Oregon Coho Plan addresses the legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The Oregon Coho Plan is a strategic approach to recovery based on science, supported by stakeholders, built on existing efforts, and including new recovery actions. NMFS determined that the depressed status of the ESU is the result of habitat degradation, water diversions, harvest, and hatchery production (National Marine Fisheries Service 2016a). NMFS concluded that the adverse effects of natural environmental variability from drought, floods, and poor ocean conditions have been exacerbated by the degradation of habitat by human activities. A subsequent status review by the Northwest Fisheries Science Center found that risks posed by hatcheries and fisheries have largely been remediated (National Marine Fisheries Service 2016b). NMFS concluded in its 5-year status review that continued threats from habitat degradation and climate change remain factors affecting the ESU's long-term status and that the Oregon Coast coho salmon ESU should remain listed under the ESA as threatened. During the summer months, many of the streams coho salmon juveniles inhabit are already at close to lethal temperatures, and with the expectation of rising stream temperatures due to global climate change, increases in infection rates of juvenile coho salmon by parasites may become an increasingly important stressor both for freshwater and marine survival (National Marine Fisheries Service 2016b).

NMFS-identified threats to coho salmon, by recovery stratum, are shown in Tables C1-3 and C1-4. The North Coast stratum has the most overlap with the plan area. Limiting factors in this stratum include a loss of stream complexity, including floodplain connectivity and large wood, and water quality (temperature, dissolved oxygen, pH, sediment, and contaminants).

Table C1-3. Limiting Factors for Oregon Coast Coho Salmon by Biogeographic Recovery Stratum

Stratum	Limiting Factors
North Coast	• Stream complexity • Water quality
Lakes	• Non-native fish species predation • Stream complexity • Water quality
Umpqua	• Stream complexity • Water quantity • Hatchery impacts
Mid-South Coast	• Hatchery impacts • Stream complexity (including spawning gravel) • Water quality

Source: NMFS 2016b.

Table C1-4. Description of Limiting Factors for Oregon Coast Coho Salmon

Limiting Factor	Description
Stream Complexity	• Loss of the physical habitat variety, including floodplain connectivity, supporting adult spawning, egg incubation, and juvenile rearing • Removal of beavers and in-stream large woody debris
Water Quality	• Elevated water temperature and pH • Diminished dissolved oxygen • Increased fine sediments and contaminants
Water Quantity	• Reduced instream flows from irrigation and population growth demands
Hatchery Impacts	• Interactions with hatchery-origin coho reduces wild coho abundance, productivity, and diversity
Non-native fish species predation	• Bass and other non-native predators preying on coho salmon

Source: NMFS 2016b.

Literature Cited

- Au, D. W. K. 1972. *Population Dynamics of the Coho Salmon and its Response to Logging in Three Coastal Streams*. Ph.D. Thesis, Oregon State University, Corvallis, OR.
- Botkin, D.B., K. Cummins, T. Dunne, H. Regier, M. Sobel, and L. Talbot. 1995. *Status and Future of Salmon of Western Oregon and Northern California: Findings and Options*. The Center for the Study of the Environment, P.O. Box 6945, Santa Barbara, CA 93160, Research Report 951002.
- Burnette, K.M., G.H. Reeves, D. J. Miller, S. Clarke, K. Vance-Borland, and K. Christiansen. 2007. Distribution of Salmon-Habitat Potential Relative to Landscape Characteristics and Implication for Conservation. *Ecology Application* 17(1):66–80.
- Chapman, D.W. 1962. Aggressive Behavior in Juvenile Coho Salmon as a Cause of Emigration. *Journal of the Fisheries Research Board of Canada* 19:1047–1080.
- Devries, Paul. 1997. Riverine Salmonid Egg Burial Depths: A Review of Published Data and Implications for Scour Studies. *Canadian Journal of Fisheries and Aquatic Sciences* 54: 1685–1698.
- Hartman, G.F., B.C. Anderson, and J.C. Scrivener. 1982. Seaward Movement of Coho Salmon (*Oncorhynchus kisutch*) Fry in Carnation Creek, an Unstable Coastal Stream in British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 39:588–597.
- Jepsen, D.B. 2006. *Abundance Monitoring of Juvenile Salmonids in Oregon Coastal Streams, 2004*. Monitoring Program Report Number OPSW-ODFW-2006-1, Oregon Department of Fish and Wildlife, Salem, OR.
- Jepsen, D.B., and J.D. Rodgers. 2004. *Abundance Monitoring of Juvenile Salmonids in Oregon Coastal Streams, 2002-2003*. Monitoring Program Report Number OPSW-ODFW-2003-1, Oregon Department of Fish and Wildlife, Portland, OR.
- Koski, K., 2009. The Fate of Coho Salmon Nomads: The Story of an Estuarine-Rearing Strategy Promoting Resilience. *Ecology & Society* 14(1).

- Kostow, K. (editor). 1995. *Biennial Report of the Status of Wild Fish in Oregon*. Oregon Department of Fish and Wildlife, Fish Division. Portland.
- Lawson, P.W., E.P. Bjorkstedt, M.W. Chilcote, C.W. Huntington, J.S. Mills, K.M.S. Moore, T.E. Nickelson, G.H. Reeves, H.A. Stout, T.C. Wainwright, and L.A. Weitkamp. 2007. *Identification of Historical Populations of Coho Salmon (Oncorhynchus kisutch) in the Oregon Coast Evolutionarily Significant Unit*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-79, 129 p.
- Lestelle, Lawrence C. 2007. *Coho Salmon (Oncorhynchus kisutch) Life History Patterns in the Pacific Northwest and California*. Final report submitted to the U.S. Bureau of Reclamation, Klamath Area Office, Klamath Falls, OR.
- Lestelle, L.C., G.R. Blair, S.A. Chitwood. 1993. Approaches to Supplementing Coho Salmon in the Queets River, Washington. Pages 104-119 in L. Berg and P.W. Delaney (eds.), *Proceedings of the Coho Workshop*. British Columbia Department of Fisheries and Oceans, Vancouver, BC.
- Mason, J.C. 1976. Response Of Underyearling Coho Salmon To Supplemental Feeding In A Natural Stream. *Journal of Wildlife Management* 40:775-778.
- Miller, B.A., and S. Sadro. 2003. Residence Time and Seasonal Movements of Juvenile Coho Salmon in the Ecotone and Lower Estuary of Winchester Creek, South Slough, Oregon. *Transactions of the American Fisheries Society* 132:546-559.
- National Marine Fisheries Service (NMFS). 2008. Endangered and Threatened Species: Final Threatened Listing Determination, Final Protective Regulations, and Final Designation of Critical Habitat for the Oregon Coast Evolutionarily Significant Unit of Coho Salmon. *Federal Register* [Docket No. 071227892-7894-01, February 11, 2008] 73 (28):7816-7873.
- National Marine Fisheries Service (NMFS). 2011. Final Rule. Listing Endangered and Threatened Species: Threatened Status for the Oregon Coast Coho Salmon Evolutionarily Significant Unit. *Federal Register* Citation 76 FR 35755. June 20, 2011.
- National Marine Fisheries Service (NMFS). 2016a. *Recovery Plan for Oregon Coast Coho Salmon Evolutionarily Significant Unit*. National Marine Fisheries Service, West Coast Region, Portland, Oregon. December 2016.
- National Marine Fisheries Service (NMFS). 2016b. *2016 5-Year Review: Summary and Evaluation of Oregon Coast Coho Salmon*. National Marine Fisheries Service, West Coast Region, Portland, Oregon. May 26, 2016.
- Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992a. Seasonal Changes in Habitat Use by Juvenile Coho Salmon (*Oncorhynchus kisutch*) in Oregon Coastal Streams. *Canadian Journal of Fisheries and Aquatic Sciences* 49:783-789.
- Oregon Department of Fish and Wildlife (ODFW). 2007. *Oregon Coast Coho Conservation Plan for the State of Oregon*. Available: https://www.dfw.state.or.us/fish/CRP/docs/coastal_coho/final/Coho_Plan.pdf.
- Oregon Department of Fish and Wildlife (ODFW). 2019. *Salmon and Steelhead Recovery Tracker*. Coho Data. Available: <http://odfwrecoverytracker.org/>. Accessed: May 2019.

- Peters, R.J. 1996. *An Evaluation of Habitat Enhancement and Wild Fry Supplementation as a Means of Increasing Coho Salmon Production of the Clearwater River, Washington*. Ph.D. Thesis, University of Washington, Seattle, WA.
- Peterson, N.P., and L.M. Reid. 1984. Wall-Base Channels: Their Evolution, Distribution, and Use by Juvenile Coho Salmon in the Clearwater River, Washington. Pages 215-225 in J.M. Walton and D.B. Houston (eds.), *Proceedings of the Olympic Wild Fish Conference*. Peninsula College and Olympic National Park, Port Angeles, WA.
- Peterson, N. P., A.P. Hendry, T. P. Quinn, 1992. *Assessment of Cumulative Effects on Salmonid Habitat: Some Suggested Parameters and Target Conditions*. Prepared for the Washington Department of Natural Resources and The Cooperative Monitoring, Evaluation and Research Committee Timber/Fish/Wildlife Agreement Olympia, Wash.
- Ptolemy, R.A. 1993. Maximum Salmonid Densities in Fluvial Habitats in British Columbia. Pages 223–250 in L. Berg and P.W. Delaney (eds.), *Proceedings of the Coho Workshop*. British Columbia Department of Fisheries and Oceans, Vancouver, BC.
- Roni, P., T. Bennett, R. Holland, G. Pess, K. Hanson, R. Moses, M. McHenry, W. Ehinger, J. Walter. 2012. Factors Affecting Migration Timing, Growth, and Survival of Juvenile Coho Salmon in Two Coastal Washington Watersheds. *Transactions of the American Fisheries Society* 141(4), 890–906.
- Sandercock, F.K. 1991. Life History of Coho Salmon (*Oncorhynchus kisutch*). Pages 396-445 in C. Groot and L. Margolis (eds.), *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver, B.C.
- Solazzi, M.F., T.E. Nickelson, S.L. Johnson, and J.D. Rodgers. 2000. Effects of Increasing Winter Rearing Habitat on Abundance of Salmonids in Two Coastal Oregon Streams. *Canadian Journal of Fisheries and Aquatic Sciences* 57:906–914.
- Sounhein, B., E. Brown, M. Lewis and M. Weeber. 2017. *The Oregon Plan for Salmon and Watersheds: Status of Oregon stocks of Coho Salmon, 2016*. Monitoring Program Report Number OPSW-ODFW-2017-3, Oregon Department of Fish and Wildlife, Salem, Oregon. Available: <https://odfw.forestry.oregonstate.edu/spawn/pdf%20files/reports/2016CohoAnnualReport.pdf>.
- StreamNet. 2019. Database (Version 98.3) [database downloaded to disk]. Portland (OR) : StreamNet. Available: <https://www.streamnet.org/data/interactive-maps-and-gis-data/>.
- Tagart, J.V. 1984. Coho Salmon Survival from Egg Deposition to Fry Emergence. Pages 173-182 in J.M. Walton and D.B. Houston (eds.), *Proceedings of the Olympic Wild Fish Conference*. Peninsula College Fisheries Technology Program and Olympic National Park, Port Angeles, WA.
- Torgersen, C., J. Ebersole, and D. Keenan. 2012. *Primer for Identifying Cold-Water Refuges to Protect and Restore Thermal Diversity in Riverine Landscapes*. Region 10, U.S. Environmental Protection Agency, Seattle, Washington under EPA Interagency Agreement No. DW-14-95755001-0.
- Ward, B.R., D.J.F. McCubbing, and P.A. Slaney. 2003. Evaluation of the Addition of Inorganic Nutrients and Stream Habitat Structures in the Keogh River watershed for Steelhead Trout and Coho Salmon. Pages 127-147 in J.G. Stockner (ed.), *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. American Fisheries Society, Symposium 34, Bethesda, MD.

C2 Lower Columbia River Coho (*Oncorhynchus kisutch*)

The Lower Columbia River coho salmon evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Lower Columbia River coho salmon ESU includes rivers and streams originating from rivers and streams in Oregon and Washington downstream and including the Big White Salmon River (WA) and Hood River (OR), and the Willamette River and its tributaries downstream of Willamette Falls.

Legal Status

State: Endangered

Federal: Threatened (Final listing National Marine Fisheries Service [NMFS] 2005; 70 *Federal Register* [FR] 37160)

Critical Habitat: Designated (NMFS 2016; 81 FR 9250)

Recovery Planning: Recovery plan approved (NMFS 2013; 78 FR 41911)



Photo: Native Fish Society

Lower Columbia River coho salmon are listed as Endangered under the Oregon State Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135). Oregon developed the *Oregon State Lower Columbia River Conservation and Recovery Plan* for the same Oregon populations as the federal listing, which includes Washington populations. The *Oregon State Lower Columbia River Conservation and Recovery Plan* addresses legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The conservation plan was approved by the Oregon Fish and Wildlife Commission in August 2010.

Taxonomy

Coho salmon (*Oncorhynchus kisutch*) were first described by Walbaum in 1792. Coho salmon are one of five recognized species of Pacific salmon (*Oncorhynchus spp.*) that occur in North America.

Distribution

General

The Lower Columbia River coho salmon evolutionarily ESU (Figure C2-1) includes the Pacific Ocean and the freshwater and estuarine habitat in the Columbia River and tributaries to the Columbia River in Oregon and Washington downstream and including the Big White Salmon River (WA) and Hood River (OR), and the Willamette River and its tributaries downstream of Willamette Falls (OR).

The Lower Columbia River coho salmon ESU historically consisted of a total of 24 independent populations. Because NMFS had not yet listed the ESU in 2003 when the Willamette-Lower Columbia Technical Recovery Team (WLC TRT) designated core and genetic legacy populations for other ESUs, there are no such designations for Lower Columbia River coho salmon.

NMFS (2013) identified three major population groups (MPG) in the lower Columbia River: (1) Coast, (2) Cascade, and (3) Gorge. Historically there were 24 independent populations in the Lower Columbia River coho salmon ESU across the three MPGs. In Oregon there were four populations in the Coast MPG (Youngs Bay, Big Creek, Clatskanie River, and Scappoose Creek). In the Cascade MPG there were three populations in Oregon (Clackamas River and Sandy River). In the Gorge MPG there were three populations with spawning in tributaries in Washington and Oregon (including the Hood River) (NMFS 2013).

ESU recovery is based on achieving sustainable independent populations with the ESU and across the MPGs. NMFS set three recovery criteria for recovery of the of the Lower Columbia River coho salmon ESU:

1. Within each MGP there should be at least two populations that have a 95% chance of persisting over a 100-year time frame.
2. Within each MPG approximately half the populations should have a persistence probability of high or very high.
3. Viable populations should be dispersed across the ESU, and include those that were historically most productive and represent the genetic diversity of the ESU. (NMFS 2013)

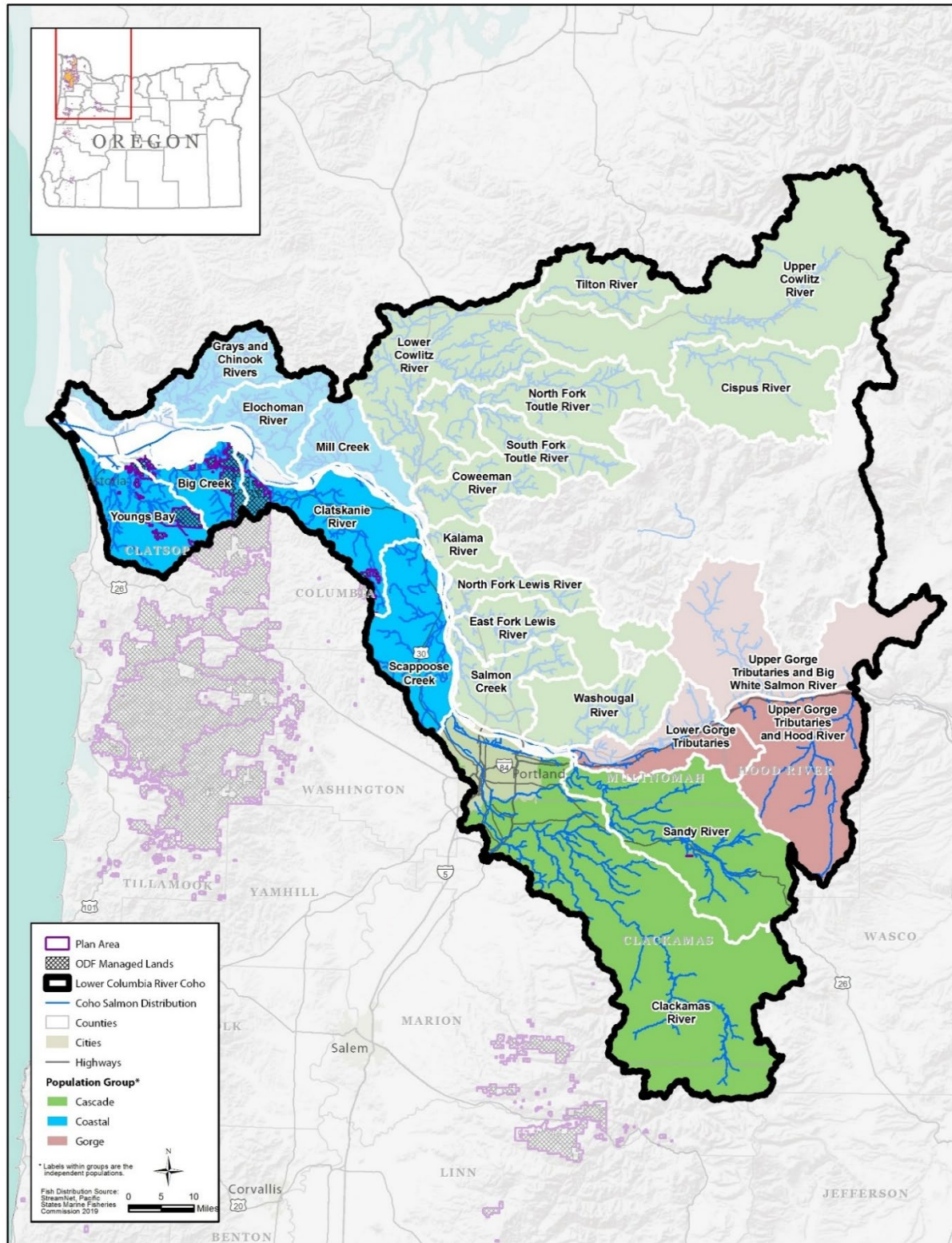


Figure C2-1. Lower Columbia River Coho Salmon ESU Strata and Independent Populations

Occurrences Within the Plan Area

Not all independent populations of coho salmon intersect or adjoin the plan area. Across the entire ESU four independent populations in Oregon intersect portions of the plan area to varying degrees (Figure C2-1). The independent populations that include portions of the plan area are (from north to south): (1) Youngs Bay, (2) Big Creek, (3) Clatskanie River, and (4) Sandy River.

Miles of streams with ODFW documented or assumed coho salmon presence within the plan area are summarized in Table C2-1. Stream miles are identified for independent populations by strata. The Big Creek and Youngs Bay independent populations have the highest occurrence of stream miles with coho salmon presence within the plan area.

Table C2-1. Miles of Lower Columbia River Coho Salmon Known or Presumed Coho Salmon Presence in the Oregon Portion of Their ESU

Biogeographic Stratum and Population	Stream Miles with Known or Presumed Coho Salmon Presence		
	Total Stream Miles	Miles Within or Adjacent to Plan Area	Percent of Total Within or Adjacent to Plan Area
Cascade Stratum	572	0.1	0.02%
Clackamas River	390	0	0%
Sandy River	181	0.1	0.06%
Gorge Stratum	367	0	0%
Lower Gorge Tributaries	125	0	0%
Upper Gorge Tributaries and Big White Salmon River	108	0	0%
Upper Gorge Tributaries and Hood River	134	0	0%
Coastal Stratum	467	27	6%
Big Creek	83	17	20%
Clatskanie River	104	3	3%
Scappoose Creek	139	0	0%
Youngs Bay	141	7	5%

Source: Streamnet 2019.

Natural History

See *Oregon Coast Coho* for the species natural history information.

Population Status and Trends

Wild coho in the Columbia basin have been in decline for the last 50 years. Historically at least 600,000 fish returned to the Columbia River; in 1996 the total return of wild fish was approximately 400 fish (ODFW 2010).

Most populations are believed to have very low abundance of natural-origin spawners (50 fish or fewer, compared to historical abundances of thousands or tens of thousands). Because of inadequate spawning surveys and, until recently, the presence of unmarked hatchery-origin spawners, data quality has been poor. Up through 2008, 25 artificial propagation programs produced coho salmon considered to be part of this ESU. However, two programs have been removed; now 23 coho salmon hatchery programs are currently included in the ESU. Low abundance, past stock transfers, other legacy hatchery effects, and ongoing hatchery straying may have reduced genetic diversity within and among coho salmon populations. It is likely that hatchery effects have also decreased population productivity. Only in the Clackamas and Sandy subbasins is there a clear record of continuous natural spawning from the 1990s to the present. Spawner abundance for both these populations is still well below long-term minimum abundance thresholds, although there was a generally positive trend from the 1990s through 2005. More recent spawning surveys indicate short-term increases in natural production in the Clatskanie, Scappoose, and Mill/Abernathy/Germany populations.

Of the 24 populations that make up this ESU, 21 are considered to have a very low probability of persisting for the next 100 years, and none are considered viable. All three strata in the ESU fall significantly short of the WLC TRT criteria for viability. The low abundance and productivity, loss of spatial structure, and reduced diversity can account for the very low persistence probability for most Lower Columbia River coho salmon populations. Although poor data quality prevents precise quantification, most populations are believed to have very low abundance of natural origin spawners. The general poor baseline population status of coho salmon reflects poor long-term trends.

Youngs Bay and Big Creek have been identified as subbasins that will not target improvements to the baseline trend, but rather continue to have a high proportion of hatchery origin spawners (NMFS 2013). These subbasins will continue to provide harvest opportunities through terminal fisheries.

Table C2-2. Adult Lower Columbia River Coho Salmon Abundance in Oregon

Biogeographic Stratum and Population	Coho Salmon Adult Abundance	
	Recent 5-year Average and Range (2014–2018)	Percent of Total ESU Abundance
Lower Columbia River ESU	9,440 (468/14,420)	
Coastal Stratum	2,169 (389/5,786)	23%
Youngs Bay ¹	93 (26/161)	1%
Big Creek ¹	400 (160/792)	4%
Clatskanie River	908 (25/3,246)	10%
Scappoose Creek	767 (178/1,587)	8%
Cascade Stratum	7,017 (2,071/16,614)	74%
Clackamas River	4,968 (1,628/10,672)	56%
Sandy River	2,049 (443/5,942)	22%
Gorge Stratum	253 (0/502)	3%
Lower Gorge Tributaries	201 (0/395)	2%
Upper Gorge Tributaries and Big White Salmon River	--	--
Upper Gorge Tributaries and Hood River	53 (0/107)	1%

Source: ODFW 2019.

¹ No data was available for 2014–2018; abundance based on data from 2008–2012.

Threats

A Lower Columbia River salmon and steelhead ESA recovery plan was finalized in July 2013. The plan provides guidance to improve the viability of the species to the point that it meets the delisting criteria and no longer requires ESA protection. The primary threat identified in the recovery plan for Lower Columbia River coho is the loss and degradation of tributary habitat (NMFS 2013).

The *Lower Columbia Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* (Plan) was approved by the Oregon Fish and Wildlife Commission in 2010 (ODFW 2010). The Plan serves as a recovery plan under the federal ESA and addresses the legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The Plan is a strategic approach to recovery based on science, supported by stakeholders, built on existing efforts, and including new recovery actions.

NMFS determined that the depressed status of the ESU is the result of habitat degradation, hydropower impacts, harvest, and hatchery production (NMFS 2013). Impaired side channel and wetland conditions, degraded floodplain and riparian conditions, and channel structure and form issues are negatively affecting all populations throughout the ESU. Water quantity issues related to withdrawals or to land uses that alter hydrology are identified as a primary limiting factor for winter parr in Youngs Bay and Big Creek (NMFS 2013). NMFS identified threats to coho salmon, by recovery habitat category are shown in Table C2-3.

Table C2-3. Limiting Factors and Threats

Habitat Threat Category	Limiting Factors	Threats Contributing to Limiting Factors and Impacting Population Survival
Tributary	• Reduced access to and suitable spawning and rearing habitat • Degraded and lost floodplain, wetland, side channel, and riparian habitat • Impaired water quality and flow	• North Fork Toutle sediment retention structure • Land use practices • Reduced flow from surface water withdrawals • Increased fine sedimentation • Extensive channelization, diking, levees, wetland conversion, and gravel extraction
Estuary	• Lack of access to transitional habitats • Reduced habitat complexity and diversity Food web shifts • Impaired water quality and flow • Impaired sediment and sand routing	• Changes in hydrologic regimes and water quality from hydropower reservoirs and mainstem dams • Impaired sediment and sand routing • Extensive channelization, diking, levees, wetland filling, and tide gates
Hydropower	• Reduced spawning habitat quantity and access • Elevated water temperatures in late summer and fall	• Tributary and mainstem dams reduce access to spawning habitat and decrease floodplain rearing habitat • Large mainstem reservoirs associated with mainstem dams
Harvest	• Direct and incidental mortality	• Recreational, tribal, and commercial fisheries

Habitat Threat Category	Limiting Factors	Threats Contributing to Limiting Factors and Impacting Population Survival
Hatchery	- Limited food and space availability - Hybridization	- Columbia Basin hatchery- and natural-origin juveniles competing for limited food and space in the estuary - Stray hatchery-origin coho interbreeding with natural-origin coho
Predation	Anthropogenic habitat alterations	Increased predation pressure from piscivorous non-salmonid fish and birds in the Columbia River estuary and plume, above and Bonneville Dam, and in the reservoir

Source: NMFS 2013.

Literature Cited

- National Marine Fisheries Service (NMFS). 2013. *ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead*. Northwest Region. June.
- National Marine Fisheries Service (NMFS). 2016. *Recovery Plan for Oregon Coast Coho Salmon Evolutionarily Significant Unit*. National Marine Fisheries Service, West Coast Region, Portland, Oregon. December 2016.
- Oregon Department of Fish and Wildlife (ODFW). 2010. *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead*. ODFW Salem Oregon.
- Oregon Department of Fish and Wildlife (ODFW). 2019. *Salmon and Steelhead Recovery Tracker. Coho Data*. Available: <http://odfwrecoverytracker.org/>. Assessed: July 2019.
- StreamNet 2019. Database (Version 98.3) [database downloaded to disk]. Portland (OR) : StreamNet. URL: <https://www.streamnet.org/data/interactive-maps-and-gis-data/>

C3 Upper Willamette River Chinook (*Oncorhynchus tshawytscha*)

The Upper Willamette River Chinook salmon evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Upper Willamette River Chinook salmon ESU includes spring-run Chinook salmon spawning in rivers and streams in the Willamette River basin upstream of Willamette Falls and the Clackamas River immediately downstream of Willamette Falls.

Legal Status

State: Sensitive-critical species

Federal: Threatened (Original listing National Marine Fisheries Service [NMFS] 1999, 64 *Federal Register* [FR] 14308; Revised listing NMFS 2005a, 70 FR 37160; Updated listing NMFS 2014, 71 FR 20802)

Critical Habitat: Designated (NMFS 2005b, 70 FR 52630)

Recovery Planning: Recovery Plan (Oregon Department of Fish and Wildlife [ODFW] and NMFS 2011), approved (NMFS 2011a, 76 FR 52317)



Photo: ODFW

Upper Willamette River Chinook salmon are listed as a sensitive-critical species under the Oregon State Sensitive Species List (OAR 635-100-0040) and are not listed under the Oregon Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135). ODFW and NMFS developed the *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* to address the conservation concerns for the species (ODFW and NMFS 2011). The *Oregon State Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* addresses legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The conservation plan was approved by the Oregon Fish and Wildlife Commission in August 2011 (OAR 635-500-6600).

Taxonomy

Chinook salmon (*Oncorhynchus tshawytscha*) were first described by Walbaum in 1792. Chinook salmon are one of five recognized species of Pacific salmon (*Oncorhynchus spp.*) that occur in North America.

Distribution

Chinook salmon distribution is described for their entire range, the Upper Willamette River ESU, and independent populations that intersect the HCP plan area and Oregon Department of Forestry (ODF) managed lands.

General

Chinook salmon have a wide range, second only to chum salmon. They can be found in Asia from Hokkaido, Japan, to the Anadyr River in Siberia, Russia, and in North America from Kotzebue Sound, Alaska, to the Central Valley and San Joaquin River in California (Healey 1991). Chinook salmon return to spawn in larger rivers from just above tidal influence to over 3,200 kilometers in the headwaters of the Yukon River, Alaska.

The Upper Willamette River Chinook salmon ESU includes spring-run Chinook salmon spawning in rivers and streams in the Willamette River basin upstream of Willamette Falls and the Clackamas River immediately downstream of Willamette Falls (NMFS 2005). Also included in the ESU are populations of spring-run Chinook salmon from six artificial propagation programs: the McKenzie River Hatchery Program; Marion Forks Hatchery/North Fork Santiam River Program; South Santiam Hatchery Program in the South Fork Santiam River and Mollala River; Willamette Hatchery Program; and the Clackamas Hatchery Program (NMFS 2014). Not included in the ESU are fall-run Chinook salmon in the Clackamas River and fall-run Chinook salmon that return to spawn in rivers and streams upstream of Willamette Falls (NMFS 1999). These fish were introduced to areas upstream of Willamette Falls by addition of an adult fish ladder at Willamette Falls first constructed in the 1880s and rebuilt in 1972 and by historical hatchery releases (Myers et al. 2006; ODFW 2019).

To achieve recovery of Upper Willamette River Chinook salmon ESU populations, NMFS requires attainment of desired levels of biological viability and reduction of the impact of the identified “listing factors” and “threats” that led to the population decline (ODFW and NMFS 2011). ODFW and NMFS (2011) based the ESA biological goals and delisting criteria on the viability criteria analyses of the Willamette/Lower Columbia Rivers Technical Recovery Team analyses (McElhany et al. 2003, as cited in ODFW and NMFS 2011; McElhany et al. 2006). Criteria that would need to be met in order to achieve delisting include (ODFW and NMFS 2011): that at least two populations in the ESU meet population viability criteria (McElhany et al. 2003, as cited in ODFW and NMFS 2011), the average of all population extinction risk category scores within the ESU is 2.25 or greater, three of four of the ESU’s “core” populations are restored to viable, the remaining “genetic legacy” population (the McKenzie population) is improved to very low risk of extinction, and that all populations not meeting population viability criteria do not deteriorate and are maintained at a minimum at their current risk of extinction. Specific threat delisting criteria are also described in the Recovery Plan in pass/fail terms (ODFW and NMFS 2011).

Additionally, the State of Oregon has a goal in the *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* to achieve a “broad sense recovery” that will provide for sustainable fisheries and other ecological, cultural and social benefits. The broad sense criteria are: all Upper Willamette River salmon and steelhead populations have a “very low” extinction risk and are “highly viable” over 100 years throughout their historic range; and the majority of Upper Willamette River salmon and steelhead populations are capable of contributing social, cultural, economic and aesthetic benefits on a regular and sustainable basis (ODFW and NMFS 2011).

To facilitate recovery of the Upper Willamette River Chinook salmon ESU, reintroduction of spring-run Chinook salmon is occurring to some areas of the Upper Willamette River basin where they are considered extirpated.

The Willamette Valley Flood Control Project (Willamette Project) consists of 13 dams operated by the U.S. Army Corps of Engineers (USACE) for flood control, hydroelectric power generation (operated by the Bonneville Power Administration), along with recreational and fishing opportunities, water quality benefits, and municipal and irrigation water (operated by the U.S. Bureau of Reclamation). NMFS' 2008 Biological Opinion for the Willamette Project found that the Willamette Project jeopardized the continued existence of the species; that project blocks access to historical major spawning and rearing habitat for four of seven spring-run populations of the Upper Willamette Chinook ESU (NMFS 2008). The Willamette Project includes operation/partial funding of a hatchery mitigation program, primarily operated by ODFW and funded by USACE.

Since the 1990s, ODFW has been out-planting excess hatchery adult spring Chinook salmon collected at the Willamette Project facilities to areas upstream of Willamette Project dams in the South Santiam, North Santiam, McKenzie, and Middle Fork Willamette subbasins (NMFS 2008; ODFW and NMFS 2011). The Willamette Project Biological Opinion's Reasonable and Prudent Alternative included upgrades to the out-planting programs, as well as additions of downstream fish passage facilities at Cougar Dam (on South Fork McKenzie River), Lookout Point Dam (Middle Fork Willamette River), and Detroit Dam (North Santiam River) to allow outmigration of juveniles resulting from successful production of out-planted adults upstream of the dams (NMFS 2008).

The *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* includes description of a hatchery program management strategy focused on conservation of native naturally-reproducing spring-run Chinook within the Upper Willamette Basin, with three primary tactics:

...1) reduce and minimize the risks of hatchery programs in the populations where substantial natural reproduction currently occurs so that the population will continue to recover and be monitored without the continual infusion of hatchery production, 2) for populations that are at high risk of extinction, use the existing hatchery Chinook programs to lessen demographic risks by outplanting hatchery fish into historic habitat above the impassable, federal dams, and 3) manage the spawning of hatchery Chinook below the federal dams over the short and long term according to the population recovery goals and the current limiting factors/threats facing the natural population in the areas downstream of the dams. (ODFW and NMFS 2011)

To achieve the goal of biological recovery, the following specific strategies are described:

...1) over the long term, reducing average [proportion hatchery origin spawners] to levels deemed appropriate by the [Willamette/Lower Columbia Technical Recovery Team] to meet different levels of population persistence for the Diversity VSP parameter, and 2) adjust aspects of the hatchery program to help re-introduce populations into areas where they are currently extirpated (example: above [Willamette Project] dams) in order to reestablish natural production in historic habitat to meet the [Abundance/Productivity] and [Spatial Structure Viability Salmonid population] parameters (and subsequently reducing [proportion hatchery origin spawners]) 3) in the short term, consider greatly reducing [proportion hatchery origin spawners] in some of the mitigation hatchery program areas, as described below. (ODFW and NMFS 2011)

More details on hatchery program management strategy for each subbasin can be found in Appendix E of the Recovery Plan and in individual Hatchery Genetic Management Plans available through ODFW's Fish Division website (ODFW 2018).

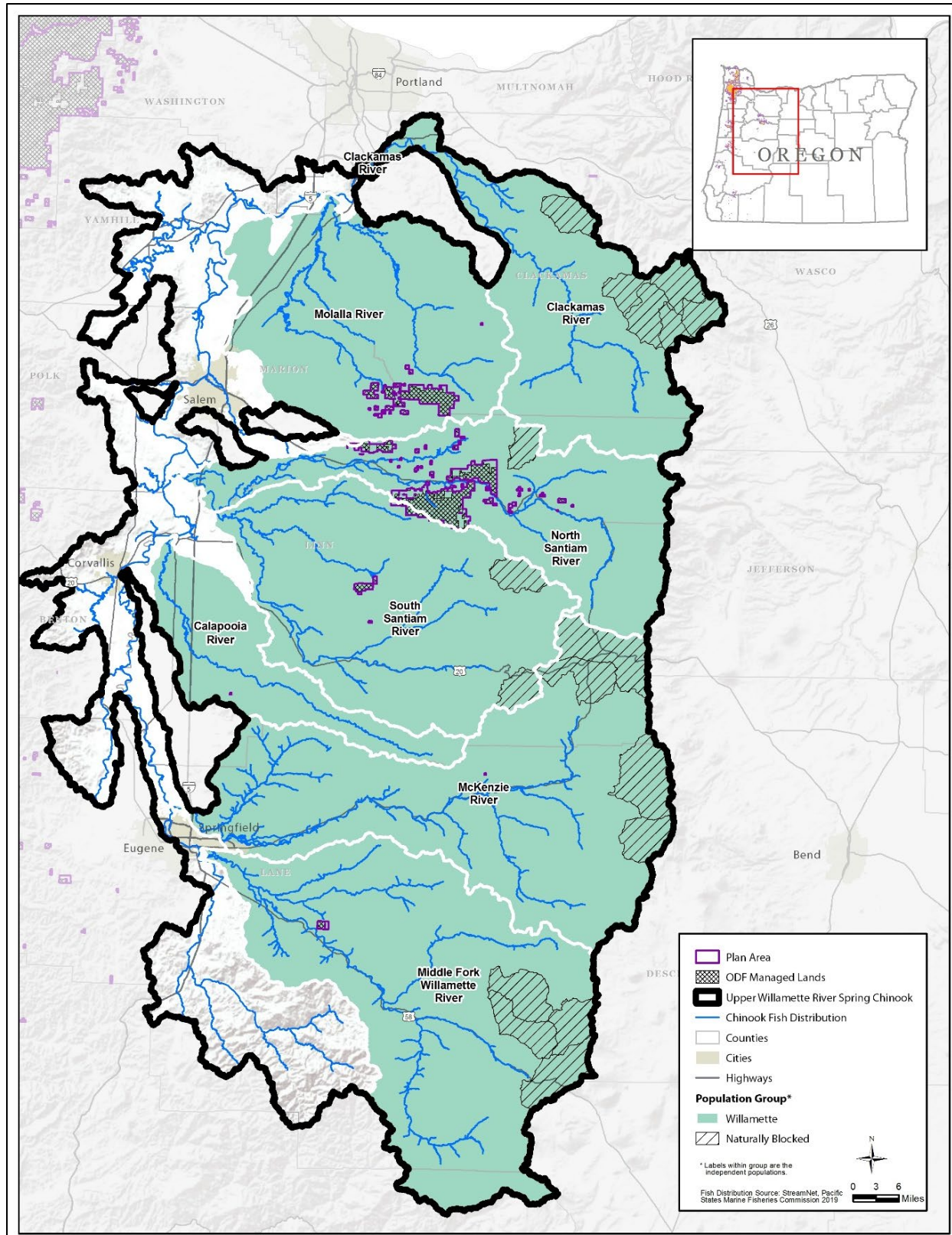


Figure C3-1. Upper Willamette River Chinook Salmon ESU Strata and Independent Populations in Oregon

Occurrences Within the Plan Area

Six of the seven independent populations of spring-run Chinook salmon intersect the plan area in some amount (Figure C3-1). The independent populations that include portions of the plan area are (from north to south): (1) Molalla River, (2) North Santiam River, (3) South Santiam River, (4) Calapooia River, (5) McKenzie River, and (6) Middle Fork Willamette River.

Miles of streams with ODFW documented or assumed spring-run Chinook salmon presence within the plan area are summarized in Table C3-1. Stream miles are identified for independent populations by strata. The plan area only intersects streams with known or presumed spring-run Chinook salmon presence within the North Santiam River population.

Table C3-1. Miles of Upper Willamette River Chinook Salmon Known or Presumed Chinook Salmon Presence

Biogeographic Stratum and Independent Populations	Stream Miles with Known or Presumed Chinook Salmon Presence		
	Total Stream Miles	Miles Within or Adjacent to Plan Area	Percent of Total Within or Adjacent to Plan Area
Willamette Stratum	1,380	5	0.4%
Clackamas River	140	0	0%
Molalla River	189	0	0%
North Santiam River	182	5	3%
South Santiam River	207	0	0%
Calapooia River	77	0	0%
McKenzie River	301	0	0%
Middle Fork Willamette River	284	0	0%

Source: Streamnet 2019.

Note: Independent populations shown in italics intersect with the plan area.

Natural History

Chinook salmon are the largest of the Pacific salmon species; adults may reach a weight of 45 kilograms (Healey 1991). Chinook salmon are anadromous and semelparous (i.e., die after spawning once), and generally have a 3- to 6-year life cycle (Healey 1991), though Upper Willamette River Chinook salmon predominantly return from the ocean at 4 to 5 years of age (ODFW and NMFS 2011). The typical freshwater period from the start of egg incubation to seaward migration is 12 to 14 months but can be as few as 2 to 5 months. Generally, after spending 1.5 to 4 years in the ocean, adult Chinook salmon return to freshwater between January and April (Healey 1991).

Within the Columbia River Basin, Upper Willamette River spring-run Chinook salmon are one of the most genetically distinct groups of Chinook. Historically, prior to laddering of Willamette Falls, passage of returning adult salmonids over the falls was possible only during the winter and spring high-flow periods. The early run timing of spring-run Chinook is believed to have developed as an adaptation to flow conditions at the falls; the populations of the ESU contain unique genetic resources compared to Chinook stocks in the Columbia River Basin (Myers et al. 2006).

Spring-run Chinook salmon ascend Willamette Falls April through August, and spawn in large headwater streams of the Upper Willamette basin between August and October. Females deposit eggs into a redd formed in the stream substrate. The eggs hatch in winter and alevins remain in the gravel until spring. Young Chinook salmon fry emerge from the gravel from December through March, sometimes as late as June, and rear in large tributaries and the mainstem Willamette River before migrating to sea the following spring, though some juveniles out-migrate to the ocean the same year of emergence (Myers et al. 2006).

Life History and Habitat Requirements

Throughout their life history stages, Upper Willamette River Chinook salmon utilize a range of habitats. They spawn in large headwater streams of the upper Willamette basin and rear in large tributaries and mainstem rivers. Adults migrate up, and juvenile migrate out, through the lower Columbia River system and estuary environments. Maturation occurs at sea, including ocean migration as far north as southeast Alaska (ODFW and NMFS 2011; Myers et al. 2006; Healey 1991).

The species has diverse and complex life history strategies, but in general, two freshwater life history types are: (1) stream-type Chinook salmon that reside in freshwater for a year or more following emergence before out-migrating to the ocean (i.e., “yearlings”), and (2) ocean-type Chinook salmon that out-migrate to the ocean within their first year following emergence (i.e., “sub-yearlings”) (Gilbert 1912, and Healey 1986, as cited in Myers et al. 2006).

The timing of adult entry to freshwater varies among Chinook salmon populations; the Upper Willamette River Chinook salmon ESU includes populations with adults that historically returned to freshwater in the early spring (spring-run), but started as early as January, and ascended Willamette Falls in the spring before low flow conditions made the falls impassible in the late summer and fall (Myers et al. 2006). Chinook salmon require varied habitats during different phases of their life cycle. Life history phases and corresponding habitat requirements are discussed below.

Upstream Migration and Spawning

Chinook salmon spawning habitat typically consists of gravels and cobbles in riffles and the tailouts of pools with clean silt-free substrate, in the mainstem of rivers and large tributaries (Healey 1991). In the Upper Willamette basin, adult spring-run Chinook may enter freshwater and migrate upstream as early as January, peaking April through August, and ending by October. Spawning occurs from August to November (NMFS 2008). Adult fish spawn in the fall and fry emerge in the following spring; thus, success of spawning is greatest where stream substrates are relatively stable such that eggs are not damaged by shifting substrate during high flow events (ODFW and NMFS 2011).

Spawning is timed so that fry emerge the following spring when productivity allows for survival and growth; exact spawn timing varies with water temperature with earlier spawning occurring in relatively cooler temperatures (Myers et al. 2006). In the Upper Willamette River, spring-run Chinook predominantly spawn in September and early October (Schroeder and Kenaston 2004, as cited in NMFS 2008).

Chinook salmon are most frequently observed spawning as seasonal water temperatures decline. Generally, water temperatures must be below 60°F (16°C) for Chinook spawning to be initiated, and water temperatures ranging from 42–55°F (5.6–12.8°C) are considered appropriate for Chinook

spawning (USEPA 2001). Water temperatures above 69.8–71.6°F (21–22°C) may block or inhibit upstream adult migration (Alabaster 1988, as cited in USEPA 2001).

Upper Willamette River Chinook salmon enter freshwater between January and April, then ascend Willamette Falls from April through August (ODFW and NMFS 2011). Adult fish spend the summer in headwater streams of the larger tributaries in the basin, where cool waters are found, often holding in large deep pools, then spawn in the fall from August into October (ODFW and NMFS 2011; Healey 1991).

Incubation and Emergence

Following spawning and egg deposition in the fall, Upper Willamette River spring-run Chinook salmon incubate in redds until spring (NMFS 2008). After hatching, alevins remain in the gravel for a few more weeks, then emerge from redds predominantly at night (Healey 1991). Incubation success and timing is dependent on many factors including stream flow, water temperature, dissolved oxygen concentration, and the proportion of fine sediment in substrates (Healey 1991).

In general, constant water temperatures above 48.2–50°F (9–10°C) and daily maximum water temperatures above 56–58°F (13.5–14.5°C) may reduce survival of Chinook embryos and alevins; water temperatures above these thresholds become sub-optimal (USEPA 2001). Complete mortality during incubation has been observed at water temperatures from 57–66.9°F (13.9–19.4°C) (USEPA 2001).

Oxygen availability is an important factor in salmonid egg survival, and success of incubation (i.e., egg-to-fry survival) generally decreases as the percent of fines in the substrate increases (Jensen et al. 2009; Grieg et al. 2005a, as cited in Jensen et al. 2009). Oxygen content around eggs may be reduced due to impeded flow of oxygenated water through the gravel within a redd when interstitial spaces are filled with fine sediments (Lisle 1989, as cited in Jensen et al. 2009). Fine sediments reducing interstitial spaces between gravels can also physically prevent fry emergence (Beschta and Jackson 1979, as cited in Jensen et al. 2009). Localized stream conditions such as groundwater upwelling, which can provide increased dissolved oxygen availability, may facilitate survival despite high proportions of fine sediment in substrate composition (Jensen et al. 2009).

Due to the timing of Upper Willamette River spring-run Chinook salmon in the fall and emergence of fry in the spring, eggs must survive in the redd through the high-flow winter season (Myers et al. 2006; ODFW and NMFS 2011). Elevated flows or channel scour may wash Chinook eggs out of redds or result in sedimentation following transport of silts (Healey 1991).

Freshwater Residence and Outmigration

Upper Willamette River spring-run Chinook salmon spend as little as 2 months to 2 years of their lives rearing in freshwater before migrating to the ocean (NMFS 2008). Juvenile Chinook out-migrate from the tributaries into the mainstem Willamette River in three phases: (1) as fry (i.e., ocean-type or sub-yearlings) in late winter to early spring, (2) as fingerlings (i.e., ocean-type sub-yearlings) fall to early winter (October through December), and (3) as yearlings (i.e., stream-type) late winter to spring (February through early May) (Mattson 1962, as cited in Myers et al. 2006; Schroeder et al. 2016). In the Upper Willamette River basin, most spring-run Chinook salmon rear in natal reaches and emigrate as yearlings; however, alternative life history strategies are important in overall productivity in the basin (Schroeder et al. 2016).

Stream-type Chinook juveniles are relatively more dependent on freshwater stream habitats than ocean-type because of their extended residence in freshwater streams. While rearing in freshwater, juvenile Chinook primarily consume larval and adult insects. Habitat requirements for freshwater rearing juvenile Chinook salmon include habitat complexity, food availability, and suitable water quality. Habitat complexity is characterized by a mixture of habitat types (e.g., pools of varying depths, riffles, and runs), instream structure for cover from predators (e.g., large woody debris, boulders, and undercut banks), and refuges from high flow (edge waters, eddies, and side-channel habitats). Juvenile Chinook depend on aquatic insects as a primary food source, and mostly feed mid-water column on drift (Healey 1991).

Rearing of juvenile Chinook salmon usually occurs in streams with water temperatures ranging from 50–63°F (10–17°C) (USEPA 2001). The optimal growth temperature range for the species is approximately 50–60°F (10–15.6°C); zero net growth of juveniles may occur below 39.4°F (4.1°C) and above 66.4°F (19.1°C) (Armour 1990, as cited in USEPA 2001). Water temperatures above approximately 77°F (25°C) are considered lethal to Chinook salmon juveniles, though mortality also depends on acclimation to elevated water temperatures and other water quality factors such as dissolved oxygen concentration (USEPA 2001).

Estuary Residence and Ocean Life

Juvenile Chinook salmon require estuarine and nearshore marine habitat for migration, foraging, refuge, and osmoregulation processes. Juveniles spend several days to months in estuarine habitat before migrating into marine waters (Healey 1991). Juveniles rely on shallow nearshore habitats such as intertidal flats, tidal marshes, and subtidal channels in and near estuaries. Once juvenile Chinook salmon are large enough to eat small fish, they move away from shore into deeper marine waters (Healey 1991).

Estuary conditions such as changes in food availability, off-channel habitat availability, presence of contaminants, and predation can affect juvenile survival into ocean life. Juvenile Chinook salmon are subject to predation in the Columbia River Estuary by predatory fishes (e.g., pikeminnow), birds (e.g., terns and cormorants), and pinnipeds (e.g., sea lions) (NMFS 2011b).

Ocean-type juvenile salmonids (i.e., sub-yearlings) have a tendency to use shallow-water habitats and have longer estuary residence times than stream-type juvenile salmonids (i.e., yearlings); thus, ocean-type salmonids are more affected than stream-type salmonids by flow alterations that cause changes to habitat quantity, quality, or access in wetlands and floodplains. Stream-type salmonids have comparably short estuary residence times and use the Columbia River plume more extensively; thus, stream-type juvenile salmonids are affected by plume dynamics (Fresh et al. 2005, as cited in NMFS 2011b).

Yearling Chinook out-migrants have been found to use the Columbia River plume as habitat, in contrast to sub-yearlings, which stay closer to shore. Thus, characteristics of the Columbia River plume are believed to be significant to yearling outmigrant Chinook salmon during transition to ocean life (Fresh et al. 2005, as cited in NMFS 2008). Most juvenile Upper Willamette River spring-run Chinook salmon out-migrate as yearlings; few out-migrate as sub-yearlings (NMFS 2011b).

Ocean Life

Chinook salmon spend 6 months to 7 years maturing in the ocean before returning to freshwater to spawn (Healey 1991). After entering the ocean as juveniles, Upper Willamette River Chinook migrate coastally north to British Columbia and southeastern Alaska (Myers et al. 2006).

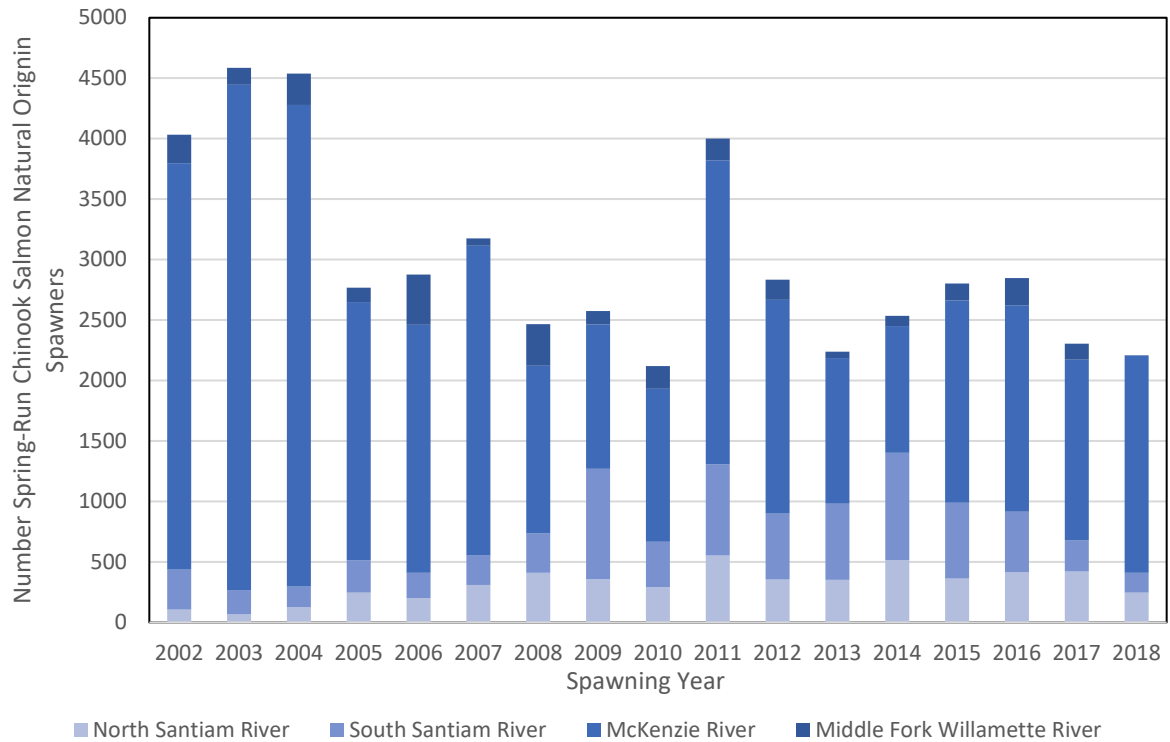
Chinook salmon are opportunistic feeders. Juveniles prey on a wide variety of food such as benthic, epibenthic, and pelagic crustaceans, as well as insects, fish larva, and juvenile fish. Adult salmon feed on squid and forage fish such as smelt, sandlance, and herring while in the estuarine and marine environment (Healey 1991).

Population Status and Trends

The *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* assumes a historical (pre-development) spring-run Chinook salmon adult return to the Upper Willamette River Chinook salmon ESU of approximately 300,000 fish (Myers et al. 2003, as cited in ODFW and NMFS 2011).

Present-day natural production is mostly limited to the Clackamas River population and McKenzie River population, though the McKenzie population has declined some in the past decade (NMFS 2016; ODFW 2019). Hatchery programs release juvenile spring-run Chinook in many subbasins and adult returns are usually composed of 80–90% hatchery origin Chinook (McElhany et al. 2007, as cited in ODFW and NMFS 2011). Additionally, pre-spawning mortality is generally high in lower reaches of tributaries, possibly due to unsuitably warm water temperatures and high fish densities, though the cause is unknown (ODFW and NMFS 2011; NMFS 2016). Conditions in Pacific Northwest marine waters inhabited by salmon are also influenced by two ocean-basin scale drivers: the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO). Starting in late 2013, abnormally warm conditions in the Central Northeastern Pacific Ocean, known as the “warm blob,” created anomalous weather patterns, temperature, and rainfall; it influenced stream and marine habitats, resulting in poor marine and stream survival, and in depressed salmonid returns in subsequent years (NMFS 2016; NOAA Fisheries 2019).

Upper Willamette River spring-run Chinook salmon natural-origin spawner abundance from 2002 to 2018 by stratum and independent population is summarized in Table C3-2 and shown on Figure C3-2. The range during this period includes the high abundance in 2003 (4,587 adults) and low in 2010 (2,121 adults). The most abundant population in the stratum has consistently been the McKensie River with an annual average of over 2,000 adults across the past 5 years, or approximately 61% of the ESU’s average annual return. As shown in Table C3-2, the plan area overlaps with six of the seven populations geographically, though only the North Santiam population has stream miles known or presumed to contain Chinook that intersect directly with the plan area. This population comprised, on average, approximately 15% of the total ESU abundance during the past 5 years (Table C3-2).



Note: Clackamas River, Calapooia River, and Mollala River populations do not have data available for this period.

Source: ODFW 2019.

Figure C3-2. Trends in Abundance of Adult Natural-Origin Spawning Spring-Run Upper Willamette River Chinook Salmon

Table C3-2. Upper Willamette River Spring-Run Chinook Salmon Natural-Origin Spawner Abundance

Biogeographic Stratum and Population	Coho Salmon Adult Abundance	
	Recent 5-year Average and Range (2014–2018)	Percent of Total ESU Abundance (5-year Average)
Willamette Stratum	2,540/(2,211–2,848)	100%
Clackamas River	No Data	No Data
<i>Molalla River</i>	<i>No Data</i>	<i>No Data</i>
North Santiam River	393/(248–517)	15%
South Santiam River	486/(162–887)	19%
Calapooia River	No Data	No Data
McKenzie River	1,544/(1,047–1,798)	61%
Middle Fork Willamette River	116/(3–226)	5%

Source: ODFW 2019.

Note: Independent populations shown in italics have some overlap with the plan area. Only the North Santiam River population, also shown in bold, has populated stream miles that intersect with the plan area.

Threats

The *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* was finalized in July 2011. The plan provides guidance to improve the viability the Upper Willamette River spring-run Chinook ESU to the point that it meets the delisting criteria and no longer requires ESA protection. Threats to the ESU include human impacts of fishing, hatchery operations, flood control/hydropower system operations, introduction of non-native species, and land use practices. Naturally occurring threats include floods, drought, climate change, and cataclysmic events (e.g., volcanos). Additional threats are posed to the ESU as a result of increasing human population growth (ODFW and NMFS 2011).

NMFS determined that the depressed status of the ESU is the result of reduction of access to historical spawning and rearing habitat and juvenile habitat degradation. Extensive dam construction in the Willamette River basin severed access to the majority of high-quality spawning and rearing habitat for the species. Within the basin, there are also elevated water temperature issues for juvenile outmigrants, extensive losses of floodplain habitat from construction of levees and other bank armoring, major reductions of habitat-forming flows, and large reductions in available shallow water habitats used as winter velocity refuges in tributaries (NMFS 2016).

The *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* describes human-induced threats in the five broad categories described above (ODFW and NMFS 2011). Table C3-3 summarizes the limiting factor and threat (LFT) analysis results for human impacts and Table C3-4 summarizes threats from climate change and human population growth.

Table C3-3. Human Impact Limiting Factor and Threat (LFT) Analysis Results

Threat Category	Limiting Factors	How Do Threats Cause or Contribute to Limiting Factors?
Flood Control and Hydropower Management	• Hydrograph/water quantity • Physical habitat quality/quantity • Food web	• Stream modifications result in stream habitat loss or alteration • Changes to hydrologic regime and flow alter habitat and food webs
Land Management	• Physical habitat quality/quantity • Water quality	• Changes in land use degrade or destroy habitat quantity and functionality
Other Species	• Competition • Predation • Physical habitat quality/quantity	• Food competition and predation directly affect populations • Invasive/non-native plants degrade habitat
Harvest Management	• Population traits	• Direct and indirect mortality to individuals • Selective targeting (age/size)
Hatchery Management	• Competition • Disease • Population traits • Habitat access	• Increased food competition and predation • Disease introduction • Interbreeding with hatchery-origin fish can reduce wild fish fitness and genetic diversity • Hatchery weirs can block access to upstream habitat

Source: ODFW and NMFS 2011.

Table C3-4. Projected Climate Change and Human Population Growth Impacts for the Pacific Northwest

Threat Category	Projected Impact for the Pacific Northwest (PNW) and Description
Climate Change	• Air temperature: each decade warmer than the one before • Precipitation: increased in winter and decreased in spring, summer, and fall • Snowpack: substantial declines due to increased air temperatures and precipitation. • Storms and flooding: increased storm events and intensity • Timing of peak spring runoff: earlier snowmelt will lead to earlier peak stream flows • Summer streamflow: continued decline in sensitive PNW basins and declines becoming more widespread
Human Population Growth and Development	• Forests, water (surface and groundwater), and land: increased demands on shared resources key to fish and wildlife • Land conversion: demand for residential land increasing agricultural and forest land conversion • Development: spreading outwards from cities causes more habitat loss and fragmentation, increases infrastructure costs, and social conflict • Impervious surfaces: increased urbanization increases impervious surfaces (e.g., roofs, pavement, and transportation corridors) and reduces groundwater recharge • Combined effect with climate change: increased pressure on fish and wildlife habitats and demands for freshwater • External to Columbia River Basin: international trade, shipping, dredging, hazardous material transport, and airborne pollution

Source: ODFW and NMFS 2011.

Literature Cited

- Groot, C. and L. Margolis. 1991. *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver, B.C.
- Healey, M.C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). In *Pacific Salmon Life Histories*, Groot and Margolis (eds.). UBC Press, 564 pp. Available partially online: http://books.google.com/books?id=I_S0xCME0CYC&dq=chum+salmon&lr=&source=gb_s_navlinks_s.
- Jensen, D.W., E.A. Steel, A.H. Fullerton, and G.R. Pess. 2009. Impact of Fine Sediment on Egg-To-Fry Survival of Pacific Salmon: A Meta-Analysis of Published Studies. *Reviews in Fisheries Science* 17(3):348–359.
- Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D.M. Van Doornik, and M.T. Maher. 2006. *Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins*. NOAA Technical Memorandum NMFS-NWFSC-73. National Marine Fisheries Service, Northwest Fisheries Science Center. 311 p. February.

- National Marine Fisheries Service (NMFS). 1999. Endangered and Threatened Species; Threatened Status for Three Chinook Salmon Evolutionarily Significant Units (ESUs) in Washington and Oregon, and Endangered Status for One Chinook Salmon ESU in Washington. *Federal Register*; 64 FR 14308. March 24.
- National Marine Fisheries Service (NMFS). 2005a. Endangered and Threatened Species; Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register*; 70 FR 37160. June 28.
- National Marine Fisheries Service (NMFS). 2005b. Endangered and Threatened Species; Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho. *Federal Register*; 70 FR 52630. August 12.
- National Marine Fisheries Service (NMFS). 2008. *Endangered Species Act Section 7(a)(2) Consultation Biological Opinion & Magnuson-Stevens Fishery Conservation & Management Act Essential Fish Habitat Consultation: Consultation on the "Willamette River Basin Flood Control Project."* Northwest Region. July 11.
- National Marine Fisheries Service (NMFS). 2011a. Endangered and Threatened Species; Recovery Plans: Notice of Availability. *Federal Register*; 76 FR 52317. August 22.
- National Marine Fisheries Service (NMFS). 2011b. *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. Northwest Region; Portland, Oregon.* Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc., subcontractor. January.
- National Marine Fisheries Service (NMFS). 2014. Endangered and Threatened Wildlife; Final Rule To Revise the Code of Federal Regulations for Species Under the Jurisdiction of the National Marine Fisheries Service. *Federal Register*; 79 FR 20802. April 14.
- National Marine Fisheries Service (NMFS). 2016. *2016 5-Year Review: Summary & Evaluation of Upper Willamette River Steelhead & Upper Willamette River Chinook.* West Coast Region; Portland, Oregon.
- National Oceanic and Atmospheric Administration (NOAA) Fisheries. 2019. *New Marine Heatwave Emerges off West Coast, Resembles "the Blob"*. Available: <https://www.fisheries.noaa.gov/feature-story/new-marine-heatwave-emerges-west-coast-resembles-blob>.
- Oregon Administrative Rules (OAR). Sensitive Species List (OAR 635-100-0040). Department of Fish and Wildlife. Available: https://secure.sos.state.or.us/oard/viewSingleRule.action;JSESSIONID_OARD=48m67GbU0TypekHPut-5Qsa91AH9S7p1TK1q5waCD-uYNCCL1RIAt!41094264?ruleVrsnRsn=173209.
- Oregon Administrative Rules (OAR). OAR 635-500-6600, Implementing the Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead. Available: <https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=174248>.
- Oregon Department of Fish and Wildlife (ODFW). 2018. Hatchery Genetic Management Plans (HGMP). Available: <https://www.dfw.state.or.us/fish/HGMP/final.asp#5>. Accessed September 2019.

Oregon Department of Fish and Wildlife (ODFW). 2019. Salmon and Steelhead Recovery Tracker Chinook Data. Available: <http://odfwrecoverytracker.org/>. Assessed: September 2019.

Oregon Department of Fish and Wildlife and National Marine Fisheries Service (ODFW and NMFS). 2011. *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead*. August 5.

StreamNet 2019. Database (Version 98.3) [database downloaded to disk]. Portland (OR) : StreamNet. URL: <https://www.streamnet.org/data/interactive-maps-and-gis-data/>

United States Environmental Protection Agency (USEPA). 2001. *Issue Paper 5: Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids*. EPA-910-D-01-005. Prepared as Part of EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. May.

C4 Upper Willamette River Steelhead (*Oncorhynchus mykiss*)

The Upper Willamette River steelhead salmon distinct population segment (DPS) is one of 19 evolutionarily significant units (ESUs) and DPSs of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Upper Willamette River steelhead DPS the only listed steelhead DPS within the plan/permit area. The DPS includes all winter-run steelhead from upstream of Willamette Falls up to and including the Calapooia River (NMFS 2006).

Legal Status

State: Sensitive species

Federal: Threatened (Original listing National Marine Fisheries Service [NMFS] 1999; 64 *Federal Register* [FR] 14517; Revised listing NMFS 2006; 71 FR 834)

Critical Habitat: Designated (NMFS 2005; 70 FR 52630)

Recovery Planning: Recovery plan approved (NMFS 2011; 76 FR 52317)



Photo: Oregon Conservation Strategy

In its 2006 listing decision, NMFS found “moderate risks” to the Upper Willamette steelhead DPS’s abundance, productivity, spatial structure, and diversity. The ESA listing of steelhead offers protection for naturally spawned steelhead; however, it does not offer protection for rainbow trout, the freshwater resident form of the species.

Upper Willamette River steelhead are listed as a sensitive species under the Oregon State Sensitive Species List (OAR 635-100-0040) and are not listed under the Oregon Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135).

The Oregon State Upper Willamette River Conservation and Recovery Plan outlines recovery needs and priorities for steelhead trout populations in the Molalla, North Santiam, South Santiam, and Calapooia watersheds (ODFW and NMFS 2011). The Recovery Plan also addresses legal requirements for conservation planning under Oregon’s Native Fish Conservation Policy. The conservation plan was approved by the Oregon Fish and Wildlife Commission in August 2011.

Taxonomy

Steelhead (*Oncorhynchus mykiss*) were first described by Walbaum in 1792. Steelhead and non-anadromous rainbow trout are close relatives of Pacific salmon (*Oncorhynchus* spp.) that occur in North America.

Myers et al. (2006) identified four historical demographically independent populations for Upper Willamette River winter steelhead: the Molalla, North Santiam, South Santiam, and Calapooia.

Distribution

Upper Willamette River steelhead distribution is described generally for their entire range, the Upper Willamette River ESU, and then specifically for independent populations that intersect the plan area and Oregon Department of Forestry (ODF) managed lands.

General

The Upper Willamette River steelhead DPS includes all naturally spawned winter-run steelhead from upstream of Willamette Falls up to and including the Calapooia River. NMFS has identified four independent populations in the Upper Willamette River steelhead DPS (Myers et al. 2006). From north to south they are: (1) Molalla River, (2) North Santiam River, (3) South Santiam River, and (4) Calapooia River.

Upper Willamette River steelhead have been observed spawning in west-side tributaries of the Willamette above the falls and are recognized by the Oregon Department of Fish and Wildlife (ODFW) as being part of the Willamette Winter Steelhead species management unit. However, these populations are not currently recognized by NMFS as being part of the Upper Willamette River steelhead DPS, likely because they are considered sink populations (where local reproductive success fails to keep pace with local mortality, per Pulliam 1998).

Approximately one-third of the DPS's historically accessible spawning habitat has been blocked by flood control structures associated with the Willamette Valley Flood Control Project (NMFS 2008; ODFW and NMFS 2011). The project consists of 13 dams, operated by the U.S. Army Corps of Engineers (USACE). Most of these dams are "high head" dams that are over 250 feet tall and do not provide fish passage.

In 2008, the Willamette River Basin Flood Control Project Biological Opinion (WP BiOp) was developed to ensure long-term ESA compliance with the dams. Stemming from the WP BiOp, in 2011, the Oregon State Legislature approved the Upper Willamette River Steelhead and Chinook Recovery Plan (ODFW and NMFS 2011), which further defined strategies and actions contained in the WP BiOp as well as in the Oregon Plan for Salmon and Watersheds and the Oregon Conservation Strategy. The recovery plan emphasizes the importance of successful reintroduction of naturally reproducing salmon and steelhead above the flood control dams in the Willamette River subbasins, and downstream passage for their offspring. This includes fish collection and transport for Detroit and Big Cliff dams on the North Fork Santiam River, which is located upstream of the nearby Santiam State Forest (USACE 2020).

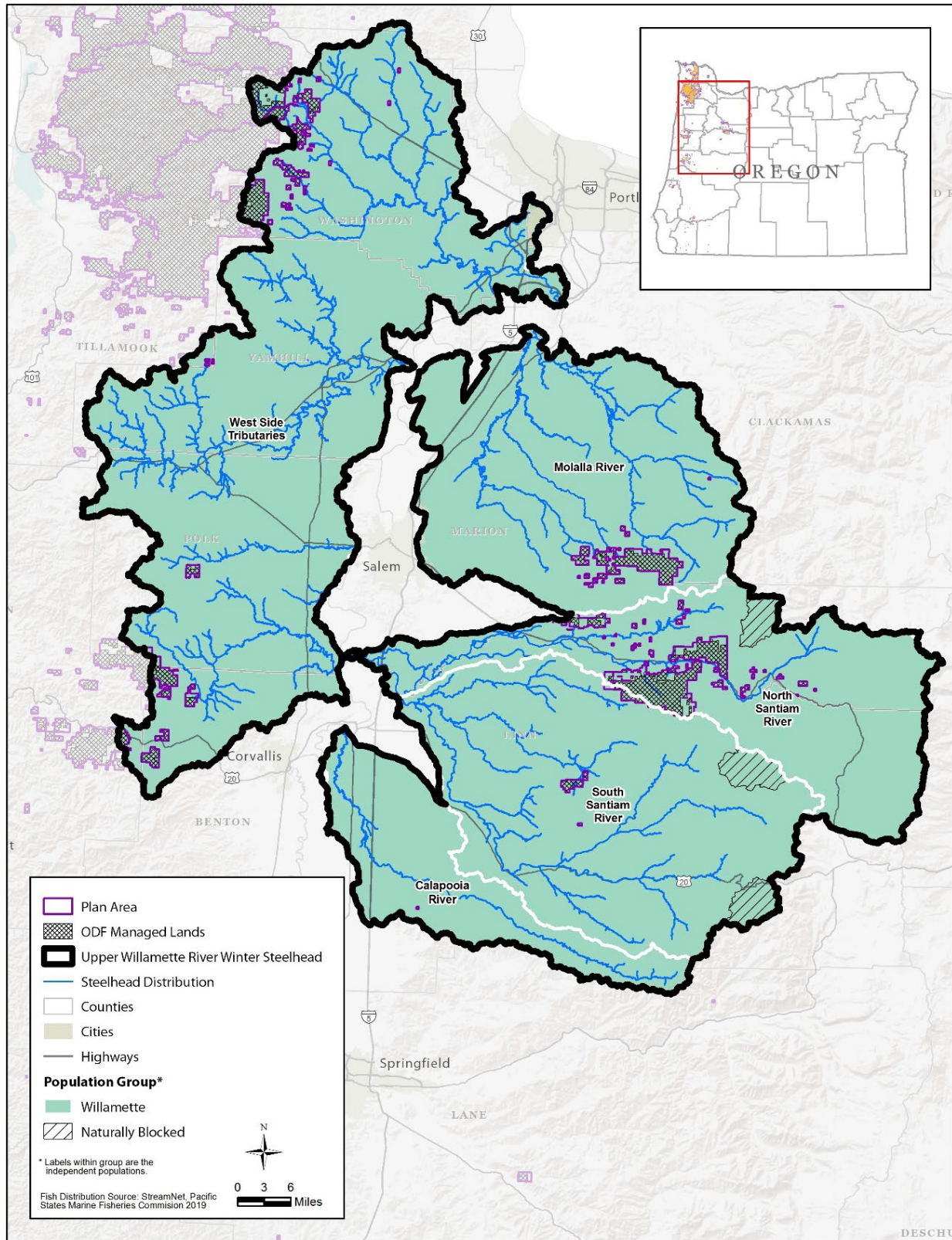


Figure C4-1. Upper Willamette River Steelhead DPS Strata and Independent Populations in Oregon

Occurrences Within the Plan Area

Based on distribution maps published by Streamnet (2019), approximately 2% of Upper Willamette River winter steelhead ESU range occurs within the plan area (Table C4-1). The highest percentage of occurrence for any specific population is in the North Santiam River, where 5% of the range of the population occurs within the plan area.

Table C4-1. Miles of Steelhead Known or Presumed Presence

Biogeographic Stratum and Population	Stream Miles with Known or Presumed Steelhead Presence		
	Total Stream Miles	Miles Within or Adjacent to Plan Area	Percent of Total Within or Adjacent to Plan Area
Willamette Stratum	1,741	29	2%
Molalla River	296	2	1%
North Santiam River	174	9	5%
South Santiam River	326	2	1%
Calapooia River	88	0	0%
West Side Tributaries	857	16	2%

Source: Streamnet 2019.

Natural History

Life History and Habitat Requirements

Steelhead are considered by many to have the greatest diversity of life history patterns of any Pacific salmonid species, including varying degrees of anadromy, differences in reproductive biology, and plasticity of life history between generations (Busby et al. 1996). Steelhead can survive spawning and a small fraction of adults may live-spawn more than once (Steelquist 1992), although repeat spawning is relatively rare. Repeat spawners are usually females that migrate back to the ocean and then return to spawn the following spring (ODFW and NMFS 2011).

Spawning

Upper Willamette River winter steelhead run return to freshwater in January through April, pass Willamette Falls from mid-February to mid-May, and spawn in March through June, with peak spawning in late April and early May. Compared to spring Chinook, Upper Willamette River steelhead typically migrate farther upstream and can spawn in smaller, higher gradient streams (ODFW and NMFS 2011).

Incubation and Freshwater Residence

Juvenile steelhead reside in headwater tributaries and upper portions of the subbasins for typically 2 years, but may reside in freshwater for as little as 1 year to up to 4 years (ODFW and NMFS 2011). Smolts migrate in the spring (April through May) and are believed to move quickly to the ocean.

Ocean Life

Juvenile steelhead utilize estuaries as rearing and foraging habitat, but such use may be only brief, with peak use in May (ODFW and NMFS 2011).

Population Status and Trends

ODFW and NMFS (2011) found that the Calapooia River independent population was at modest risk of extinction and that the North Santiam, South Santiam, and Molalla populations were at low risk.

Table 4-2. Upper Willamette River Adult Steelhead Abundance

Biogeographic Stratum and Population	Steelhead Adult Abundance	
	Recent 5-year Average and Range (2004–2008)	Percent of Total ESU Abundance
Willamette Stratum	6,611 (140/3,863)	
<i>Molalla River</i>	1,484 (1,273/1,987)	22%
<i>North Santiam River</i>	2,826 (1,650/3,863)	43%
<i>South Santiam River</i>	1,988 (1,519/3,546)	30%
Calapooia River	312 (140/684)	5%

Source: ODFW 2019.

Note: italics populations occur in the plan area

Threats

The Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead (ODFW and NMFS 2011) describes human threats in five broad categories. In addition, the Recovery Plan for Upper Willamette River Chinook and Steelhead (ODFW and NMFS 2011) identifies a wide range of human impacts on these two ESUs, including the following related to forest management:

- Timber harvest on unstable slopes and riparian areas as leading to the decoupling of watershed processes.
- Improperly located, constructed, or maintained roads have degraded stream flow and sediment supply processes.
- The legacy effects of splash dams to transport logs continues to inhibit instream structural complexity and available spawning gravel in several stream systems.

Table C4-3 summarizes the limiting factor and threat (LFT) analysis results, and Table C4-4 summarizes threats from climate change and human population growth.

Table C4-3. Human Impact Limiting Factor and Threat (LFT) Analysis Results

Threat Category	Limiting Factors	How Do Threats Cause or Contribute to Limiting Factors?
Flood Control and Hydropower Management	• Hydrograph/water quantity • Physical habitat quality/quantity • Food web	• Stream modifications result in stream habitat loss or alteration • Changes to hydrologic regime and flow alter habitat and food webs

Threat Category	Limiting Factors	How Do Threats Cause or Contribute to Limiting Factors?
Land Management	- Physical habitat quality/quantity - Water quality	Changes in land use degrade or destroy habitat quantity and functionality
Other Species	- Competition - Predation - Physical habitat quality/quantity	- Food competition and predation directly affect populations - Invasive/non-native plants degrade habitat
Harvest Management	Population traits	- Direct and indirect mortality to individuals - Selective targeting (age/size)
Hatchery Management	- Competition - Disease - Population traits - Habitat access	- Increased food competition and predation - Disease introduction - Interbreeding with hatchery-origin fish can reduce wild fish fitness and genetic diversity - Hatchery weirs can block access to upstream habitat

Source: ODFW and NMFS 2011.

Table C4-4. Projected Climate Change and Human Population Growth Impacts for the Pacific Northwest

Threat Category	Projected Impact for the Pacific Northwest and Description
Climate Change	- Air temperature: each decade warmer than the one before - Precipitation: increased in winter and decreased in spring, summer, and fall - Snowpack: substantial declines due to increased air temperatures and precipitation - Storms and flooding: increased storm events and intensity - Timing of peak spring runoff: earlier snowmelt will lead to earlier peak stream flows - Summer streamflow: continued decline in sensitive PNW basins and declines becoming more widespread
Human Population Growth and Development	- Forests, water (surface and groundwater), and land: increased demands on shared resources key to fish and wildlife - Land conversion: demand for residential land increasing agricultural and forest land conversion - Development: spreading outwards from cities causes more habitat loss and fragmentation, increases infrastructure costs, and social conflict - Impervious surfaces: increased urbanization increases impervious surfaces (e.g., roofs, pavement, and transportation corridors) and reduces groundwater recharge - Combined effect with climate change: increased pressure on fish and wildlife habitats and demands for freshwater - External to Columbia River Basin: international trade, shipping, dredging, hazardous material transport, and airborne pollution

Source: ODFW and NMFS 2011.

Literature Cited

- Busby, P.J., T.C. Wainwright, E.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum 27.
- Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D.M. Van Doornik, and M.T. Maher. 2006. Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-73, 311 pp. February 2006.
- National Marine Fisheries Service (NMFS). 2005. Endangered and Threatened Species; Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register*; 70 FR 37160. June 28.
- National Marine Fisheries Service (NMFS). 2006. Endangered and Threatened Species; Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. *Federal Register*; 71 FR 833. January 5.
- National Marine Fisheries Service (NMFS). 2008. *Endangered Species Act Section 7(a)(2) Consultation Biological Opinion & Magnuson-Stevens Fishery Conservation & Management Act Essential Fish Habitat Consultation: Consultation on the "Willamette River Basin Flood Control Project."* Northwest Region. July 11.
- National Marine Fisheries Service. 2011a. Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. NMFS Northwest Region. Portland, OR. Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc. (subcontractor). January 2011.
- Oregon Department of Fish and Wildlife (ODFW). 2019. Salmon and Steelhead Recovery Tracker Steelhead Data. Available: <http://odfwrecoverytracker.org/>. Assessed: July 2019.
- Oregon Department of Fish and Wildlife and National Marine Fisheries Service (ODFW and NMFS). 2011. *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead*. August.
- Pulliam, H.R. 1988. Sources, Sinks, and Population Regulation. *Am. Nat.* 132:652–661.
<https://www.journals.uchicago.edu/doi/abs/10.1086/284880>
- Steelquist, Robert. 1992. Field guide to the Pacific salmon: including salmon-watching in Alaska, British Columbia, Washington, Oregon, and Northern California. Sasquatch Books.
- StreamNet. 2019. Database (Version 98.3) [database downloaded to disk]. Portland (OR) : StreamNet. URL: <https://www.streamnet.org/data/interactive-maps-and-gis-data/>
- U.S. Army Corps of Engineers (USACE). 2020. *Minto Fish Collection Facility*. Available: <https://www.nwp.usace.army.mil/Missions/Current/Minto-fish-facility/>. Accessed: January 20, 2020.

C5 Columbia River Chum (*Oncorhynchus keta*)

The Columbia River chum salmon evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Lower Columbia River chum salmon ESU includes the Columbia River and rivers and streams originating from Oregon and Washington. Legal Status

State: Sensitive-critical species

Federal: Threatened (Final listing NMFS 1999; 64 FR 14508. Revised NMFS 2005a; 70 FR 37160. Updated NMFS 2014; 79 FR 20802)

Critical Habitat: Designated (Final listing NMFS 2000; 65 FR 7764. Revised NMFS 2005b; 70 FR 52630)

Recovery Planning: Recovery plan approved (NMFS 2013; 78 FR 41911)

Status Review: 5-year status review (NMFS 2016)



Photo: NMFS

Columbia River chum salmon are listed as a sensitive-critical species under the Oregon State Sensitive Species List (ODFW 2019) per state regulation OAR 635-100-0040, and are not listed under the Oregon Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135). Oregon developed the Oregon State Lower Columbia River Conservation and Recovery Plan for the same Oregon chum salmon populations as the federal listing (ODFW 2010). The Oregon State Lower Columbia River Conservation and Recovery Plan addresses legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The conservation plan was approved by the Oregon Fish and Wildlife Commission in August 2010.

Taxonomy

Chum salmon (*Oncorhynchus keta*) were first described by Walbaum in 1792. Chum salmon are one of eight recognized species of Pacific Salmon (*Oncorhynchus* spp.) that occur in North America.

Distribution

Chum salmon distribution is described for their entire range, the Lower Columbia River ESU, and independent populations that intersect the plan area and Oregon Department of Forestry (ODF) managed lands.

General

Chum salmon have the widest range of all Pacific salmon. They can be found in Asia from Japan to Siberia and in North America from Alaska to Monterey, California (Groot and Margolis 1991). Historically, Columbia River chum salmon were abundant and spawned throughout the lower Columbia Basin, as far upstream as the Walla Walla and Umatilla rivers (Nehlsen et al. 1991). Since the construction of Bonneville Dam, the species' distribution is mostly limited to the Columbia River mainstem and tributaries below the dam, and very few adult fish have been observed upstream of the dam (NMFS 2013; McElhany et al. 2004; NWFSC 2015).

The Lower Columbia River chum salmon ESU (Figure C5-1) includes naturally spawned chum salmon originating from the Pacific Ocean and the freshwater and estuarine habitat in the Columbia River and tributaries to the Columbia River in Oregon and Washington, as well as from two artificial propagation programs (NMFS 1999; 64 FR 14508, NMFS 2005a; 70 FR 37160, NMFS 2014; 79 FR 20802).

NMFS (2013a) identified three major population groups (MPG) in the Columbia River chum salmon ESU: (1) Coast, (2) Cascade, and (3) Gorge. Within these three MPGs, NMFS identified 17 independent populations, all occurring within Oregon and Washington. In Oregon, four independent populations are within the Coast MPG (Youngs Bay, Big Creek, Clatskanie River, and Scappoose Creek), two independent populations in the Cascade MPG (Clackamas River and Sandy River), and two independent populations in the Gorge MPG (Lower Gorge Tributaries and Upper Gorge Tributaries) (NMFS 2013). Within the ESU, most remaining natural production is limited to the Grays/Chinook population, and the Washougal River and Lower Gorge tributaries populations (NWFSC 2015). Within Oregon, chum salmon have been considered to be extirpated, or nearly so, from tributaries of the Columbia River, due to little or no observed spawning populations (McElhany et al. 2007; NWFSC 2015).

ESU recovery is based on achieving sustainable independent populations within the ESU and across the MPGs. NMFS set three recovery criteria for recovery of the of the Columbia River chum salmon ESU: (1) within each MGP, there should be at least two populations that have a 95% chance of persisting over a 100-year time frame; (2) within each MPG, approximately half the populations should have a persistence probability of high or very high; and (3) viable populations should be dispersed across the ESU, include those that were historically most productive, and represent the genetic diversity of the ESU (NMFS 2013).

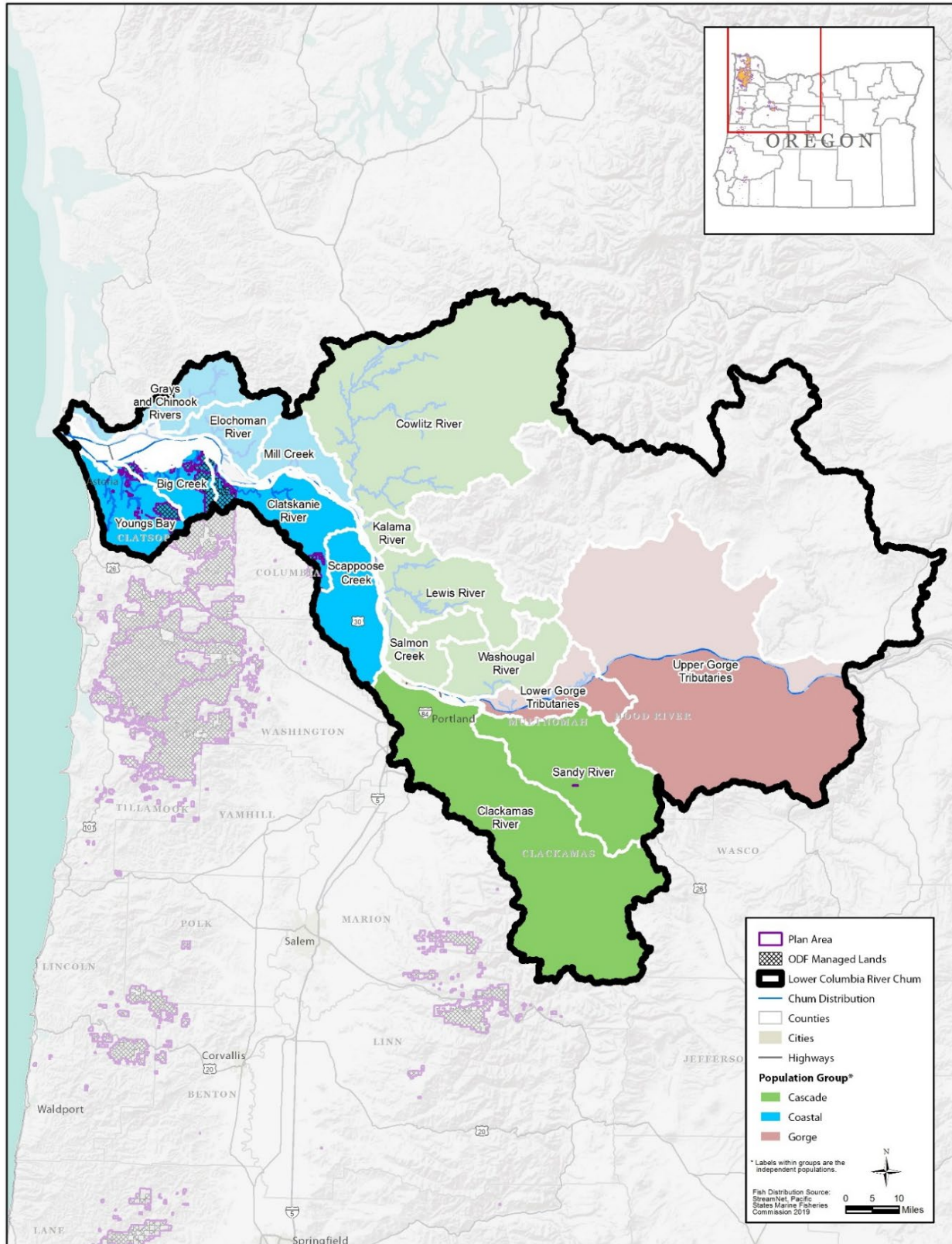


Figure C5-1. Columbia River Chum Salmon ESU Strata and Independent Populations in Oregon

Occurrences Within the Plan Area

Five independent populations within two MPGs of the Columbia River chum salmon ESU intersect the plan area (Figure C5-1):

- Coastal MPG:
 - Youngs Bay independent population
 - Big Creek independent population
 - Clatskanie River independent population
 - Scappoose Creek independent population
- Cascade MPG:
 - Sandy River independent population

Miles of streams with documented or presumed chum salmon presence within the ESU and within the plan area are summarized in Table C5-1 (Streamnet 2019). Stream miles are identified for independent populations by strata. Only the Big Creek (18%) and Youngs Bay (2%) independent populations in the Coastal Stratum have stream miles with known or presumed chum salmon presence within the plan area.

Table C5-1. Stream Miles with Chum Salmon Known or Presumed Presence Within Biogeographic Strata in Oregon that Intersect with the Plan Area

Biogeographic Stratum and Independent Populations ¹	Stream Miles with Known or Presumed Chum Salmon Presence		
	Total Stream Miles Within ESU	Miles Within or Adjacent to Plan Area	Percent of ESU Total Within or Adjacent to Plan Area
Coastal Stratum			
Big Creek	45	8	18%
Youngs Bay	57	1	2%
Clatskanie River	25	0	0%
Scappoose Creek	0	0	0%
Cascade Stratum			
Sandy River	0	0	0%

Source: Streamnet 2019.

¹ Only independent populations located entirely and/or partially within Oregon and that intersect with the plan area are shown; populations that are located entirely outside of Oregon (i.e., entirely within Washington) or that do not overlap with the plan area are not listed.

Natural History

Chum salmon are found throughout the lower and mid-river mainstem reaches of streams entering the lower Columbia River. Columbia River chum salmon typically have a 4-year life cycle and all die after spawning. Most fish are fall-run; adults return to freshwater between mid-October and November, depending on geographic location, after 3 to 6 years in the ocean. Spawning primarily occurs in the lower reaches of mainstem rivers, tributaries, or side channels. Incubation in gravel

can last approximately 1 to 6 months depending on water temperature. In the spring, the chum salmon fry emerge from the gravel, typically at night, and promptly migrate to estuarine habitats to rear. Once emerged from gravel, chum salmon fry spend less time in freshwater and more time in the estuary than other anadromous salmonids. Chum do not have a clearly defined smolt stage, but are nonetheless capable of adapting to seawater soon after emerging. Juveniles rear in estuaries prior to entering the ocean. This critical period allows for growth to occur prior to undertaking long-distance ocean migrations. Chum are dependent on different habitats through their life history, which are discussed in more detail below.

Life History and Habitat Requirements

Upstream Migration and Spawning

Chum salmon spend 2 to 6 years in the ocean before returning to their natal streams (Steelquist 1992, and Bigler 1985, as cited in Salo 1991; LCFRB 2010). In the fall, adult chum salmon return to tributaries of the Columbia River to spawn in the lower gradient reaches of large rivers and small tributaries. Upstream migration occurs from November through December. Spawning typically ranges from November through January (Salo 1991; LCFRB 2010). Historically, summer-run chum salmon returned to the Cowlitz River, and observations of this life history variation occur occasionally (Ford 2011, and Myers et al. 2006, as cited in NMFS 2013).

Spawning typically occurs close to salt water and can occur in the tidal zone (Salo 1991; Hale et al. 1985), though Chum salmon may utilize various habitats for spawning across the species' range (Smirnov 1975, as cited in Salo 1991; Bakkala 1970). Generally, the species does not pass substantial barriers during upstream migrations (Neave 1953, 1966, and Thorsteinson et al. 1971, as cited in Hale et al. 1985; Bakkala 1970). Within the lower Columbia River, chum salmon spawn in the lower mainstem just outside tidal reaches, in subbasin tributaries such as Grays River, Hamilton Creek, and Hardy Creek, and can also occur up to 60 miles from sea in the Columbia River system (LCFRB 2010).

Chum salmon generally spawn in areas of turbulence or upwelling (Smirnov 1975, as cited in Salo 1991; Bakkala 1970; Hale et al. 1985). Within the Lower Columbia River, spawning sites are usually in low-elevation and low-gradient reaches with no barriers (LCFRB 2010). Within the lower Columbia River watershed, spawning sites are typically found in areas with upwelling water (usually near the mouth of rivers) and clean gravel (LCFRB 2010).

Each spawning season, females typically construct four to six redds in substrates of gravel and mixed sand, with minimal fine sediments present. Females excavate a nest, then males and females spawn simultaneously, depositing fertilized eggs into the nest. Females cover the nest with gravel to complete the redd, then begin excavating another redd (Salo 1991). Females may lay approximately 2,000 to 4,000 eggs per year in North American chum salmon populations (Salo 1991).

Incubation

Chum salmon egg incubation generally begins sometime between November and January (spawning season) and lasts through March, but can extend into April of some years (LCFRB 2010). The species, like other salmonids, are dependent on clean, cold water with sufficient flow or upwelling. Duration of incubation may be influenced by factors such as dissolved oxygen, gravel size, salinity, nutritional condition, and/or even the behavior of alevins, though water temperature is thought to be the most

influential factor in time to emergence (Bakkala 1970, and Koski 1975, as cited in Hale et al. 1985; Salo 1991; LCRFB 2010). Eggs generally incubate in gravel redds approximately 50 to 130 days before hatching (Bakkala 1970; Salo 1991), and low water temperatures can delay fry emergence by 1.5 to 4.5 months (Hale et al. 1985). Typical spawning temperature ranges from 39–61°F (4–16°C) (Neave 1966, as cited in Bakkala 1970). Upper thermal limits for chum salmon incubation are not yet known (LCRFB 2010), and mortality of eggs, alevin (post hatching), and fry increases when incubation temperatures fall below 34.7°F (1.5°C) (Schroder et al. 1974, as cited in LCRFB 2010).

Two habitat factors that affect chum salmon performance in freshwater are channel stability and fine sediment. These habitat relationships are likely the most important environmental factors affecting populations of chum salmon in freshwater in many streams and rivers of the Pacific Northwest (need citation). Increases in fine sediments negatively affect survival during the egg and alevin life stages (Jensen et al. 2009). Bed scour and channel instability can be major sources of mortality affecting the survival of incubating chum eggs and alevins. Montgomery et al. (1996) found that even minor increases in depth of bed scour due to land use practices can significantly reduce embryo survival. Scour and fill of gravel beds are normal physical processes that occur during high flow events, but watershed development can change their rates and associated equilibria. Fine sediment affects the survival of salmonid embryos in at least three ways: (1) by direct suffocation of eggs and alevins, (2) by reduction of intragravel water flow and dissolved oxygen content, and (3) by providing a physical barrier to emergence (entombment) (as synthesized in Salo 1991). Because chum salmon tend to spawn in the lower reaches of stream systems where gradient is low and fine sediments accumulate, they may be generally more exposed to increased sedimentation than most other salmonid species. Evidence for the effect of intra-gravel fine sediment on salmonids is well documented (Chapman and McLeod 1987; Bjornn and Reiser 1991; Kondolf 2000).

The relationship between fines and survival described above apply where flow through the redd is downwelling. None of the streams where the studies were conducted are strongly influenced by springs; therefore, downwelling would characterize flow through redds in these cases (see Bjornn and Reiser 1991; Waters 1995). In streams fed largely by springs, salmonid spawning is usually associated with upwelling due to the groundwater influx occurring through a reach. When spawning occurs in upwelling groundwater, the adverse effects of sediment on eggs and emerging fry are largely negated, resulting in high survival provided the groundwater is not low in dissolved oxygen (Bjornn and Reiser 1991; Garrett et al. 1998). Spawning areas at these locations may be very high in fines. This explains why salmonids may have very high rates of reproduction in some streams despite excessive deposits of fine sediment (e.g., chum and sockeye salmon are known to spawn heavily in groundwater fed streams, even in areas with high fines).

Emergence and Downstream Migration

Chum salmon fry emerge from the gravel, typically at night, and almost immediately emigrate downstream to estuary rearing habitat (Salo 1991). Factors affecting the initiation of outmigration in chum populations include day length (increasing), estuarine water temperatures (warming), and seasonal densities of plankton (high) (Walters et al. 1978, as cited in LCRFB 2010). Some additional factors influencing downstream migration timing include: stream temperatures, fry size and nutritional condition, physiological changes in the fry, population density, food availability, stream discharge volume and turbidity, and tidal cycles (Simenstad et al. 1982, as cited in LCRFB 2010; Salo 1991). Water temperatures above 23.8°C or below -0.1°C are lethal for fry within their first summer after hatching (Brett 1952, and Brett and Alderdice 1958, as cited in Bakkala 1970), and fry prefer water temperatures between 12°C and 14°C (Bakkala 1970).

Emigration timing in the Columbia River system is not well investigated, but is thought to last from March through May, peaking in April (LCRFB 2010), and some fry have been observed in the Columbia River estuary in February (Bottom et al. 2011).

Predators of juvenile chum salmon include coho juveniles, resident trout species, and sculpins, though predators depend on species composition in each system. Predation mortality during downstream emigration has been described as significant for chum salmon (ranging from 22% to 58%) because fry migrate at small sizes shortly after emergence (Beall 1972, and Hiyama et al. 1972, as cited in LCRFB 2010). Chum fry school and move in concert during downstream emigration to minimize predation mortality (Pitcher 1986, and Biller and Brannon 1982, as cited in LCRFB 2010).

Freshwater Residence

As described above, most chum salmon fry typically migrate to estuary habitats immediately after emerging from the gravel. Some fry may migrate slowly downstream while feeding in the spawning areas. In larger, northern rivers, juvenile chum may remain up to a year in freshwater. In larger rivers to the Columbia River, duration of emigration may be relatively longer (Salo 1991). Feeding within freshwater generally appears to be important within the larger rivers where emigration duration is extended (LCRFB 2010). In rivers that drain directly into the Pacific Ocean, chum fry may linger in freshwater longer before moving directly into the open ocean, compared to chum freshwater residence times in other rivers that drain to estuaries. Rivers that drain directly into the ocean have limited opportunities for fry to experience estuarine exposure and residency (citation needed).

Estuary Rearing and Growth

The period of estuarine residence appears to be the most critical phase in the life history of chum salmon, having a major role in determining the size of the subsequent adult run (Mazer and Shepard 1962, Mathews and Senn 1975, Fraser et al. 1978, Peterman 1978, Sakuramoto and Yamada 1980, Martin et al. 1986, Healey 1982, and Bax 1983a, as cited in Johnson et al. 1997; Bakkala 1970; Salo 1991). Chum salmon are considered second only to Chinook salmon in dependence upon estuarine waters (Salo 1991). Chum salmon typically may spend weeks to months in estuary habitat before ocean entry (NMFS 2011), though residence may be as short as a few days (Congleton 1979, Healey 1982, Simenstad et al. 1982, and Bax 1983a, as cited in LCRFB 2010). Roegner et al. (2016) noted that shallow water habitat conservation and restoration are particularly important for chum salmon, which exhibit an ocean-type life history (outmigrate shortly after emerging from gravel, spending little time in stream habitat).

Estuaries are ideal habitats for foraging and rapid growth of chum outmigrants. In general, chum salmon grow rapidly in estuaries. They prefer shallow sublittoral habitats before moving into neritic deepwater habitats. In the estuaries chum will continue feeding and smolt when they are between 50 and 80 millimeters (Simenstad et al. 1980). Estuarine survival may be primarily determined by timing of entry into estuaries, due to seasonal variations in plankton abundance (Gunsolus 1978, Helle 1979, Gallagher 1979, and Simenstad and Salo 1982, as cited in LCRFB 2010). Additionally, estuary plankton populations may be “overgrazed” when juvenile salmonids enter estuaries in large numbers simultaneously (Reimers 1973, and Healey 1991, as cited in LCRFB 2010), which could contribute to lowered chum growth and/or survival rates.

In the Columbia River Estuary, chum have been found primarily in shallow shoreline habitats, and some have been sampled from deep water channel habitats. Smaller fish (fry) tended to occupy shallow habitats, and larger fish (fingerlings) were found in the deeper habitats (Roegner et al. 2016). Sampling in the Columbia River Estuary has observed juvenile chum salmon from March through June (Roegner et al. 2016), and fish have been observed within the freshwater, brackish, and marine regions of the estuary (Bottom et al. 1984, 2011).

Predation in the Columbia River estuary on juvenile salmonids has potentially increased from historical levels following recovery of predator populations (Fresh et al. 2005, NMFS 2016). Predators include marine mammals (primarily pinnipeds), smallmouth bass (*Micropterus salmoides*), northern pikeminnow (*Ptychocheilus oregonensis*), and double-crested cormorants (*Phalacrocorax auritus*) (Beamesderfer et al. 1996, Collis et al. 2001b, and Ryan et al. 2003, as cited in Fresh et al. 2005).

Ocean Life

Pacific salmon are anadromous fish; adults migrate from the ocean to spawn in freshwater lakes and streams where their offspring hatch and rear prior to migrating back to the ocean to forage until maturity. The physiological and behavioral changes required for the transition of juveniles from freshwater to saltwater happens more rapidly in chum than it does in most other anadromous salmonids. Unlike most other salmonids, chum salmon do not have a defined smoltification period; they typically enter salt water while retaining parr marks, and are capable of osmoregulation at the fry and fingerling stages (Iwata 1982, as cited in Salo 1991). Chum generally migrate to coastal waters and continue feeding until they reach between 110 and 170 millimeters. From there, the offshore cold water and open ocean life stages begin.

Juvenile chum salmon mortality shortly after entry into the marine environment can be high, and early marine residence is considered a critical period in the marine phase of chum life history (Bax 1983a, as cited in Salo 1991). Factors affecting early marine residence include food availability/limitations (Gunsolus 1978, Helle 1979, Gallagher 1979, and Simenstad and Salo 1982, as cited in Salo 1991) and predation (Hargreaves and LeBrasseur 1986, as cited in Salo 1991).

Chum salmon spend 3 to 6 years in the ocean before returning to spawn in freshwater streams (Bigler 1985, as cited in Salo 1991; LCFRB 2010). Chum salmon generally spend their first year in the marine environment schooling with other salmonids (pink and sockeye juveniles), and remain near-shore (within a few dozen kilometers of shore). After migrating north toward Alaska, groups generally move offshore, and directional movement may be influenced by currents (Hart 1980, and Hart and Dell 1986, as cited in LCFRB 2010). North American and Asian chum salmon populations mix in high-seas environments in the North Pacific Ocean and Bering Sea (LCFRB 2010).

Habitat capacity for chum salmon on the Oregon Coast has significantly decreased from historical levels. During periods of poor ocean survival, high quality habitat is necessary to sustain chum populations. Disease and infection of juvenile chum salmon in the first few months of ocean residence is a key concern.

In May and June, maturing adults residing in the North Pacific migrate toward the coast, then reside in coastal waters from June to November before beginning upstream migrations for spawning (Neave et al. 1976, Fredin et al. 1977, and Hartt 1980, as cited in LCFRB 2010).

Ecological Relationships

Please refer to *Ecological Relationships* in Section C1, *Oregon Coast Coho* above.

Population Status and Trends

Historically, chum salmon returns to the Columbia River Basin numbered in the hundreds of thousands and approached a million, before declining in the 1940s and 1950s (Good et al. 2005). The historical chum run size in the Columbia River has also been estimated at nearly 1.4 million fish per year (LCFRB 2010). Since the mid-1900s, returns have been estimated to average a few thousand fish per year, only returning to a small subset of the historical range within the ESU (Good et al. 2005; NWFSC 2015; NMFS 2016).

As of 2010, it was estimated that 14 of 17 of the historical spawning populations, also known as demographically independent populations (DIPs), within the Columbia River chum salmon ESU had been extirpated or nearly so (Ford et al. 2011). Two populations are considered relatively stable: the Washougal River and Lower Gorge DIP each maintain moderate numbers of spawners (NWFSC 2015; NMFS 2016). One population is considered only at low risk of extinction: the Grays River DIP, which has spawner abundances in the thousands annually and has exhibited a recent positive trend (NWFSC 2015; NMFS 2016).

Within Oregon, chum salmon have been considered to be extirpated, or nearly so, from tributaries of the Columbia River, due to little or no observed spawning populations (McElhany et al. 2007; NWFSC 2015). The term “functionally extirpated” describes a species that has been extirpated from an area; although a few individuals may occasionally be found, there are not enough fish or habitat in suitable condition to support a fully functional population (NMFS 2013).

Additionally, four hatchery programs exist in the Lower Columbia River Basin that release juvenile chum fry: Grays River Hatchery (releases to Grays River), Big Creek Hatchery (releases to Big Creek), Lewis River Hatchery (releases to East Fork Lewis River), and Washougal Hatchery (releases into Duncan Creek) (NWFSC 2015). Integrated stocks are developed to supplement natural production. The majority of fry are unmarked and are released during their first spring. Total annual hatchery production has not exceeded 500,000 fish. Unmarked returning adults are allowed to spawn naturally above the Big Creek weir, and excess fish are released into nearby basins to assist in reestablishment of naturally spawning populations (NWFSC 2015).

The current population statuses and trends within each of the three MPGs (Coastal, Cascade, and Gorge) are discussed below.

Coastal Range MPG

Oregon Coastal Range DIPs

Within the Coastal MPG, the Big Creek DIP, Youngs Bay DIP, Clatskanie DIP, and Scappoose DIP overlap with the plan area.

Only the Big Creek and Youngs Bay DIPs have streams within the plan area that are known or presumed to have chum salmon presence. Refer to *Distribution* above, Figure C5-1, and Table C5-1 for details.

The Big Creek DIP (Oregon) has had observations of spawning chum salmon normally in the tens of fish, as counted at the Big Creek weir. Most other DIPs within the Coastal Range MPG exist at very low abundances (less than 10 observations per year), and some may be functionally extinct (NWFSC).

There are currently two hatchery programs in the Coastal MPG releasing juvenile chum salmon: Grays River Hatchery and Big Creek Hatchery. Some supplementation programs and reintroductions using hatchery broodstock occur in other tributaries in the Coastal MPG, and outmigrating fry observations have been made (NWFSC 2015).

Washington Coastal Range DIPs

Within the Coastal MPG, the Grays River DIP, the Elochoman/Skamakowa Rivers DIP, and the Mill/Abernathie/Germany Creeks DIP do not overlap with the plan area.

The Grays and Chinook Rivers DIP is considered a stronghold in the MPG and ESU (NWFSC 2015). Standardized mark-recapture surveys occur and population estimates are available for Grays River (NWFSC 2015). Since the early 2000s, the Grays River population has had spawner abundances in the thousands, peaking over 10,000 spawners in 2002. The population has demonstrated a recent positive trend and is estimated to consist of an average of 93.4% naturally produced fish (only 6.4% hatchery-produced fish); thus, it is considered to be at a low risk of extirpation (NWFSC 2015; NMFS 2016).

Very low numbers (<10) of returning adult chum salmon are observed occasionally in most other tributaries of the Coastal Range DIPs (NWFSC 2015).

Cascade MPG

Washington DIPs

Within the Cascade MPG, the Washougal River DIP, Salmon Creek DIP, Lewis River, Kalama River, and Cowlitz River summer/Cowlitz River fall-run DIP do not overlap with the plan area.

In the early 2000s, spawning chum salmon were observed in the Columbia River mainstem near the Interstate-205 bridge (at Woods Landing and Rivershore, in Washington), and are considered part of the Washougal population (Good et al. 2005). These populations were observed at groundwater seeps. The population has experienced large 5-fold fluctuations, but appears generally stable with a few thousand fish observed annually across two spawning aggregations (NWFSC 2015).

Very low numbers of spawners (e.g., less than 100) have been observed at the following locations on the Washington side of the ESU, within the Cascade MPG: Bonneville Dam, Cowlitz, Elochoman, North Fork Lewis, and Skamakawa (Good et al. 2005). Recurring observations have been made of early returning “summer” chum salmon at the Cowlitz Salmon Hatchery Trap on the Cowlitz River (NWFSC 2015).

There are currently two hatchery programs in the Cascade MPG releasing juvenile chum salmon: Lewis River Hatchery and Washougal Hatchery (NWFSC 2015).

Oregon DIPs

Within the Cascade MPG, the Sandy DIP overlaps with the plan area, and the Clackamas DIP does not overlap with the plan area.

As of 2005, Oregon spawning populations of Columbia River chum salmon were considered extirpated or nearly so, with the exception of the lower Columbia Gorge population (Good et al. 2005). Systematic surveys for chum are not undertaken in Oregon tributaries within the Cascade MPG, and very few observations of spawning chum salmon are made in the streams of the Clackamas DIP and Sandy DIP. For example, in November 2013, two adults were observed at the North Fork Dam in the Clackamas River, and few (less than 10) adults are collected at hatcheries throughout the MPG annually (NWFSC 2015).

Gorge MPG

Lower Columbia Gorge DIP (Washington/Oregon)

Within the Gorge MPG, the Lower Columbia Gorge DIP (including all subpopulations) does not overlap with the plan area.

The lower Columbia Gorge populations consist of four subpopulations below Bonneville Dam: Hardy Creek (Washington), Hamilton Creek (Washington), Ives Island (within mainstem Columbia River, Washington), and the Multnomah area (within mainstem Columbia River, Oregon) (Good et al. 2005). Standardized mark-recapture surveys occur in the mainstem and population estimates are available for the lower Columbia River mainstem (NWFSC 2015). Additionally, spawning aggregations occur in Multnomah and Horsetail Creeks (Oregon) and St. Cloud area along the Washington shoreline (NWFSC 2015). Abundance estimates for all populations collectively within the Lower Columbia Gorge DIPs are a few thousand annually, though a negative trend has been observed (NWFSC 2015).

Upper Columbia Gorge DIP (Washington/Oregon)

Within the Gorge MPG, the Upper Columbia Gorge DIP (including all subpopulations) does not overlap with the plan area.

Though a large amount of chum salmon habitat upstream of Bonneville Dam is considered to have been eliminated by inundation after construction of the dam, small numbers of chum are recorded passing Bonneville Dam annually (Good et al. 2005). Between 2010 and 2014, chum salmon adult counts at the dam averaged approximately 105.6 ± 47.7 (Standard Deviation) fish, and, in 2010, chum fry were observed at the Bonneville Dam juvenile monitoring facility (NWFSC 2015).

Threats

In general, Columbia River chum salmon population declines have resulted from the combined and compounded impacts of human activities on freshwater and estuary habitats, dam construction and operation, fishing, fish hatcheries, and ecological factors such as predation (LCFRB 2010). A federal recovery plan for the Columbia River chum salmon ESU was finalized in June 2013 (NMFS 2013). The plan provides guidance to improve the viability of Lower Columbia River chum salmon to the point that it meets the delisting criteria and no longer requires ESA protection. NMFS (2013) describes listing factors and threats to Columbia River chum salmon:

Columbia River chum salmon have been—and continue to be—affected by loss and degradation of spawning and rearing habitat, the impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the persistence probability of all populations. Under baseline conditions, constrained spatial structure at the ESU level (related to conversion, degradation, and inundation of habitat) contributes to very low abundance and low genetic diversity in most populations and increases risk to the ESU from local disturbances.

Additionally, NMFS (2013) describes adverse effects of natural environmental variability from drought, floods, and poor ocean conditions that have been exacerbated by the degradation of habitat by human activities. The recovery strategy addresses threats influencing limiting factors for tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation. NMFS describes restoration of tributary spawning and estuary rearing habitat as essential in the recovery of the species.

The most recent status review that addressed Columbia River chum salmon synthesized previous status conclusions and evaluated recent data and observations (NWFSC 2015). The status review determined that, as of 2015, some improvements and declines in individual populations have been observed, but the majority of DIPs in the ESU remain at a high or very high risk category, and most chum populations require substantial improvements to meet their recovery viability goals.

The Lower Columbia Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead, approved in August 2010, describes the population status and recovery plans for salmon and steelhead, including the Oregon sub-basin populations of the Columbia River chum salmon ESU. The document addresses federal legal requirements (under ESA) and state legal requirements (under Oregon's Native Fish Conservation Policy). It provides a strategic approach to recovery based on science, with stakeholder support, and using specific recovery actions. (ODFW 2010)

The Lower Columbia Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead includes Appendix I, Oregon's Columbia River Chum Salmon Recovery Strategy (ODFW 2010). All of the streams in the Oregon portion of the Columbia River chum ESU have been altered by human development, specifically the construction of Bonneville Dam, Interstate 84, and a railroad line and the development of the Portland Metropolitan Area. All Oregon populations are threatened by altered hydrology and land uses, which affect water quality, water quantity, and food web (plume) dynamics. Harvest from targeted fishery threatens both population abundance and diversity. Oregon's Columbia River Chum Salmon Recovery Strategy document focused mostly on recovery efforts for the Coastal stratum because the Oregon Department of Fish and Wildlife (ODFW) believed basins within the Coastal stratum have been altered to a lesser extent by human development than the Cascade and Gorge strata, and will focus efforts in the latter strata in the future.

Table C5-2 summarizes key threats and limiting factors facing each chum salmon DIP in Oregon.

Table C5-2. Threat Summary by Oregon Population

Oregon Population	Key Threats and Limiting Factors
Young's Bay	• Diking and wetland filling alters and degrades estuarine rearing habitat • Hatchery-origin coho, steelhead, and Chinook smolt predation on chum fry • Stray hatchery fish interbreeding with wild fish • Hatchery weirs block access to historical spawning and rearing habitat
Big Creek	• Altered and degraded estuarine habitat

Oregon Population	Key Threats and Limiting Factors
	- Excess fine sediment in spawning gravels - Hatchery-origin coho, steelhead, and Chinook smolt predation on chum fry - Stray hatchery fish interbreeding with wild fish - Hatchery weirs block access to historical spawning and rearing habitat
Clatskanie River	- Altered and degraded estuarine habitat - Excess fine sediment in spawning gravels - Low large woody debris (LWD) density and habitat complexity/diversity - Hatchery-origin coho, steelhead, and Chinook smolt predation on chum fry
Scappoose Creek	- Altered and degraded estuarine habitat - Excess fine sediment in spawning gravels - Marginal channel complexity and diversity - Hatchery-origin coho, steelhead, and Chinook smolt predation on chum fry
Clackamas	- Impaired physical habitat diversity and complexity - Elevated water temperatures from large hydropower reservoirs impair water quality - Stray hatchery fish interbreeding with wild fish
Sandy	- Impaired physical habitat diversity and complexity - Hatchery weirs block access to historical spawning and rearing habitat
Lower Gorge	- Transportation corridor development impairs habitat quality and quantity - Stray hatchery fish interbreeding with wild fish
Upper Gorge/Hood	- Irrigation withdrawals alter hydrology and water quantity - Impaired physical habitat diversity and complexity - Stray hatchery fish interbreeding with wild fish

Sources: Oregon Department of Fish and Wildlife 2010; NMFS 2013.

Literature Cited

- Bakkala, R. G. 1970. Synopsis of biological data on the chum salmon, *Oncorhynchus keta*. Circular 315 U.S. Fish and Wildlife Service, Conservation Library, Shepherdstown, WV.
- Bjornn, T. C., and D. W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitat*. American Fisheries Society.
- Bottom, D. L., A. Baptista, J. Burke, L. Campbell, E. Casillas, S. Hinton, D. A. Jay, M. Austill Lott, G. McCabe, R. McNatt, M. Ramirez, G. Curtis Roegner, C. A. Simenstad, S. Spilseth, L. Stamatiou, D. Teel, and J. E. Zamon. *Estuarine Habitat and Juvenile Salmon: Current and Historical Linkages in the Lower Columbia River and Estuary. Final Report 2002-2008*. Northwest Fisheries Science Center, National Marine Fisheries Service; Seattle, Washington. Report Prepared for U.S. Army Corps of Engineers, Portland District. December. Available: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.386.4191&rep=rep1&type=pdf>.
- Chapman, D. W., and K. P. McLeod. 1987. Development of Criteria for Fine Sediment in the Northern Rockies Ecoregion. Prepared for U.S. EPA. Boise, ID. 285 p.
- Ford, M. J., A. Albaugh, K. Barnas, T. Cooney, J. Cowen, J. J. Hard, R. G. Kope, M. M. McClure, P. McElhany, J. M. Myers, N. J. Sands, D. J. Teel, and L. A. Weitkamp. 2011. Status review update for

- Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce NMFS-NWFSC-113, Seattle, WA.
- Fresh, K. L., E. Casillas, L. L. Johnson, and D. L. Bottom. 2005. Role of the estuary in the recovery of Columbia River Basin salmon and steelhead: An evaluation of the effects of selected factors on salmonid population viability. U.S. Dept. Comm., NOAA Technical Memorandum NMFS-NWFSC-69, U.S. Department of Commerce, Seattle, WA.
- Garrett, J. W., D. H. Bennett, F. O. Frost, and R. F. Thurow. 1998. Enhanced incubation success for kokanee spawning in groundwater upwelling sites in a small Idaho stream. *North American Journal of Fisheries Management* 18:925-930. Good, T.P., R.S. Waples, and P. Adams (editors). 2005. *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 pp.
- Groot, C., and L. Margolis. 1991. *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver, B.C.
- Hale, S. S., T. E. McMahon, and P. C. Nelson. 1985. Habitat Suitability Index Models and Instream Flow Suitability Curves: Chum Salmon. *U.S. Fish Wildl. Servo Biol. Rep.* 82(10.108). 48 pp.
- Jensen, D. W., E. A. Steel, A. H. Fullerton, and G. R. Pess. 2009. Impact of Fine Sediment on Egg-to-Fry Survival of Pacific Salmon: A Meta-Analysis of Published Studies. *Reviews in Fisheries Science*; 17(3):348–359.
- Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, and R. S. Waples. 1997. *Status Review of Chum Salmon from Washington, Oregon, and California*. NOAA Technical Memorandum NMFS-NWFSC-32. National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division; Seattle, WA. December.
- Kondolf, G. M. 2000. Assessing Salmonid Spawning Gravel Quality. *Transactions of the American Fisheries Society* 129(1):262-281.
- Lower Columbia Fish Recovery Board. 2010. Lower Columbia Salmon and Fish & Wildlife Subbasin Plan at: <https://www.lcfrb.gen.wa.us/librarysalmonrecovery> Maher, M., M.B. Sheer, E.A. Steel, and P. McElhany. 2005. *Atlas of Salmon and Steelhead Habitat in the Oregon Lower Columbia and Willamette Basins*. Report for the Willamette-Lower Columbia Technical Recovery Team. Produced by the NOAA Northwest Fisheries Science Center. 203 pp.
- McElhany, P., T. Backman, C. Busack, S. Kolmes, J. Myers, D. Rawding, A. Steel, C. Steward, T. Whiteset, and C. Willis. 2004. *Status Evaluation of Salmon and Steelhead Populations in the Willamette and Lower Columbia River Basins*. Northwest Fisheries Science Center; Seattle, WA.
- McElhany, P., M. Chilcote, J. Myers, and R. Beamesderfer. 2007. *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins, Review Draft*. National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, Washington
- National Marine Fisheries Service. 1998. Threatened and Endangered Species: Proposed Threatened Status and Designated Critical Habitat for Hood Canal Summer-Run Chum Salmon and Columbia River Chum Salmon; Proposed Rule. *Federal Register*, 63 FR 1174. March 10, 1998.
- . 1999. Endangered and Threatened Species: Threatened Status for Two ESUs of Chum Salmon in Washington and Oregon. *Federal Register*, 64 FR 14508. March 25, 1999.

- . 2000. Designated Critical Habitat: Critical Habitat for 19 Evolutionarily Significant Units of Salmon and Steelhead in Washington, Oregon, Idaho, and California. *Federal Register*, 65 FR 7764. March 25, 1999.
- . 2005a. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register*, 70 FR 37160. February 16, 2005.
- . 2005b. Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho. *Federal Register*, 70 FR 52630. September 2, 2005.
- . 2011. *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*. NMFS Northwest Region. Portland, OR. January. Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc., subcontractor.
- . 2013. *ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead*. Northwest Region. June.
- . 2014. Endangered and Threatened Wildlife; Final Rule To Revise the Code of Federal Regulations for Species Under the Jurisdiction of the National Marine Fisheries Service. *Federal Register*, 79 FR 20802. April 14, 2014.
- . 2016. *2016 5-Year Review: Summary & Evaluation of Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, Lower Columbia River Coho, Salmon Lower Columbia River Steelhead*. West Coast Region; Portland, OR.
- Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. *Fisheries* 16(2):4-21.
- Northwest Fisheries Science Center. 2015. Status Review Update for Pacific Salmon and Steelhead listed under the Endangered Species Act: Pacific Northwest. December 21, 2015. Northwest Fisheries Science Center. National Marine Fisheries Service, Seattle, WA. 356p.
- Oregon Department of Fish and Wildlife. 2005. *Oregon Native Fish Status Report, Volume I: Species Management Unit Summaries*. ODFW Fish Division, Salem, OR.
- . 2010. *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead*. August.
- . 2019. ODFW Sensitive Species List. Available:
https://www.dfw.state.or.us/wildlife/diversity/species/docs/Sensitive_Species_List.pdf.
- Roegner, G. C., L. A. Weitkamp, and D. A. Teel. 2016. Comparative Use of Shallow and Deepwater Habitats by Juvenile Pacific Salmon in the Columbia River Estuary Prior to Ocean Entry. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 8:536–552.
- Salo, E. O. 1991. Life History of Chum Salmon (*Oncorhynchus keta*). In *Pacific Salmon Life Histories*, Groot and Margolis (eds.). UBC Press, 564 pp. Available (partially):
http://books.google.com/books?id=I_S0xCME0CYC&dq=chum+salmon&lr=&source=gbs_navlinks_s.

Simenstad, C., K. L. Fresh, and E. O Salo. 1980. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. *Estuarine comparisons*. Academic Press, Inc.

Streamnet. 2019. Chum Salmon Distribution. File Geodatabase Feature Class. Pacific States Marine Fisheries Commission. Available: <http://www.streamnet.org>. Accessed: January 2019.

C6 Southern Oregon/Northern California Coast Coho (*Oncorhynchus kisutch*)

The Southern Oregon/Northern California Coast coho salmon evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Southern Oregon/Northern California Coast coho salmon ESU includes rivers and streams from Cape Blanco, Oregon, to Punta Gorda, California.

Legal Status

State: Sensitive species

Federal: Threatened (Original listing National Marine Fisheries Service [NMFS] 1997, 62 *Federal Register* [FR] 24588; Revised listing NMFS 2005, 70 FR 37160)

Critical Habitat: Designated (NMFS 1999, 64 FR 24049)

Recovery Planning: Recovery plan approved (NMFS 2014a; NMFS 2014b, 79 FR 58750)



Photo: Native Fish Society

Southern Oregon coho salmon are listed as a sensitive species under the Oregon State Sensitive Species List (OAR 635-100-0040) and are not listed under the Oregon Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135). Oregon prepared a limiting factors and threats analysis for the same Oregon coho salmon populations as the federal listing (Nicholas et al. 2005). The Oregon State Lower Columbia River Conservation and Recovery Plan addresses legal requirements for conservation planning under Oregon's Native Fish Conservation Policy (ODFW 2010).

There is no critical habitat for Southern Oregon/Northern California Coast coho within the plan area.

Taxonomy

Coho salmon (*Oncorhynchus kisutch*) were first described by Walbaum in 1792. Coho are one of five recognized species of Pacific Salmon (*Oncorhynchus spp.*) that occur in North America.

Distribution

Coho salmon distribution for the species' entire range is described in the section for the Oregon Coast coho salmon ESU above. The following describes the distribution of coho salmon in the Southern Oregon/Northern California Coast coho salmon ESU as well as populations and portions of watersheds in Oregon.

General

The Southern Oregon/Northern California Coast coho salmon ESU includes the Pacific Ocean and the freshwater and estuarine habitat along the Oregon and California Coast from the Cape Blanco on the north to Punta Gorda on the south (NMFS 2005, 70 FR 37160). Although most coho spawning occurs within 240 kilometers of the coast, large river systems like the Klamath, Trinity, Eel, and Rogue rivers have historically supported coho salmon in their upper tributaries (NMFS 2014a; Williams et al. 2006). Rivers in the Oregon portion of the ESU originate from the Oregon Coast Range, except for the Rogue River, which extends east through the Oregon Coast Range to drain the Cascade Mountains. Portions of the Upper Klamath River are also in Oregon.

NMFS identified seven diversity strata across the ESU (Williams et al. 2006). Of the seven diversity strata, five have all or portions in Oregon. They are: (1) North Coastal, (2) Interior Rogue, (3) Interior Klamath, and (4) Central Coastal. Across the seven strata, 59 historical populations were defined, which included 19 functionally independent populations, 12 potentially independent populations, 26 dependent populations, and 2 ephemeral populations (Williams et al. 2006). In the species' Recovery Plan, 40 populations in the ESU were identified for recovery goals, of which 14 are partially or wholly within Oregon (NMFS 2014a). Of these, seven populations were identified as functionally independent, three were identified as potentially independent, and four were identified as dependent (Table C6-1).

The ESU recovery strategy calls for achieving sustainable independent populations within the ESU (NMFS 2014). ESU recovery is based on achieving low risk of extinction in all "Core" populations. All Non-Core 1 populations should at least be at moderate risk of extinction or lower, and all Non-Core 2 and dependent populations should have juvenile presence indicating natural production (NMFS 2014; NMFS 2016). To define recovery of the Southern Oregon/Northern California Coast coho salmon ESU, NMFS set biological recovery criteria for each population role type, which address the four viability parameters: abundance (spawners), productivity (growth rates), spatial structure (distribution of occupied habitat), and diversity (proportion of hatchery origin fish and variation in life history parameters).

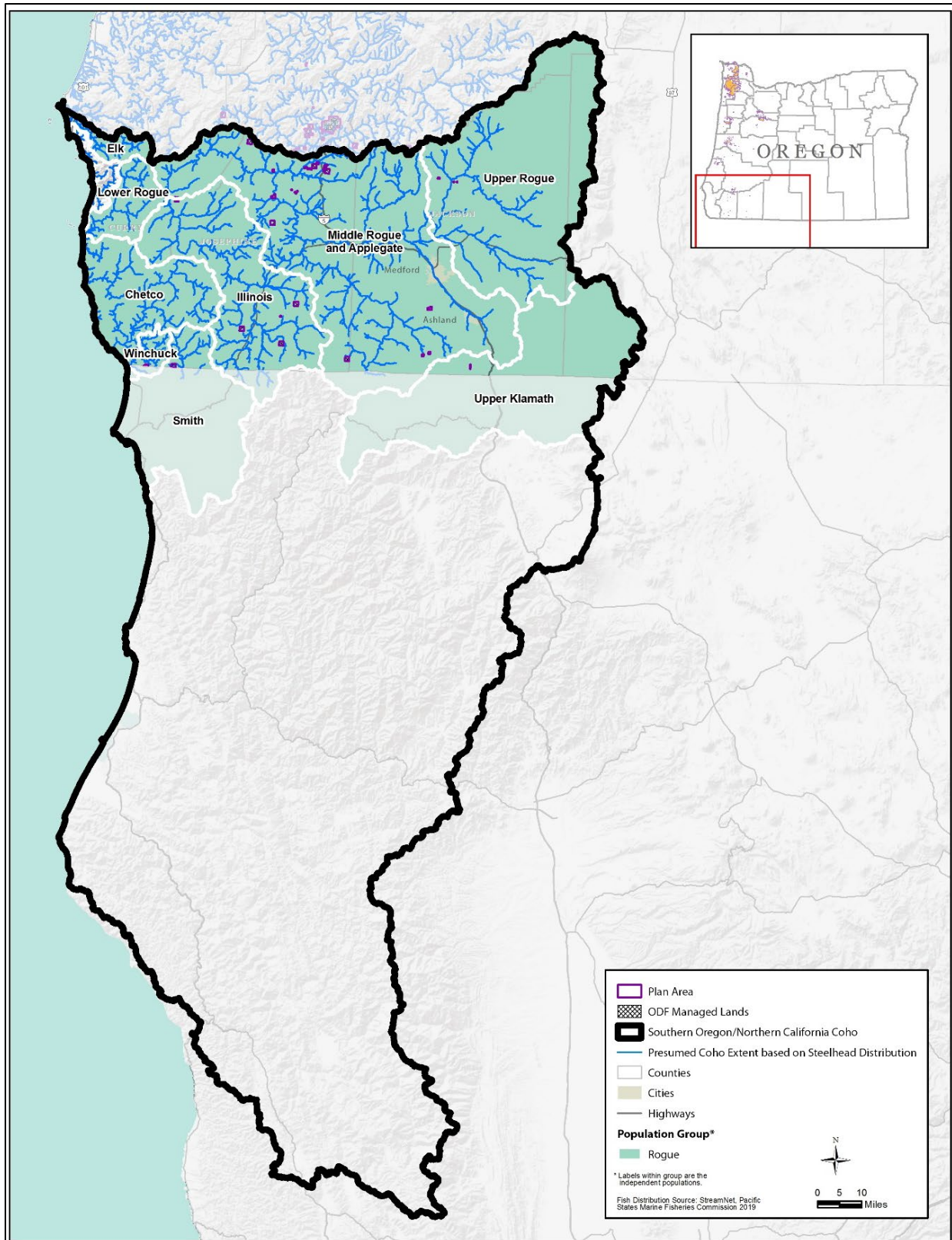


Figure C6-1. Southern Oregon/Northern California Coho (ESU) Strata and Independent Populations in Oregon

Occurrences Within the Plan Area

Across the entire ESU, six independent populations intersect portions of the plan area, within four diversity strata (Figure C6-1). The independent populations that include portions of the plan area or Oregon Department of Forestry (ODF) managed lands are:

- Northern Coastal Basins Stratum:
 - Winchuck River
- Central Coastal Basins Stratum:
 - Smith River
- Interior Rogue Stratum:
 - Illinois River
 - Middle Rogue and Applegate
 - Upper Rogue River
- Interior Klamath Stratum:
 - Upper Klamath River

However, not all independent populations intersecting or adjacent to the plan area or ODF managed lands have coho salmon distribution. Miles of streams with Oregon Department of Fish and Wildlife (ODFW) documented or assumed coho salmon presence within the plan area are summarized in Table C6-1. Stream miles are identified for independent populations by strata. The Smith River and Middle Rogue/Applegate rivers independent populations have the highest percentage of stream miles with Southern Oregon/Northern California Coast coho salmon presence within the plan area: 2% and 0.1%, respectively.

Table C6-1. Stream Miles with Coho Salmon Known or Presumed Presence Within Biogeographic Strata in Oregon that Intersect with the Plan Area

Biogeographic Stratum and Independent Populations ¹	Stream Miles with Known or Presumed Coho Salmon Presence		
	Total Stream Miles Within ESU	Miles Within or Adjacent to Plan Area	Percent of ESU Total Within or Adjacent to Plan Area
Northern Coastal Basins Stratum			
Winchuck River	63	0	0%
Central Coastal Basins Stratum			
Smith River	56	1	2%
Interior Rogue Stratum			
Illinois River	451	0.2	0%
Middle Rogue and Applegate rivers	826	1	0.1%
Upper Rogue River	253	0	0%
Interior Klamath Stratum			
Upper Klamath River	0	0	0%

Source: Streamnet 2019.

- ¹ Only independent populations located entirely and/or partially within Oregon and that intersect with the plan area are shown; populations that are located entirely outside of Oregon (i.e., entirely within Washington) or that do not overlap with the plan area are not listed.

Natural History

Southern Oregon and Northern California coho generally have a 3-year life cycle. Typically, adults begin their freshwater spawning migration in the late summer and fall, spawn by mid-winter, and then die. The run and spawning times vary between and within populations. Eggs incubate in redds for 1.5 to 4 months before hatching, depending on river temperatures. Coho salmon fry transition to the juvenile stage by about mid-June. Juveniles develop vertical dark bands, or parr marks, and begin partitioning available instream habitat through aggressive agonistic interactions with other juvenile fish. Juveniles rear in freshwater for up to 15 months, then migrate in spring to the ocean as smolts. Coho salmon typically spend 2 growing seasons in the ocean before returning to their natal stream to spawn as 3 year olds. However, some males, known as jacks, return to spawn after only 6 months at sea.

Life History and Habitat Requirements

Refer to Section C1, *Oregon Coast Coho* above for discussion of life history and habitat requirements for coho salmon. Additional life history and habitat requirements information specific to the Southern Oregon/Northern California Coast coho ESU are noted below.

Freshwater Residence

Extended freshwater residence, when fish spend a second winter in freshwater before outmigrating to the ocean, has been observed for age 1+ coho in California streams (Bell and Duffy 2007, and Ransom 2007, as cited in NMFS 2014a). In Northern California streams, extended freshwater residence is correlated to peak winter streamflow, and 0 to 30% of cohorts may exhibit the trait (Bell and Duffy 2007, Ransom 2007, as cited in NMFS 2014a). In California and Oregon watershed with adequate estuarine rearing habitat, some ocean-type coho salmon rear in the estuary during the spring, summer, and fall, and return upstream to overwinter (Miller and Sadro 2003, Jones et al. 2014, and Merrell and Koski 1978, as cited in NMFS 2014a).

Downstream Migration

Within the Southern Oregon/Northern California Coast coho ESU, downstream smolt migration begins in the spring between April and May, and continues into June (Shapovalov and Taft 1954). The earliest outmigration in ESU occurs at Roach Creek (a tributary to the Klamath) and at Ten Mile Creek (a tributary to the Eel River) in March or earlier. The latest outmigration occurs at the South Fork of the Eel River, beginning in mid-June or later; thus, the Eel River has the largest range of outmigrant timing in the ESU (March to August) (Weitkamp et al. 1995).

Timing of emigration commencement may be influenced by fish size, flow conditions, water temperature, dissolved oxygen levels, day length, and the availability of food (Shapovalov and Taft 1954). Most smolts are between 90 and 115 millimeters fork length when beginning downstream migration (Shapovalov and Taft 1954). The occurrence of age-0 “ocean-type” coho salmon migrants to the estuary, stream-estuary ecotone, or lower main-stem reaches is thought to be an alternative

life-history strategy, and has been observed throughout the species' range (Chapman et al. 1961, Chapman 1962, Hartman et al. 1982, Murphy et al. 1984; Rodgers et al. 1987, Au 1972, Kahler et al. 2001, Ryall and Levings 1987, Miller and Sadro 2003, and Pinnix et al. 2013, as cited in NMFS 2014a).

In the Klamath River, a positive relationship between flow volume and travel time and survival of juvenile coho has been documented (Beeman et al. 2012, as cited in NMFS 2014a). Depending on a watershed's estuary characteristics, coho salmon on the Oregon and California coast may spend a few days to a few weeks in estuaries before continuing to the ocean (Miller and Sadro 2003, Clements et al. 2012, Pinnix et al. 2013, and Jones et al. 2014, as cited in NMFS 2014a). The average size of outmigrating coho salmon is approximately 128 millimeters, and the range of smolts sizes in the Southern Oregon/Northern California Coast coho salmon ESU is between 90 and 200 millimeters (Weitkamp et al. 1995).

Ocean Life

Compared to other coho populations, the ESU has a relatively small marine distribution (NMFS 2014a). Dispersal at sea is regionally specific; coho from northern California and Oregon south of Cape Blanco disperse locally to California and Oregon waters (Weitkamp and Neely 2002, as cited in NMFS 2014a).

Population Status and Trends

Historically, hundreds of thousands of coho salmon returned to spawn in the rivers and streams of Southern Oregon and Northern California (Good et al. 2005). As of the 1990s, run-size estimates combining the California portion of the ESU and the Rogue River Basin were approximately 10,000 naturally spawned fish and 20,000 hatchery fish (Weitkamp et al. 1995).

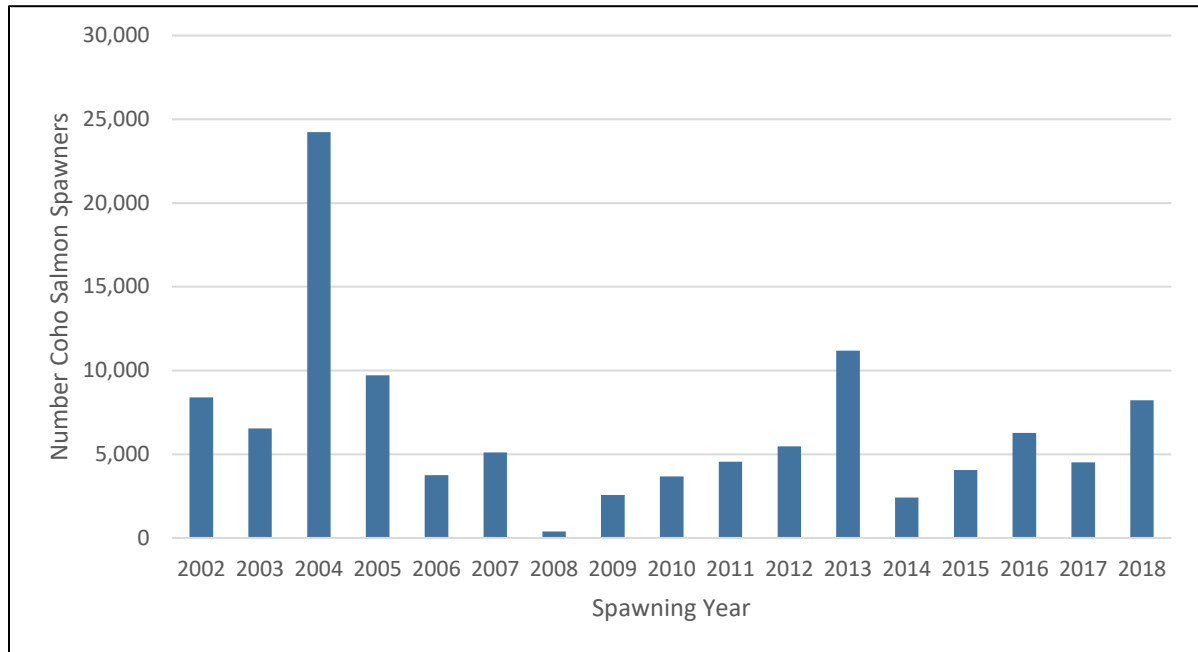
Long-term quantitative population-level estimates of adult spawner abundance are scarce for Southern Oregon and Northern California coho salmon (NMFS 2016). Available monitoring data indicate that spawner abundance has generally declined for populations in this ESU, a majority of independent populations are below low-risk abundance targets, and many may be below high-risk depensation thresholds (where a decrease in the breeding population leads to reduced production and survival of eggs or offspring) (Williams et al. 2011; NMFS 2016). Population-level estimates of abundance for most independent populations are lacking, and the best available data indicate that none of the seven diversity strata appears to support a single viable population, with one at low risk of extinction, though all seven strata are occupied by coho (NMFS 2014a).

Currently, over three quarters of Southern Oregon and Northern California coho salmon independent populations are at high risk of extinction (NMFS 2014a). NMFS (2016) predicted most populations in Oregon in this ESU currently have a high risk of extinction. The exception was the Upper Rogue River population with a moderate risk of extinction. Occasional annual estimates for other populations in Oregon range from 0 fish to several hundred (Table C6-2) (NMFS 2016).

Estimates of coho salmon spawner abundance are scarce for populations in this ESU, but long-term counts are available for some populations (NMFS 2016). An estimate of wild coho salmon returning to the Rogue River Basin is available for 2002 to 2018 (Figure C6-2). The estimate is a composite of coho salmon returning to the Lower Rogue and interior Rogue River populations (Illinois River,

Middle Rogue/Applegate, and Upper Rogue River populations). The recent 5-year average abundance (2013 to 2018) for this population composite is 5,092 coho salmon (ODFW 2018, 2019).

As shown in Table C6-1, the plan area has the largest overlap with the Central Coastal Basins stratum, specifically the Smith River independent population. This population comprises, on average, 8% of the total ESU abundance (Table C6-2).



Source: ODFW 2019.

Figure C6-2. Trends Abundance Adult Spawning Coho Salmon in the Rogue River Basin

Table C6-2. Adult Coho Salmon Abundance Estimates

Biogeographic Stratum and Independent Populations ^{1, 2}	Coho Salmon Adult Abundance		
	Years of Data ²	Arithmetic Mean ²	Percent of Total ESU Abundance ³
North Coastal Basins			N/A
Elk River	-	-	N/A
Lower Rogue River	-	-	N/A
Checto River	-	-	N/A
<i>Winchuck River</i>	-	-	N/A
Central Coastal Basins			16%
<i>Smith River^{a, b}</i> (redd estimate)	2	355	8%
Lower Klamath River	-	-	
Redwood Creek ^{b, c} (redd estimate)	4	529	12%
Maple Creek/Big Lagoon ^d	-	-	N/A
Little River	-	-	N/A
Mad River	-	-	N/A

Biogeographic Stratum and Independent Populations ^{1, 2}	Coho Salmon Adult Abundance		
	Years of Data ²	Arithmetic Mean ²	Percent of Total ESU Abundance ³
Southern Coastal Basins			25%
Humboldt Bay tributaries ^{b, e} (redd estimate)	4	1038	24%
Lower Eel/Van Duzen rivers	-	-	N/A
Bear River ^a	-	-	N/A
Mattole River ^{b, f} (redd estimate)	2	47	1%
Interior – Rogue			N/A
<i>Illinois River</i>	-	-	N/A
<i>Middle Rogue/Applegate rivers</i>	-	-	N/A
<i>Upper Rogue River</i>	-	-	N/A
Interior – Klamath			22%
Middle Klamath River	-	-	N/A
<i>Upper Klamath River</i>	-	-	N/A
Salmon River	-	-	N/A
Scott River ^g (video weir – adults)	8	810	19%
Shasta River ^h (video weir – adults)	14	127	3%
Interior – Trinity			N/A
South Fork Trinity River	-	-	N/A
Lower Trinity River	-	-	N/A
Upper Trinity River	-	-	N/A
Interior – Eel			32%
South Fork Eel River ^{b, i} (redd estimate)	4	1347	32%
Mainstem Eel River	-	-	N/A
North Fork Eel River ^d	-	-	N/A
Middle Fork Eel River ^d	-	-	N/A
Middle Mainstem Eel River	-	-	N/A
Upper Mainstem Eel River ^d	-	-	N/A

¹ Populations shown in *italics* occur in the plan area.

² Abundance data from Table 7 in *2016 5-Year Review: Summary & Evaluation of Southern Oregon/Northern California Coast Coho Salmon* (NMFS 2016).

Data notes, as described by NMFS:

- N/A indicates not available or applicable; dash (-) indicates no estimate of appropriate spatial scale or sampling design for viability analysis. Trends are shown only for populations where time series is at least 6 years; bold indicates significant trend.

^a Data from Garwood and Larson (2014). Data available for 2011 and 2012; data for 2013 and 2014 not available at time of analysis.

^b Redd counts (estimates), not adult escapement.

^c Data from Ricker et al. (2014a, 2014b, 2014c, and 2014d); data from 2010 to 2013.

^d Population unit designated by Williams et al. (2006 and 2008), not included in NMFS (2014).

^e Data from Ricker et al. (2015a, 2015b, 2015c, and 2015d); data from 2010 to 2013.

^f Data from Ricker and Lindke 2014 and Ricker et al. 2014e; data for 2011 and 2012.

^g Data from Morgan Knechtle, California Department of Fish and Wildlife; data from 2007 to 2014.

^h Data from Morgan Knechtle, California Department of Fish and Wildlife; data from 2001 to 2014.

ⁱ Data from Ricker et al. (2015e, 2015f, 2015g, and 2015h); data from 2010 to 2013.

³ Percent of total ESU abundance does not sum to 100% due to rounding of percentages.

Threats

The combined effects of fish harvest, hatcheries, hydropower operations, and habitat alterations caused by land management led to declines in coho salmon populations, declining coho salmon abundance and productivity, as well as range reductions and diminished life-history diversity.

The most recent status review that addressed Southern Oregon/Northern California Coast coho synthesized previous status conclusions and evaluated recent data and observations (NMFS 2016). The status review determined that, as of 2016, the ESU on the whole is still at a high risk of extinction. Specifically, NMFS (2016) describes that, “Twenty-four out of thirty-one independent populations are at high risk of extinction, six are at moderate risk of extinction, and none is at low risk of extinction. All core populations (those intended to serve as anchors for recovery) are thousands of adults short of the numbers needed for them to play their role in recovery of the entire ESU.” There has not been a trend toward recovery since the species’ listing or since the previous status review in 2010–2011, and NMFS’s overall concern for the species’ continued existence has increased due to likely effects from increased water withdrawal in many parts of the species’ known range and due to drought conditions.

In 2008, ODFW convened an expert panel to develop strategic guidance on limiting factors and threats to recovery of Oregon populations of the Southern Oregon/Northern California Coast coho ESU. Limiting factors were identified for each population and effects on all life stages were considered. Key concerns for populations that intersect with the plan area include: land management and water management impacts on habitat quality (e.g., loss of habitat complexity and loss of floodplain connectivity), water quality (e.g., high water temperatures), and habitat access (e.g., low flows and road crossings), as well as hatchery impacts (e.g., genetic effects of strays on limited numbers of wild spawners) (ODFW 2008).

Threats to this ESU are summarized by independent population in Tables C6-3 and C6-4 (NMFS 2014a). These threats are listed as “overall threat rank” categories in the NMFS Southern Oregon/Northern California Coast coho salmon ESU recovery plan. Key stressors to the independent populations that overlap the plan area include lack of floodplain and channel structure, impaired water quality, impaired estuary/mainstem function, altered hydrologic function, degraded riparian forest conditions, and barriers. These stressors are caused by threats including agricultural practices, channelization and diking, dams and diversions, road and stream crossings, roads, timber harvest, invasive and non-native species, high severity fire, hatcheries, mining and gravel extraction, development, fishing, and climate change.

NMFS (2016) concluded in the most recent status review that, “Over the next five years, the most important action to safeguard SONCC coho salmon against extinction is to ensure sufficient instream flows. The most important areas to carry out these actions are those that currently support coho salmon.” Additionally, recovery actions suggested for areas where Southern Oregon/Northern California Coast coho occur included: increasing habitat complexity, expanding population specific monitoring, revising Oregon’s forest practices and agricultural water quality practices legislations so that those activities do not limit recovery, removing Klamath dams, implementing emergency efforts

to prevent local extinctions of high-risk independent populations, and ensuring sufficient funds to enforce regulation of environmental impacts of marijuana cultivation (especially water use and clean up).

Table C6-3. Threats Summary by Independent Population for Populations that Overlap the Plan Area

Threats	Biogeographic Strata and Independent Populations					
	Northern Coastal Basins	Central Coastal Basins	Interior Rogue Basin			Interior Klamath Basin
	Winchuck River	Smith River	Illinois River	Middle Rogue/Applegate Rivers	Upper Rogue River	Upper Klamath River
Agricultural Practices	High	High	High	Very High	Very High	High
Channelization/Diking	Very High	High	High	Very High	High	Very High
Dams/Diversions	Medium	Low	Very High	Very High	High	Very High
Road/Stream Crossings	Medium	High	High	High	Medium	Medium
Roads	High	High	Very High	Very High	Very High	Very High
Timber Harvest	Medium	Low	High	High	Very High	Medium
Invasive/ Non-Native Species	High	Medium	Medium	Medium	Medium	Low
Climate Change	Low	Medium	High	Low	High	Very High
High Severity Fire	Medium	Medium	Medium	Medium	Medium	Medium
Hatcheries	Low	Medium	Medium	Medium	Medium	Very High
Mining/Gravel Extraction	Low	Medium	Very High	High	Medium	Low
Urban/Residential/Industrial Development	Very High	Medium	Medium	Very High	Very High	Low
Fishing and Collecting	Low	Low	Medium	Low	Low	Low

Source: NMFS 2014a.

Table C6-4. Threats and Key Stressors by Independent Population for Populations that Overlap the Plan Area

Biogeographic Strata and Independent Populations	Key Stressors	Threats Contributing to Key Stressors and Impacting Population Survival
Northern Coastal Basins		
Winchuck River	- Lack of floodplain and channel structure - Impaired water quality	Water diversions and degraded riparian habitat increase temperature in the lower mainstem, which has been listed as impaired under the Clean Water Act Section 303(d).

Biogeographic Strata and Independent Populations	Key Stressors	Threats Contributing to Key Stressors and Impacting Population Survival
Central Coastal Basins		
Smith River	• Impaired estuary/mainstem function • Lack of floodplain and channel structure	• Over 70% of historical tidal wetland coho habitat lost through channelization, diking, dredging, tide gates, and wetland filling. • Reed canary grass reduces estuary function. • Lack of large woody debris and floodplain and channel structure, along with increased sediment, decrease suitable summer and rearing habitat for juvenile coho salmon.
Interior Rogue Basin		
Illinois River	• Altered hydrologic function • Degraded riparian forest conditions	• Water diversion dewateres and impairs Illinois River tributaries. • High road densities, particularly along streams, exceeding levels that may result in higher sediment input to streams and alter hydrology. • Two large dams, Lake Selmac Dam and Pomeroy Diversion Dam, can hinder salmonid migration.
Middle Rogue River/Applegate	• Degraded riparian forest conditions • Altered hydrologic function	• Agricultural, irrigation diversions diminish tributary flows and elevate water temperature. • Increased impervious surfaces, such as roads, can lead to higher peak flows, channelization, diking, and non-point source pollution.
Upper Rogue River	• Altered hydrologic function • Impaired water quality	• Potential for instream water diversions and groundwater pumping to result in decreased stream flows. • Agricultural impacts, such as grazing, removal of riparian vegetation, chemical application, and channelization can increase water temperature and decrease dissolved oxygen. • Increased development can lead to increases in impervious surface area, peak flows, non-point source pollution, and water demands.
Interior Klamath Basin		
Upper Klamath River	• Barriers • Altered hydrologic function	• Four dams (Iron Gate, Copco 1, Copco 2, and J.C. Boyle) currently block approximately 76 miles of upstream coho habitat. • Highway 96 at Tom Martin Creek and Seiad Creek Road at Canyon Creek are significant road-stream barriers in the watershed. • Surface water diversions and groundwater pumping in the mainstem Klamath River alter natural timing and volume of flows. Many Klamath River tributaries experience low flow conditions.

Source: NMFS 2014a.

Literature Cited

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598p

- National Marine Fisheries Service (NMFS). 1997. Endangered and Threatened Species; Threatened Status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU) of Coho Salmon. *Federal Register*, 62 FR 24588. May 6.
- National Marine Fisheries Service (NMFS). 1999. Designated Critical Habitat; Central California Coast and Southern Oregon/Northern California Coasts Coho Salmon. *Federal Register*, 64 FR 24049. May 5.
- National Marine Fisheries Service (NMFS). 2005. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register*, 70 FR 37160. June 28.
- National Marine Fisheries Service (NMFS). 2014a. *Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon* (*Oncorhynchus kisutch*). *West Coast Region*. Arcata, CA. Available: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/southern_oregon_northern_california_coast/southern_oregon_northern_california_coast_salmon_recovery_domain.html.
- National Marine Fisheries Service (NMFS). 2014b. Final Endangered Species Act (ESA) recovery plan for the Southern Oregon/Northern California Coast coho salmon (*Oncorhynchus kisutch*) Evolutionarily Significant Unit (ESU) (Final Recovery Plan). *Federal Register*, 79 FR 58750. September 20.
- National Marine Fisheries Service (NMFS). 2016. *2016 5-Year Review: Summary & Evaluation of Southern Oregon/Northern California Coast Coho Salmon*. National Marine Fisheries Service West Coast Region; Arcata, California.
- Nicholas, J., B. McIntosh, and E. Bowles. 2005. Oregon Coastal Coho Assessment. Final Report. Oregon Watershed Enhancement Board and Oregon Department of Fish and Wildlife; State of Oregon. May 6.
- OAR 635-100-0040. *Sensitive Species List*. Oregon Administrative Rules, Department of Fish and Wildlife. Available: https://secure.sos.state.or.us/oard/viewSingleRule.action;JSESSIONID_OARD=48m67GbU0TypkHPut-5Qsa91AH9S7p1TK1q5waCD-uYNCCL1RIAt!41094264?ruleVrsnRsn=173209.
- Oregon Department of Fish and Wildlife (ODFW). 2008. *Limiting Factors and Threats to the Recovery of Oregon Coho Populations in the Southern Oregon-Northern California Coast Evolutionarily Significant Unit: Results of Expert Panel Deliberations*. September 5.
- Oregon Department of Fish and Wildlife (ODFW). 2010. *Lower Columbia River Conservation & Recovery Plan for Oregon Populations of Salmon & Steelhead*. August 6.
- Oregon Department of Fish and Wildlife (ODFW). 2018. *Estimated Abundance of Wild Adult Coho spawners in the Southern Oregon/Northern California Coast Coho ESU, 2002–2017 – Oregon Populations Only*. Available: <https://odfw.forestry.oregonstate.edu/spawn/cohoabund.htm>. Accessed: June 2018.
- Oregon Department of Fish and Wildlife (ODFW). 2019. *Estimated Abundance of Wild Adult Coho spawners in the Southern Oregon/Northern California Coast Coho ESU, 2004–2018 – Oregon*

Populations Only. Available: <https://odfw.forestry.oregonstate.edu/spawn/cohoabund.htm>. Accessed: August 2019.

Shapovalov, L. and A.C. Taft. 1954. *The Life Histories of the Steelhead Rainbow Trout (Salmo gairdneri gairdneri) and Silver Salmon (Oncorhynchus kisutch)*. Fish and Game Bulletin. 98. 275 pp.

StreamNet 2019. Database (Version 98.3) [database downloaded to disk]. Portland (OR) : StreamNet. URL: <https://www.streamnet.org/data/interactive-maps-and-gis-data/>

Williams, T.H., E.P. Bjorkstedt, W.G. Duffy, D. Hillemeier, G. Kautsky, T.E. Lisle, M. McCain, M. Rode, R.G. Szerlong, R.S. Schick, N.M. Goslin, and A. Agrawal. 2006. *Historical Population Structure of Coho Salmon in the Southern Oregon/Northern California Coasts Evolutionarily Significant Unit*. NOAA-TM-NMFS-SWFSC-390. National Marine Fisheries Service. June.

Williams, T.H., S.T. Lindley, B.C. Spence, and D.A. Boughton. 2011. *Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Southwest*. National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division; Santa Cruz, CA. May 20.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryan, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. *Status Review of Coho Salmon from Washington, Oregon, and California*. NOAA Technical Memorandum NMFS-NWFSC-24. National Marine Fisheries Service, Southwest Region, Protected Species Management Division; Long Beach, CA. September.

C7 Lower Columbia River Chinook (*Oncorhynchus tshawytscha*)

The Lower Columbia River Chinook salmon evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the federal Endangered Species Act (ESA). The Lower Columbia River Chinook salmon ESU includes fall-run and spring-run Chinook salmon spawning in rivers and streams in Oregon and Washington downstream and including the White Salmon River (WA) and Hood River (OR), and the Willamette River and its tributaries downstream of Willamette Falls. Not included in the ESU are spring-run Chinook salmon in the Clackamas River.

Legal Status

State: Sensitive-critical species

Federal: Threatened (National Marine Fisheries Service [NMFS] 2005; 70 *Federal Register* [FR] 37160)

Critical Habitat: Designated (NMFS 2005; 70 FR 52630)

Recovery Planning: Recovery plan approved (NMFS 2013; 78 FR 41911)



Photo: ODFW

Lower Columbia River Chinook salmon are listed as a sensitive species under the Oregon State Sensitive Species List (OAR 635-100-0040) and are not listed under the Oregon State Endangered Species Act (ORS 496.171 to 496.192, 498.026, and 564.100 to 564.135). Oregon developed the Oregon State Lower Columbia River Conservation and Recovery Plan for the same Oregon Chinook salmon populations as the federal listing. The Oregon State Lower Columbia River Conservation and Recovery Plan addresses legal requirements for conservation planning under Oregon's Native Fish Conservation Policy. The conservation plan was approved by the Oregon Fish and Wildlife Commission in August 2010 (NMFS 2013).

Taxonomy

Chinook salmon (*Oncorhynchus tshawytscha*) were first described by Walbaum in 1792. Chinook salmon are one of five recognized species of Pacific salmon (*Oncorhynchus spp.*) that occur in North America. Chinook salmon are the largest of the Pacific salmon species; adults may reach a weight of 45 kilograms (Healey 1991). The timing of adult entry to freshwater varies among Chinook salmon populations. The Lower Columbia River Chinook salmon ESU includes populations with adult return to freshwater in the fall (fall-run) and populations with adult return to freshwater in the spring (spring-run).

Distribution

Chinook salmon distribution is described for their entire range, the Lower Columbia River ESU, and independent populations that intersect the plan area and Oregon Department of Forestry (ODF) managed lands.

General

Chinook salmon have a wide range, second only to chum salmon. They can be found in Asia from Hokkaido, Japan, to the Anadyr River in Siberia, Russia, and in North America from Kotzebue Sound, Alaska, to the Central Valley and San Joaquin River in California (Healey 1991). Chinook salmon return to spawn in larger rivers from just above tidal influence to over 3,200 kilometers in the headwaters of the Yukon River, Alaska.

The Lower Columbia River Chinook salmon ESU includes fall-run and spring-run Chinook salmon spawning in rivers and streams in Oregon and Washington downstream and including the White Salmon River (WA) and Hood River (OR), and the Willamette River and its tributaries downstream of Willamette Falls. Not included in the ESU are spring-run Chinook salmon in the Clackamas River and fall-run Chinook salmon that originated from an up-river population and spawn in the Columbia River and tributaries upstream of the Sandy River. Also not included are several spring-run Chinook salmon hatchery releases that originated from populations outside this ESU.

To achieve recovery of Lower Columbia River Chinook salmon ESU, NMFS aims to increase probability of persistence in all populations and reduce threats in all categories. The recovery strategies for the Lower Columbia River Chinook salmon ESU are presented below and organized by classification: spring, fall (tule), and late-fall (NMFS 2013)

The recovery strategy for the spring Lower Columbia River Chinook salmon aims to restore the Cascade spring stratum to a high probability of persistence and improving persistence probabilities of the two Gorge spring populations. The spring Lower Columbia River Chinook salmon recovery strategy also involved reducing threats in all categories with the highest priority elements entailing protection and improvement of the Sandy spring Chinook population; reestablishing naturally spawning populations above dams on the Cowlitz and North Fork Lewis rivers and in the mid- to upper-elevation habitat; protection and restoration of favorable tributary habitats; and reestablishing spring Lower Columbia River Chinook salmon in the White Salmon and Hood subbasins (NMFS 2013).

The recovery strategy for the fall (aka tule) Lower Columbia River Chinook salmon ESU aims to restore the Coast and Cascade tule strata to a high probability of persistence and improving persistence probabilities of all four Gorge-stratum populations. The tule Lower Columbia River Chinook salmon ESU recovery strategy also involved reducing threats in all categories with the highest priority elements entailing protection and improvement of the Coweemen and Lewis populations; filling information gaps regarding natural population extent and hatchery-origin spawner extent; focusing recovery efforts on populations that have the greatest change at recovery; protection of existing high-functioning habitat; aggressively implementing efforts to improve the quantity and quality of tributary and estuarine habitat; implementing aggressive efforts to reduce the influence of hatchery fish; adjusting harvest as needed to maintain abundance; and assessing habitat quantity, quality, and distribution (NMFS 2013).

The recovery strategy for the late-fall Lower Columbia River Chinook salmon ESU aims to maintain two healthy populations (the North Fork Lewis and Sandy populations) and increase persistence probability of the Sandy population. Key elements of this recovery strategy include implementation of the regional hatchery strategy aimed at minimizing impacts of hatchery releases; reducing harvest impacts on Sandy late-fall population and continuing to manage the fisheries to meet the spawning escapement goal for the Lewis River late-fall population; and implementing actions in the regional tributary and estuary habitat to benefit the tule fall Chinook salmon (NMFS 2013).

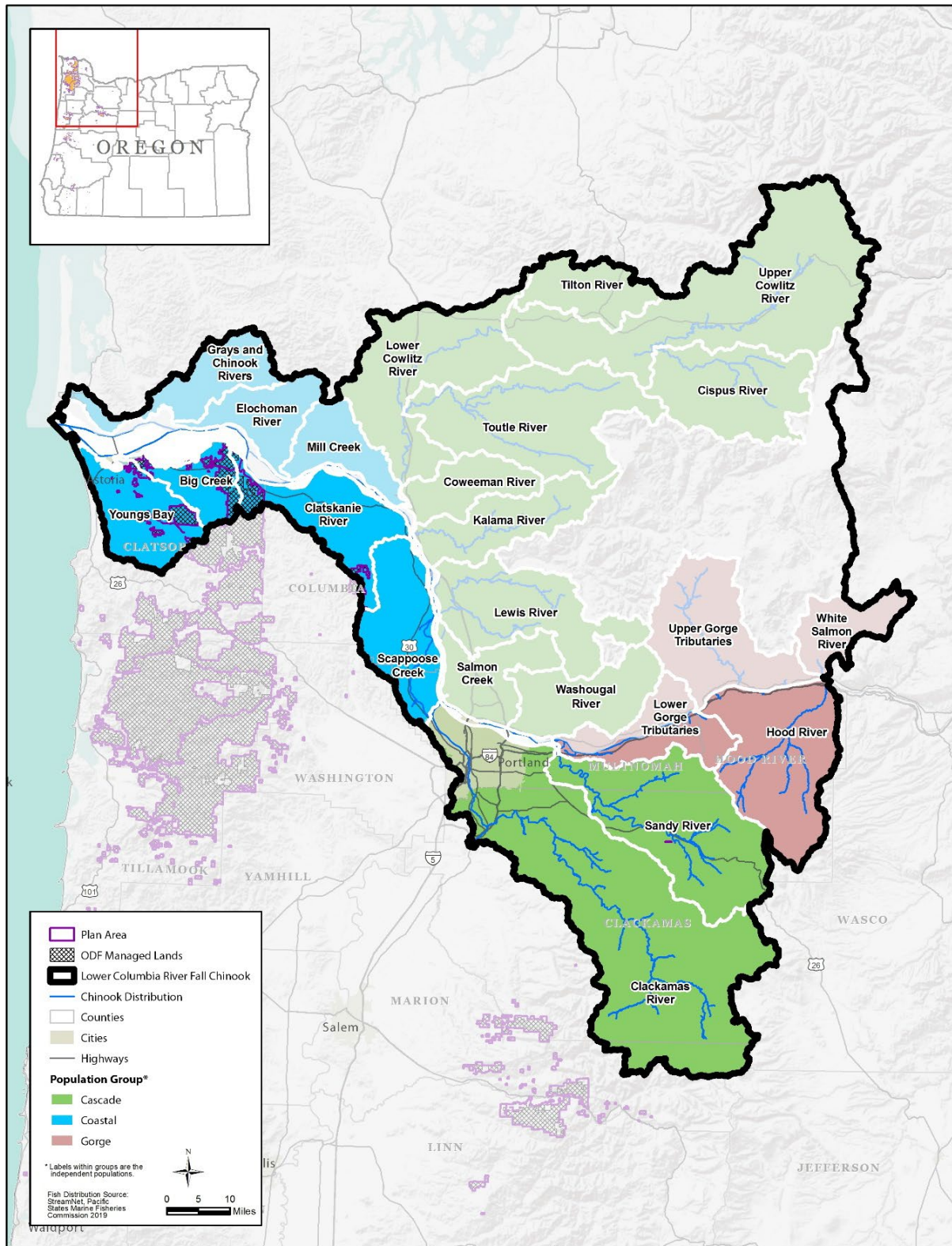


Figure C7-1. Lower Columbia River Chinook Salmon (ESU) Strata and Independent Populations in Oregon

Occurrences Within the Plan Area

The plan area does not intersect the range of any independent populations of Lower Columbia River Chinook salmon (Table 7-1).

Table C7-1. Miles of Lower Columbia River Chinook Salmon Known or Presumed Chinook Salmon Presence

Biogeographic Stratum and Independent Populations	Stream Miles with Known or Presumed Chinook Salmon Presence		
	Total Stream Miles	Miles Within or Adjacent to Plan Area	Percent of Total Within or Adjacent to Plan Area
Clackamas River	173	0	0
Sandy River	110	0	0
Lower Gorge Tributaries	68	0	0
Upper Gorge Tributaries	61	0	0
Hood River	107	0	0
Scappoose Creek	26	0	0

Source: Streamnet 2019.

Natural History

As discussed above, Chinook salmon are the largest of the Pacific salmon species and adults may reach a weight of 45 kilograms (Healey 1991), though the Lower Columbia River Chinook salmon are smaller and may approach weights of up to 25 kilograms (NMFS 2013). Chinook salmon are anadromous and semelparous (i.e., die after spawning once), and generally have a 3- to 6-year life cycle (Healey 1991); Lower Columbia River Chinook salmon return from the ocean to spawn at 2 to 6 years old (NMFS 2013).

The Lower Columbia River Chinook salmon are classified as either spring, fall, or late fall run depending on the time adults return to fresh waters. Differences between run types include time of spawning, incubation, emergence, migration, and maturation. This diversity fosters adaptability in a wide variety of systems including small streams to the large Columbia River mainstem (NMFS 2013). Lower Columbia River spring Chinook salmon enter the lower Columbia River between March and June several months prior to spawning. Lower Columbia River spring Chinook salmon are considered a “stream-type” and rear in the river for an extended period. Spring Chinook salmon usually rear in the river for a full year and migrate to the ocean as yearlings. Lower Columbia River fall (aka tule) Chinook salmon enter the lower Columbia River between August and September and spawn September through November. This run contains dark skin pigmentation and an advanced state of maturation when returning to the lower Columbia River. The Lower Columbia River fall Chinook salmon are considered “ocean-type,” and juveniles typically migrate to the ocean as subyearlings from 1 to 4 months old. They are known to use the estuary extensively and can be found there year-round (NMFS 2013). Lower Columbia River late-fall Chinook salmon, also referred to as “brights,” are the last run to return to the lower Columbia River, are less mature when they return, spawn the latest in the year, and exhibit a “stream-type” life history. They return to the lower Columbia River between August and October, and spawn from November to January.

Life History and Habitat Requirements

Throughout their life history stages, Lower Columbia River Chinook salmon utilize a range of habitats. They spawn in riffles, tailouts, and glides in tributaries and mainstems and rear in slow-water areas within large tributaries and mainstem rivers. Adults migrate up, and juvenile migrate out, through the lower Columbia River system and estuary environments. Maturation occurs at sea, including ocean migration as far north as southeast Alaska and the Aleutian Islands (NMFS 2013).

As described above, the species has diverse and complex life history strategies, but in general, there are two freshwater life history types: (1) stream-type Chinook salmon that reside in freshwater for a year or more following emergence before out-migrating to the ocean (i.e., “yearlings”), and (2) ocean-type Chinook salmon that out-migrate to the ocean within their first year following emergence (i.e., “sub-yearlings”) (Gilbert 1912, and Healey 1986, as cited in Myers et al. 2006).

The timing of adult entry to freshwater varies among Chinook salmon populations; Lower Columbia River Chinook salmon ESU includes populations with adults that historically returned to freshwater in the early spring (spring-run), fall (fall run), and late fall (late-fall run) (NMFS 2013). Chinook salmon require varied habitats during different phases of their life cycle. Life history phases and corresponding habitat requirements are discussed below.

Upstream Migration and Spawning

Chinook salmon spawning habitat typically consists of gravels and cobbles in riffles and the tailouts of pools with clean silt-free substrate, in the mainstem of rivers and large tributaries (Healey 1991). In the Lower Columbia River, spawning occurs from August to January—adult Chinook may enter freshwater and migrate upstream as early as August (spring-run), through November (fall-run), and end by January (late-fall run) (NMFS 2013). Due to the variability in time of spawning between the three runs, rearing strategies vary. Spring and late-fall runs rear in the river an extended period (for up to a year) while fall run rear for 1–4 months before emigrating as sub-yearlings.

Incubation and Emergence

Following spawning and egg deposition in the fall or winter, Lower Columbia River Chinook salmon incubate in redds until for 1–2 months. After hatching, alevins remain in the gravel for a few more weeks, then emerge from redds predominantly at night (Healey 1991). Incubation success and timing is dependent on many factors including stream flow, water temperature, dissolved oxygen concentration, and the proportion of fine sediment in substrates (Healey 1991). Abiotic requirements and mortality thresholds are described in Section C3, *Upper Willamette River Chinook*.

As with Upper Willamette River Chinook, due to the timing of Lower Columbia River Chinook salmon spawning in the fall or winter and emergence of fry in the spring, eggs must survive in the redd through the high-flow winter season (Myers et al. 2006; ODFW and NMFS 2011). Elevated flows or channel scour may wash Chinook eggs out of redds or result in sedimentation following transport of silts (Healey 1991).

Freshwater Residence and Outmigration

Lower Columbia River Chinook salmon display both “stream-type” and “ocean-type” life histories. Both spring and late-fall runs display stream-type life histories while the fall run displays an ocean-type life history. Stream-type life histories entail rearing in the river for a full year, constituting an

extended freshwater residency. This extended freshwater rearing occurs in watersheds with suitable rearing conditions occurring year-round. After rearing in freshwater, Spring stream-type Chinook salmon usually outmigrate quickly through the estuary and into open coastal waters. They migrate as far as the Aleutian Islands in the Northern Pacific and are widely distributed in open ocean away from the coast where they remain between 1 and 5 years (LCFRB 2010). In the ocean-type life history (fall-run), juveniles may begin to outmigrate to saline waters at 1–4 months old. Ocean-type juveniles spend weeks to months rearing in estuaries where they can be found year-round. After rearing in the estuary for weeks to months, the Lower Columbia River fall Chinook migrate northward into ocean waters in Washington, British Columbia, and Southeast Alaska where they remain for 1–5 years and return between 2–6 years of age in the late summer or fall and spawn within a few weeks. Specific rearing conditions and habitat requirements for Chinook salmon are described in Section C3 for Upper Willamette River Chinook.

Estuary Residence and Ocean Life

Like the Upper Willamette River Chinook salmon, the Lower Columbia River Chinook, and particularly the ocean-type fall-run Chinook out-migrants salmon, require estuarine and nearshore marine habitat for migration, foraging, refuge, and osmoregulation processes. Juveniles rely on shallow nearshore habitats such as intertidal flats, tidal marshes, and subtidal channels in and near estuaries. Once juvenile Chinook salmon are large enough to eat small fish, they move away from shore into deeper marine waters (Healey 1991).

Estuary conditions such as changes in food availability, off-channel habitat availability, presence of contaminants, and predation can affect juvenile survival into ocean life. Juvenile Chinook salmon are subject to predation in the Columbia River Estuary by predatory fishes (e.g., pikeminnow), birds (e.g., terns and cormorants), and pinnipeds (e.g., sea lions) (NMFS 2011b).

Ocean-type juvenile salmonids (i.e., sub-yearlings) have a tendency to use shallow-water habitats and have longer estuary residence times than stream-type juvenile salmonids (i.e., yearlings); thus, ocean-type salmonids are more affected than stream-type salmonids by flow alterations that cause changes to habitat quantity, quality, or access in wetlands and floodplains. Stream-type salmonids have comparably short estuary residence times and use the Columbia River plume more extensively; thus, stream-type juvenile salmonids are affected by plume dynamics (Fresh et al. 2005, as cited in NMFS 2011b).

Yearling Chinook out-migrants have been found to use the Columbia River plume as habitat, in contrast to sub-yearlings, which stay closer to shore. Thus, characteristics of the Columbia River plume are believed to be significant to yearling outmigrant Chinook salmon during transition to ocean life (Fresh et al. 2005, as cited in NMFS 2008).

Chinook salmon spend 6 months to 7 years maturing in the ocean before returning to freshwater to spawn (Healey 1991). After entering the ocean, Lower Columbia River Chinook migrate north to Washington, British Columbia, and southeastern Alaska (Myers et al. 2006).

Chinook salmon are opportunistic feeders. Juveniles prey on a wide variety of food such as benthic, epibenthic, and pelagic crustaceans, as well as insects, fish larva, and juvenile fish. Adult salmon feed on squid and forage fish such as smelt, sandlance, and herring while in the estuarine and marine environment (Healey 1991).

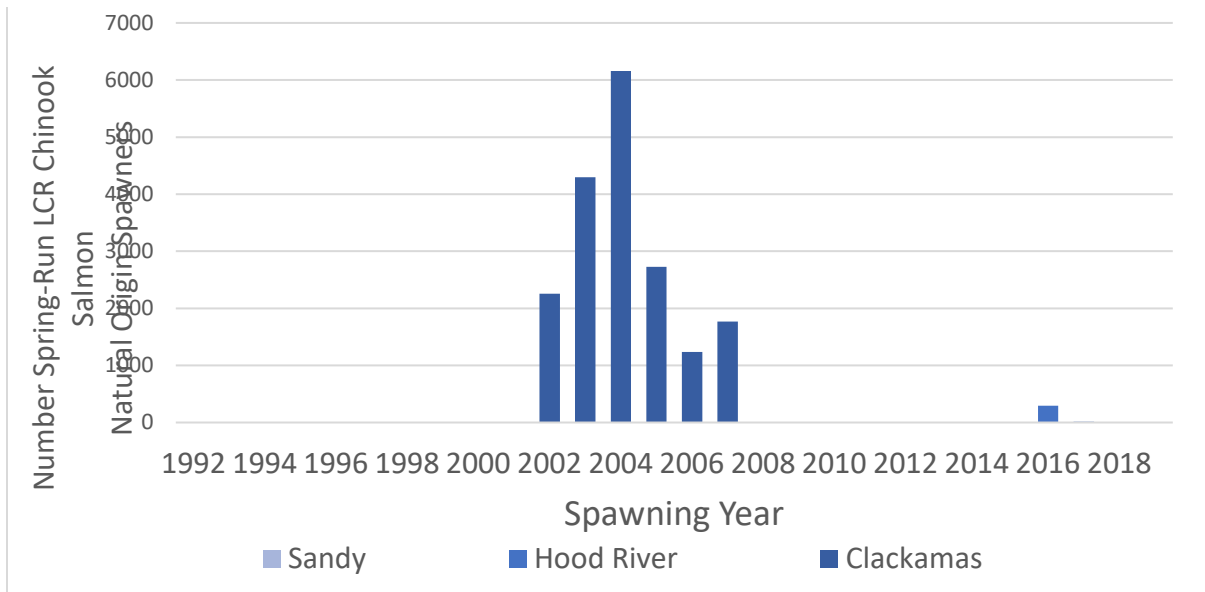
Population Status and Trends

Historically, 32 independent populations once occurred in the Lower Columbia River Chinook salmon ESU: 21 fall, 2 late-fall, and 9 spring-run populations. Fourteen of these independent populations were considered highly productive “core” populations and six represent “legacy populations” which contain important genetic diversity. The Lower Columbia River Chinook Salmon Recovery Plan assumes a historical abundance off all runs in the ESU to be over 260,000 fish (NMFS 2013).

Lower Columbia River Chinook salmon population have declined significantly from once abundant historical levels, and present-day natural populations comprise less than 2% of the historical ESU abundance. Of the 32 independent populations in this ES, only 2 late-fall are considered viable (North Fork Lewis and Sandy) and most of the populations have a very low persistence probability over the next 100 years and are at high risk of extinction (NMFS 2013; LCFRB 2010; ODFW 2010; Ford et al. 2011). Low abundance, poor productivity, loss of habitat, habitat degradation, and reduced diversity are contributing to the very low persistence probability for the Lower Columbia River Chinook salmon populations.

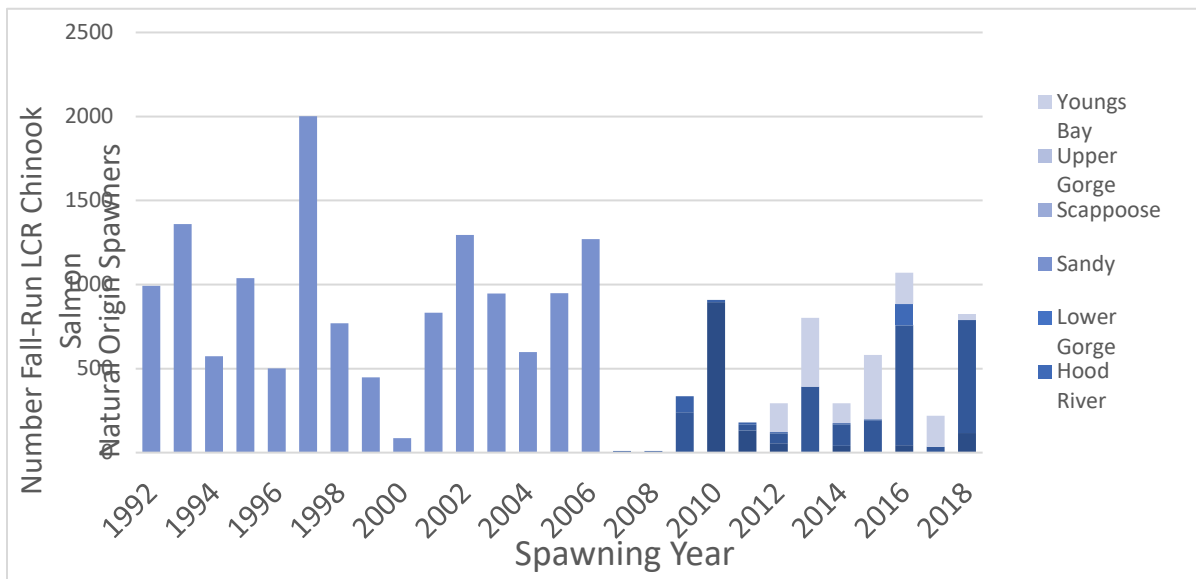
According to the most recent status review (NMFS 2016), the majority of the populations in the Lower Columbia River Chinook salmon ESU remain at high risk, with low natural-origin abundance levels. A number of populations have a significant hatchery-origin contribution to naturally spawning fish.

Lower Columbia River Chinook salmon natural origin spawner abundance by independent population from 1992 to 2018 is summarized in Table C7-2 and shown on Figures C7-2 and C7-3 below. The range during this period includes the high abundance in 2004 (6,157 spring-run Clackamas adults) and low in 2018 (1 fall-run Clatskanie adult), and many independent populations regularly having zero abundance during this period. The most abundant population in the ESU has consistently been the spring-run Clackamas River with an annual average of over 3,237 adults across the past 5 years of data (2003–2007), or approximately 64% of the ESU’s average annual return.



Note: the Sandy population has no data reported (1992–present).

Figure C7-2. Natural Origin Spring-Run Spawning LCR Chinook Abundance by Year and Independent Population



Note: Lower Gorge, Scappoose, and Upper Gorge have no reported abundance data (1992–present).

Figure C7-3. Natural Origin Fall-Run Spawning LCR Chinook Abundance by Year and Independent Population

Table C7-2. Lower Columbia River Chinook Adult Salmon Abundance In Oregon

Biogeographic Stratum and Population	Chinook Salmon Adult Abundance		
	Recent 5-year Average and Range (2013–2017)		Percent of Total ESU Abundance
	Spring Run	Recent 5-year Average & Range (2013–2017) Fall Run	
Clackamas River	3,237 (1,234/6157) ¹	347.4 (34/673)	71
Sandy River	No Data	1,011 (598/1,295) ³	20
Lower Gorge Tributaries	Not Reported	No Data	No Data
Upper Gorge Tributaries	Not Reported	No Data	No Data
Hood River	153.5 (15/292) ²	61 (0/122) ⁴	4
Scappoose Creek	Not Reported	No data	No Data
Big Creek	Not Reported	40.4 (0/116)	1
Clatskanie River	Not Reported	4 (0/7)	0.08
Young's Bay	Not Reported	181.6 (34/382)	4
ESU Total	5,037		

Source: ODFW 2019.

1 - 2003-2007

2 - Data only available for 2016 and 2017

3- Data reported for 2002-2006

4- Data only available for 2016 and 2018

Threats

Tables C7-3 and C7-4 describe limiting factors impacting Lower Columbia River spring- and fall-run Chinook salmon population survival and the threats contributing to those limiting factors.

Table C7-3. Lower Columbia River Spring-Run Chinook Salmon Limiting Factors and Threats

Habitat Threat Category	Limiting Factors	Threats Contributing to Limiting Factors and Impacting Population Survival
Tributary	- Reduced access to historical spawning habitat - Degraded and lost floodplain, wetland, side channel, and riparian habitat - Impaired water quality and flow	- Dams and reservoirs - Land use practices - Roads and road crossings - Reduced flow from surface water withdrawals (dams, irrigation, municipal, hatchery) - Increased sedimentation
Estuary	- Toxic contaminants - Food web shifts - Impaired water quality and flow - Reduced habitat complexity and diversity	- Non-point source pollution from agricultural, urban, and industrial land practices - Changes in hydrologic regimes and water quality due to dams and reservoirs - Increased sedimentation - Extensive channelization, diking, levees, and tide gates

Habitat Threat Category	Limiting Factors	Threats Contributing to Limiting Factors and Impacting Population Survival
Hydropower	Reduced habitat quantity access	Tributary and mainstem dams reduce access to spawning habitat and decrease floodplain rearing habitat
Harvest	Direct mortality	Recreational and commercial fisheries
Hatchery	- Limited food availability - Hybridization	- Columbia Basin hatchery smolts competing for limited food resources - Hatchery fish interbreeding with wild fish
Predation	Anthropogenic habitat alterations	Increased predation pressure from piscivorous fish, birds, and marine mammals

Source: Adapted from Table 7-5 in NMFS 2013.

Table C7-4. Lower Columbia River Fall-Run Chinook Salmon Limiting Factors and Threats

Habitat Threat Category	Limiting Factors	Threats Contributing to Limiting Factors and Impacting Population Survival
Tributary	- Degraded and lost floodplain, wetland, side channel, and riparian habitat - Impaired water quality and flow - Increased sedimentation	- Extensive channelization, diking, levees, and wetland conversion - Land use and timber harvest practices - Reduced vegetative cover and increased impermeable surfaces - Roads and road crossings
Estuary	- Food web shifts - Impaired water quality and flow - Reduced habitat complexity and diversity	- Altered hydrologic regimes and water quality due to dams and reservoirs - Increased sedimentation - Extensive channelization, diking, levees, and tide gates - Land conversion
Hydropower	- Reduced habitat quantity access - Impaired sediment routing and estuarine food web	- Tributary dams reduce access to spawning habitat and decrease floodplain rearing habitat - Altered hydrologic regimes change natural sediment processes (i.e., Columbia River plume)
Harvest	Direct mortality	Recreational, tribal, and commercial fisheries
Hatchery	- Limited food availability - Hybridization	- Columbia Basin hatchery smolts competing for limited food resources - Hatchery fish interbreeding with wild fish
Predation	Anthropogenic habitat alterations	Increased predation pressure from piscivorous fish, birds, and marine mammals

Source: Adapted from Table 7-7 in NMFS 2013.

Literature Cited

Ford, M.J., A. Albaugh, K. Barnas, T.D. Cooney, J. Cowen, J.J. Hard, R.G. Kope, M.M. McClure, P. McElhany, J.M. Myers, and N.J. Sands. 2011. *Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest*.

- Healey, M.C., 1991. Life History of Chinook salmon (*Oncorhynchus tshawytscha*). *Pacific Salmon Life Histories*.
- Lower Columbia Fish Recovery Board. 2010. *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* Lower Columbia Fish Recovery Board, Washington.
- Myers, J., C. Busack, D. Rawding, A. Marshall, D. Teel, D.M. Van Doornik, and M.T. Maher. 2006. *Historical Population Structure of Pacific Salmonids in the Willamette River and Lower Columbia River Basins*. NOAA Technical Memorandum NMFS-NWFSC-73. National Marine Fisheries Service, Northwest Fisheries Science Center. 311 p. February.
- National Marine Fisheries Service (NMFS). 2005a. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4 (d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register*, 70(123 (28 June 2005), pp.37160–37204.
- National Marine Fisheries Service (NMFS). 2005b. Endangered and Threatened Species; Designation of Critical Habitat for 12 Evolutionarily Significant Units of West Coast Salmon and Steelhead in Washington, Oregon, and Idaho; Final Rule. *Federal Register*, 70, pp.52630–52858.
- National Marine Fisheries Service (NMFS). 2008. *Endangered Species Act Section 7(a)(2) Consultation Biological Opinion & Magnuson-Stevens Fishery Conservation & Management Act Essential Fish Habitat Consultation: Consultation on the "Willamette River Basin Flood Control Project."* Northwest Region. July 11.
- National Marine Fisheries Service. 2011. Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. NMFS Northwest Region. Portland, OR. Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc. (subcontractor). January 2011.
- National Marine Fisheries Service (NMFS). 2013. *ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead*. Northwest Region. June.
- Oregon Department of Fish and Wildlife (ODFW). 2010. *Lower Columbia River Conservation & Recovery Plan for Oregon Populations of Salmon & Steelhead*. August 6. Oregon Department of Fish and Wildlife, Salem, Oregon.
- Oregon Department of Fish and Wildlife and National Marine Fisheries Service (ODFW and NMFS). 2011. *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead*. August.
- Oregon Department of Fish and Wildlife (ODFW). 2019. Salmon and Steelhead Recovery Tracker Chinook Data. Available: <http://odfwrecoverytracker.org/>. Assessed: September 2019.
- State of Oregon. 1987. Oregon Endangered Species Act. (ORS 469.171 to 496.192, 498.026 and 564.135). Oregon Department of Fish and Wildlife, Salem, Oregon.
- State of Oregon. 1997. Rules, O.A., Sensitive Species List (OAR 635-100-0040). State of Oregon, Oregon Department of Fish and Wildlife, Portland, Oregon.
- StreamNet. 2019. Database (Version 98.3) [database downloaded to disk]. Portland (OR) : StreamNet. URL: <https://www.streamnet.org/data/interactive-maps-and-gis-data/>

C8 Oregon Coast Chinook (*Oncorhynchus tshawytscha*)

Legal Status

The National Marine Fisheries Service (NMFS) does not currently consider Oregon Coast spring Chinook as a distinct population (evolutionarily significant unit/distinct population segment [ESU/DSP]) but rather consider them collectively with fall-run Chinook as part of the Oregon Coast Chinook ESU (NMFS 1999, ODFW 2014). However, the Native Fish Society, Center for Biological Diversity, and Umpqua Watersheds have petitioned the NMFS to list Oregon coast spring-run Chinook salmon as a threatened or endangered species under the federal Endangered Species Act (ESA) based on recent genetic evidence (Native Fish Society et al. 2019 and 2022). NMFS reviewed that listing petition and determined that there was sufficient scientific evidence to move forward with a formal status review of the OC Chinook ESU to determine if listing under the ESA is warranted. Oregon Coast Chinook was determined in 2025 to be not warranted for listing as endangered or

threatened (90 FR 56993). ODF will include this ESU in the Habitat Conservation Plan (HCP) as the potential for future ESA listing considerations in the future is considered likely.

State: Sensitive species

Federal: None

Critical Habitat: None

Recovery Planning: None



Photo: ODFW

Taxonomy

Oregon Coast spring Chinook have historically been considered collectively with fall-run as part of a single ESU (ODFW 2014; NMFS 1999). Waples et al. (2004) found that spring- and fall-run populations of Chinook on the Oregon coast were very similar genetically, indicating that the two forms have only recently diverged and may still occasionally interbreed. This is notably different from spring- and fall-run Chinook in the Columbia River, which are believed to be of distinct genetic lineages with much older divergence than coastal populations (Waples et al. 2004; Quinn 2018).

The recent petition for listing Oregon Coast spring Chinook (Native Fish Society et al. 2019) referenced recently published studies that the petitioners felt demonstrated a genetic basis for designating Oregon Coast spring Chinook populations as an ESU distinct from the fall-run (citing Prince et al. 2017; Davis et al. 2017; Narum et al. 2018; Thompson et al. 2019). Thompson et al.

(2019) noted that widespread declines and extirpation of spring-run genetic lines will hinder recovery of spring-run populations.

Distribution

General

Based on available historical records, spring Chinook were likely present in almost all watersheds draining the Oregon Coast range that included an estuary (Native Fish Society et al. 2019), and naturally spawned Oregon Coast spring-run Chinook still occur in most Oregon coastal rivers south of the Columbia River. The Oregon Department of Fish and Wildlife (ODFW 2005) identified a Coastal spring Chinook Species Management Unit (SMU) that overlaps with the NMFS Oregon Coast Chinook ESU (Figure C8-1). The Coastal Spring-run Chinook SMU includes nine historic river populations between Tillamook Bay and the Coquille River (ODFW 2005):

- Tillamook River
- Nestucca River
- Siletz River
- Alsea River
- Siuslaw River
- South Fork Umpqua River
- North Fork Umpqua River
- Coos River
- Coquille River

The Coos River and Siuslaw River populations are presumed extinct (ODFW 2005).

Occurrences Within the Plan Area

Coastal spring-run Chinook can occur within the larger rivers and streams in any of the planning area within the Coast Range Ecoregion and in the Umpqua drainage, which includes the West Cascades Ecoregion. According to the Oregon Native Fish Status Report (2005), essentially all potential spring Chinook habitat within the Coastal ESU is accessible. Table C8-1 lists a general estimate of miles of habitat, as preliminarily identified in ODFW's Native Fish Status Report (2005). The overlap of potential occupied streams with the plan area is not provided because actual habitat usage by coastal spring Chinook is not currently quantifiable (ODFW 2005).

Table C8-1. Miles of Oregon Coast Spring-Run Chinook Salmon Known or Presumed Chinook Salmon Presence

Biogeographic Stratum and Independent Populations	Stream Miles with Known or Presumed Spring Chinook Salmon Presence
	Total Stream Miles
Tillamook	93
Nestucca	44
Siletz	87
Alsea	98
Siuslaw	Presumed extinct
South Umpqua	72
North Umpqua	108
Coos	Presumed extinct
Coquille	158

Source: ODFW 2005b.

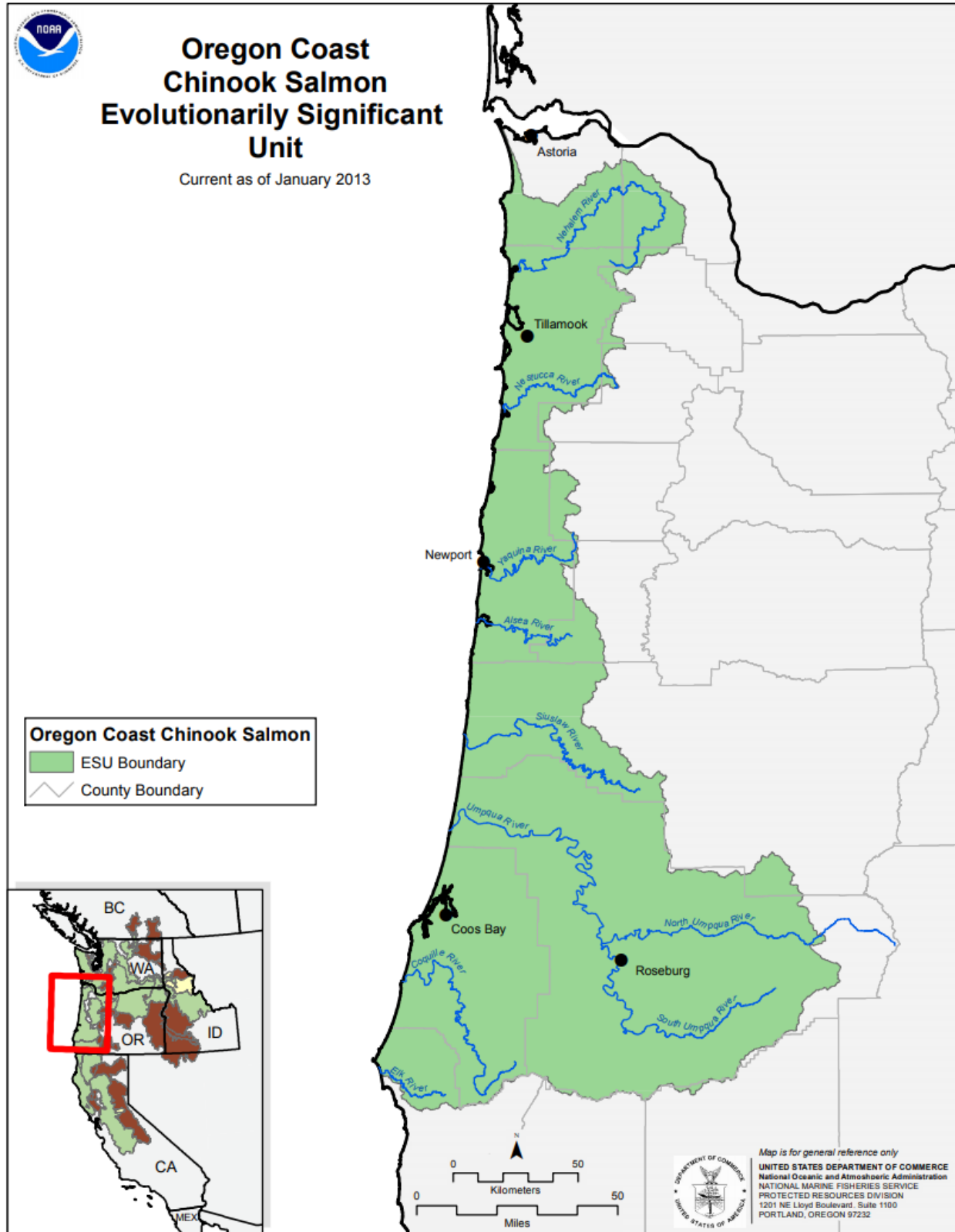


Figure C8-1. Oregon Coast Chinook Salmon ESU in Oregon

Natural History

Life History and Habitat Requirements

Upstream Migration and Spawning

Spring Chinook enter rivers during highwater in the spring to access upstream spawning areas, where they seek cold water in deep pools to hold over several months, where they sexually mature and wait for fall spawning (Quinn 2018). Low water temperature and the presence of cool, deep holding water over the dry summer season are key habitat requirements for spring-run adults.

Healey (1991) reported that Chinook spawning in general occurs in a wide range of depths, from upper reaches of streams to the mainstreams of major rivers. However, most authors note a preference for locations where subsurface flows are high, particularly near the head of riffles (shallower, rougher waters less intense than rapids). Other spawning habitat indicators noted by Healey (1991) include pools below log jams and the upstream sides of large gravel dunes oriented across the river channel.

Incubation and Emergence

Little specific information is available regarding spring Chinook incubation and emergence.

Freshwater Residence and Outmigration

Populations with spring-migrating adults often have stream-type juveniles, living in freshwater for at least a year following emergence (Quinn 2018). However, the petition to list the Oregon Coast spring-run Chinook states that this population exhibits an ocean-type life-history, migrating to sea during their first year of life, normally within 3 months after emergence from spawning gravels (Native Fish Society et al. 2019).

Estuary Residence and Ocean Life

Healey (1991) reported that Coastal Oregon stocks that spawn in rivers on the central and northern parts of the Oregon coast (from the Elk River north) migrate north to contribute to Oregon and Alaska fisheries, while stocks that spawn in rivers on the southern part of the Oregon coast (from the Rogue River south) migrate south and contribute to fisheries off Oregon and northern California.

Population Status and Trends

The 2005 Oregon Native Fish Status Report (ODFW 2005b) noted that little information was available regarding Oregon Coast spring Chinook populations, but based on available information and indirect indices, found that all river populations were at risk, with the exception of the North Umpqua. According to the listing petition (Native Fish Society et al. 2019), spring Chinook populations in every Oregon coastal basin declined significantly from historical abundance, with spring-run populations in the Siuslaw and Coos rivers potentially extirpated. Small, remnant populations of spring Chinook persist in the Tillamook, Nestucca, Siletz, Alsea, and Coquille rivers. The North Umpqua River is the only Oregon coast river to support large spring-run Chinook population, with annual returns ranging from 2,500 to 16,000.

Based on the literature review conducted by Native Fish Society et al. (2019), the population status of the nine coastal populations of spring Chinook are as follows:

- **Stable:** North Umpqua River
- **Declining:** Siletz River, Alsea River, Tillamook River, Nestucca River
- **Declining, near extinction:** Coquille River, South Umpqua River
- **Extirpated:** Siuslaw River, Coos River

Threats

Threats reported in the listing petition are similar to those reported for other salmon populations, including dams, water diversions, migration barriers, and habitat degradation due to logging and roads. Habitat effects noted include reduced stream shade, increased fine sediment levels, reduced levels of in-stream large wood, and altered watershed hydrology. The petition notes that logging can reduce summer and fall flows, which can be particularly harmful to spring Chinook during the summertime holding period of their reproduction cycle (Jones and Post 2004).

The petition also notes that hatchery spring Chinook are currently released in the Trask, Nestucca, and North Umpqua rivers and that hatcheries may inadvertently mix spring and fall stock, thereby reducing the genetic distinctness between spring and fall runs in these systems.

Literature Cited

- Davis, C.D., J.C. Garza, and M.A. Banks. 2017. Identification of Multiple Genetically Distinct Populations of Chinook Salmon (*Oncorhynchus tshawytscha*) in a Small Coastal Watershed. *Environmental Biology of Fishes* 100:923–933.
- Healey, M.C., 1991. Life History of Chinook salmon (*Oncorhynchus tshawytscha*). *Pacific Salmon Life Histories*.
- Jacobs S., J. Firman, and G. Susac. 2001. *Status of Oregon Coastal Stocks of Anadromous Salmonids, 1999-2000*. Monitoring Program Report Number OPSW-ODFW-2001-3, Oregon Department of Fish and Wildlife, Portland, Oregon.
- Jones, J. A., and Post, D. A. 2004. Seasonal and Successional Streamflow Response to Forest Cutting and Regrowth in the Northwest and Eastern United States. *Water Resources Research* 40(5):W05203, doi:10.1029/2003WR002952.
- Narum, S. R., A. Di Genova, S.J. Micheletti, and A. Maass. 2018. Genomic Variation Underlying Complex Life-History Traits Revealed by Genome Sequencing in Chinook Salmon. *Proceedings of the Royal Society B: Biological Sciences* 285(1883):20180935.
- Native Fish Society, Center for Biological Diversity, and Umpqua Watersheds. 2019. Petition to List the Oregon Coast ESU of Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) under the Endangered Species Act. September 24.
- Native Fish Society, Center for Biological Diversity, and Umpqua Watersheds. 2022. Petition to List the Oregon Coast, Southern Oregon and Northern California Coastal ESUs of Chinook Salmon (*Oncorhynchus tshawytscha*) under the Endangered Species Act. August 4.

- National Marine Fisheries Service (NMFS). 1999. Endangered and Threatened Species; Threatened Status for Three Chinook Salmon Evolutionarily Significant Units (ESUs) in Washington and Oregon, and Endangered Status for One Chinook Salmon ESU in Washington. *Federal Register*, 64 FR 14308. March 24.
- NMFS (National Marine Fisheries Service). 2023. Endangered and Threatened Wildlife; 90-Day Finding on a Petition To List Oregon Coast and Southern Oregon and Northern California Coastal Chinook Salmon as Threatened or Endangered Under the Endangered Species Act. *Federal Register*, 88 FR 00214. January 10.
- ODFW (Oregon Department of Fish and Wildlife). 2005a. *Oregon Native Fish Status Report, Volume I: Species Management Unit Summaries*. ODFW Fish Division, Salem, OR.
- ODFW (Oregon Department of Fish and Wildlife). 2005b. *Oregon Native Fish Status Report, Volume II: Assessment Methods & Population Results*. ODFW Fish Division, Salem, OR.
- ODFW (Oregon Department of Fish and Wildlife). 2014. *Coastal Multi-Species Conservation and Management Plan*.
- Prince, D.J., S.M. O'Rourke, T.Q. Thompson, O.A. Ali, H.S. Lyman, I.K. Saglam, T.J. Hotaling, A.P. Spidle, and M.R. Miller. 2017. The Evolutionary Basis of Premature Migration in Pacific Salmon Highlights the Utility of Genomics for Informing Conservation. *Science Advances* 3, August 16, 2017.
- Quinn, Thomas P. 2018. *The Behavior and Ecology of Pacific Salmon and Trout*. University of Washington Press. Seattle, WA.
- Thompson T.Q., R.M. Bellinger, S.M. O'Rourke, D.J. Prince, A.E. Stevenson, A.T. Rodrigues, M.R. Sloat, C.F. Speller, D.Y. Yang, V.L. Butler, M.A. Banks, and M.R. Miller. 2019. Anthropogenic Habitat Alteration Leads to Rapid Loss of Adaptive Variation and Restoration Potential in Wild Salmon Populations. *Proceedings of the National Academy of Sciences* 116 (1), 177-186.
- Teel, D.J., B.J. Burke, D.R. Kuligowski, C.A. Morgan and D.M. Van Doornik. 2015. Genetic Identification of Chinook Salmon: Stock-Specific Distributions of Juveniles Along the Washington and Oregon Coasts. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 7: 274–300.
- Waples, R., D.J. Teel, J.M. Myers and A.R. Marshall. 2004. Life-History Divergence in Chinook Salmon; Historic Contingency and Parallel Evolution. *Evolution* 58 (2):386-403.

C9 Southern Oregon/Northern California Spring Chinook (*Oncorhynchus tshawytscha*)

Legal Status

Southern Oregon/Northern California Coastal (SONCC) spring Chinook salmon are not listed as threatened or endangered under the Oregon State Endangered Species Act nor the California State Endangered Species Act.

The National Marine Fisheries Service (NMFS) does not currently consider SONCC spring Chinook as a distinct population (evolutionarily significant unit/distinct population segment [ESU/DSP]) but rather consider them collectively with fall-run Chinook as part of the SONCC Chinook ESU (NMFS 1999). However, there has been a petition to designate SONCC spring-run Chinook as a separate ESU and list them as a threatened or endangered species under the Endangered Species Act (Nawa 2020). NMFS has since reviewed the petition and concluded that SONCC spring-run Chinook salmon do not meet the criteria to be a designated separate ESU and thus do not warrant Endangered Species Act (ESA) listing (Ford et al. 2021; NMFS 2021). However, in August 2022, NMFS received a petition from the Native Fish Society, Center for Biological Diversity, and Umpqua Watersheds to list Oregon SONCC spring-run Chinook salmon as a threatened or endangered species under the federal ESA based on recent genetic evidence (Native Fish Society et al. 2019). Early in 2023, NMFS issued a 90-day petition finding

indicating sufficient information was presented by the petitioners to warrant a formal status review (FR Vol. 88, No. 7). SONCC Chinook was determined in 2025 to be not warranted for listing as endangered or threatened (90 FR 56993). ODF will include this ESU in the Habitat Conservation Plan (HCP) as the potential for future ESA listing considerations in the future is considered likely.

State: Oregon - Sensitive species, California – Moderate concern

Federal: None

Critical Habitat: None

Recovery Planning: None



Photo: ODFW

Taxonomy

SONCC spring Chinook have historically been considered collectively with fall-run as part of a single ESU (Moyle et al. 2015; ODFW 2014; NMFS 1999). Waples et al. (2004) found that spring- and fall-

run populations of Chinook on the Oregon coast were very similar genetically, indicating that the two forms have only recently diverged and may still occasionally interbreed. This is notably different from spring- and fall-run Chinook in the Columbia River, which are believed to be of distinct genetic lineages with much older divergence than coastal populations (Waples et al. 2004; Quinn 2018).

The recent petition for listing SONCC spring Chinook (Nawa 2020) referenced recently published studies that the petitioner felt demonstrated a genetic basis for designating SONCC spring Chinook populations as an ESU distinct from the fall-run (citing Prince et al. 2017; Davis et al. 2017; Narum et al. 2018; Thompson et al. 2019). Thompson et al. (2019) noted that widespread declines and extirpation of spring-run genetic lines will hinder recovery of spring-run populations.

Distribution

General

Based on available historical records, SONCC spring Chinook were likely present in almost all watersheds along the Oregon Coast south to the Russian River in California that included an estuary (Native Fish Society et al. 2019). Because this HCP is a document for the state of Oregon, the scope of this section is limited to Oregon. Currently, spring Chinook in the SONCC Chinook ESU are essentially limited to Rogue River. However, spring Chinook have been observed incidentally in the Applegate, Pistol, Illinois, and Chetco Rivers during surveys conducted for other purposes (ODFW 2007).

The Oregon Department of Fish and Wildlife (ODFW 2005) identifies a Coastal spring Chinook Species Management Unit (SMU) that is a portion of the NMFS SONCC Chinook ESU (Figure C9-1). The Rogue Spring Chinook SMU consists of a single population in the upper Rogue River basin upstream of the historical site of Gold Ray Dam.

Occurrences Within the Plan Area

SONCC spring-run Chinook can occur within the larger rivers and streams in any of the planning area within the Coast Range Ecoregion and West Cascades Ecoregions. According to the Oregon Native Fish Status Report (2005), 79% of the potential spring Chinook habitat within the Rogue SMU is accessible. Table C9-1 provides an estimate of miles of habitat, as identified in ODFW's Native Fish Status Report (2005). The overlap of potentially occupied streams with the plan area is not provided because actual habitat usage by SONCC spring Chinook is not currently quantifiable (ODFW 2005).

Table C9-1. Miles of Southern Oregon and California Coastal Spring Chinook Salmon Known or Presumed Spring Chinook Salmon Presence

Biogeographic Stratum and Independent Populations	Stream Miles with Known or Presumed Spring Chinook Salmon Presence
	Total Stream Miles
Rogue	33

Source: ODFW 2005.

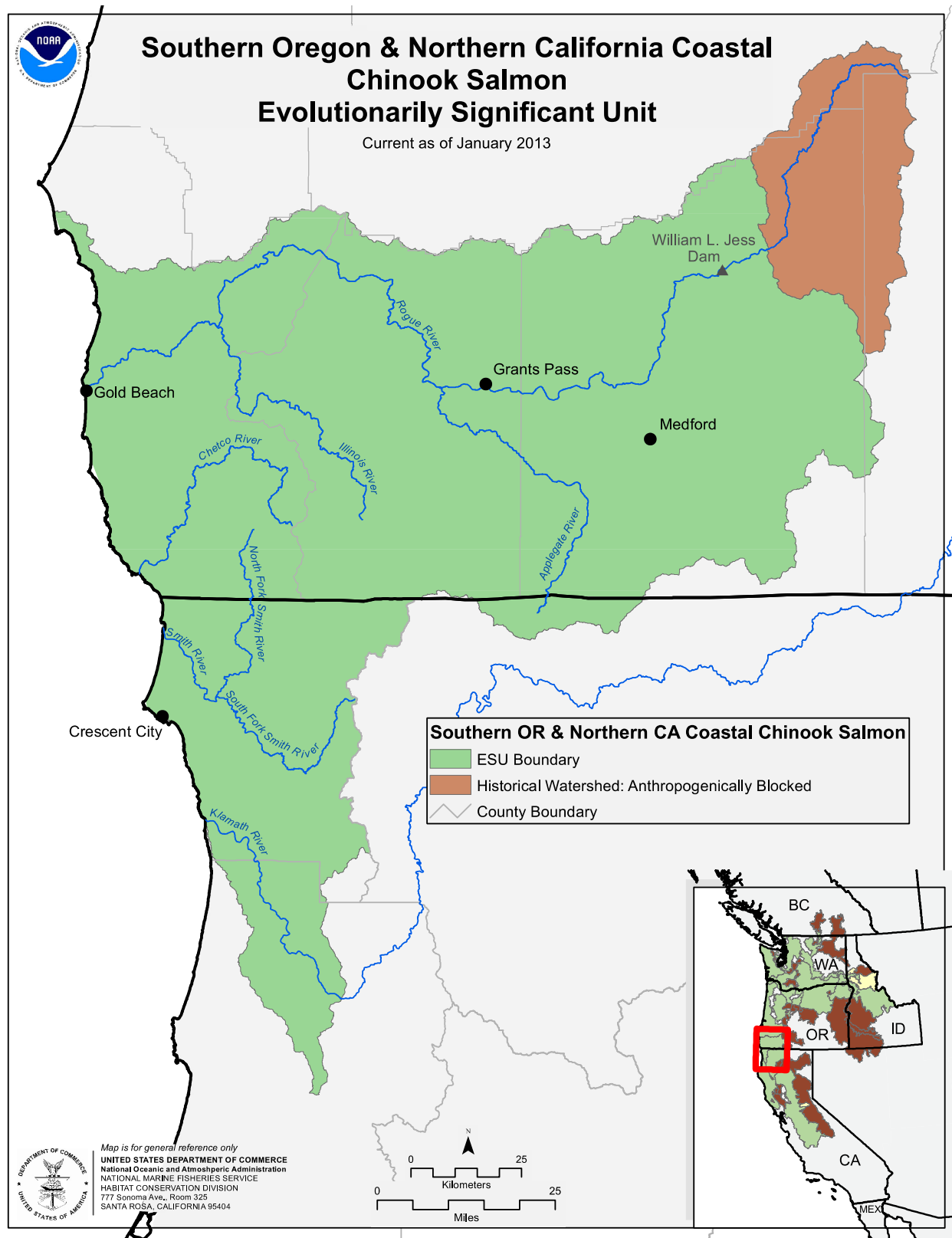


Figure C9-1. Southern Oregon and Northern California Coastal Chinook Salmon ESU in Oregon and California

Natural History

Life History and Habitat Requirements

Upstream Migration and Spawning

Spring Chinook enter rivers during highwater in the spring to access upstream spawning areas, where they seek cold water in deep pools to hold over several months, where they sexually mature and wait for fall spawning (Quinn 2018). Low water temperature and the presence of cool, deep holding water over the dry summer season are key habitat requirements for spring-run adults.

Healey (1991) reported that Chinook spawning in general occurs in a wide range of depths, from upper reaches of streams to the mainstems of major rivers. However, most authors note a preference for locations where subsurface flows are high, particularly near the head of riffles (shallower, rougher waters less intense than rapids). Other spawning habitat indicators noted by Healey (1991) include pools below log jams and the upstream sides of large gravel dunes oriented across the river channel.

Incubation and Emergence

Peak spawning time tends to be during the second week of October with fry emergence from the gravel beginning in January and ending in late April or early May (ODFW 2000).

Freshwater Residence and Outmigration

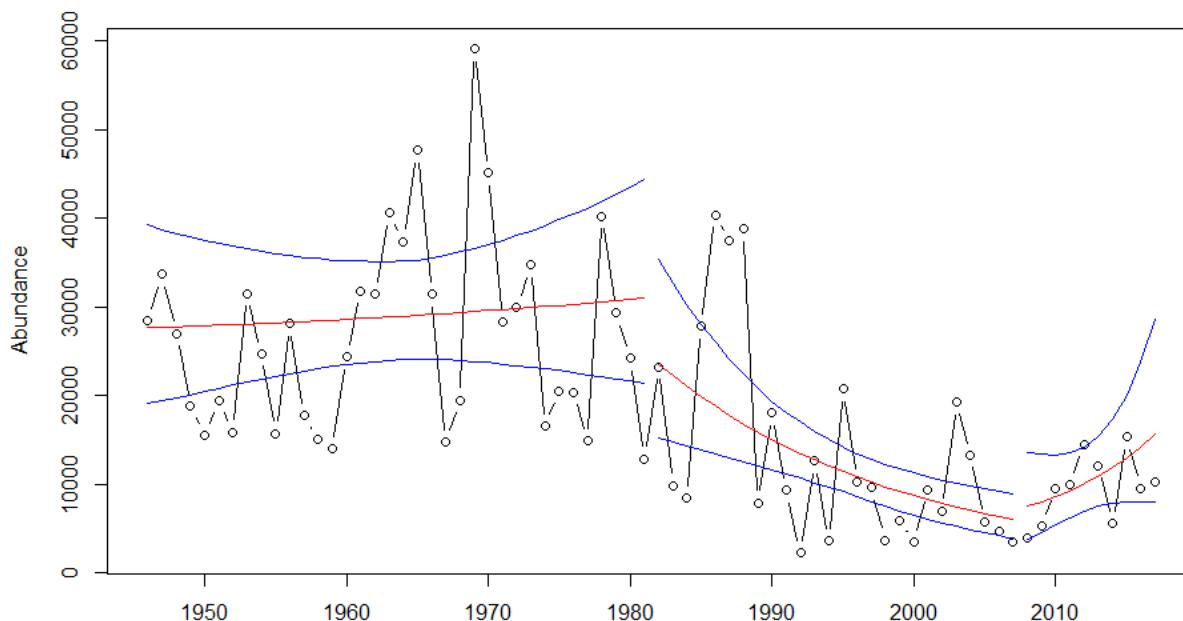
In the Rogue River spring Chinook juveniles outmigrants were predominately sub-yearlings with a small portion outmigrating as yearlings (ODFW 2000). Outmigration timing begins in mid-May and continues through late-September with ocean entry tending to occur from August to October for sub-yearlings and May and June for yearlings (ODFW 2000). Sub-yearling tended to rearing in the Rogue for 4–5 months.

Estuary Residence and Ocean Life

Healey (1991) reported that stocks that spawn in rivers on the southern part of the Oregon coast (from the Rogue River south) migrate south and contribute to fisheries off Oregon and northern California.

Population Status and Trends

The Rogue River has a long time series of spawner abundance estimates that started in 1942 and continues to today. Estimates of the number of spring Chinook salmon above the historic Gold Ray Dam site, 1942–2017, ranged from 1,617 to 57,797 (ODFW 2007). Though well below historic spawner abundance levels the current trend has been increasing abundance since 2000 (Figure C9-2).



Source: ODFW 2019

Figure C9-2. Spring Chinook Spawner Abundance Estimates for Rogue River Above the Historic Gold Ray Dam Site, 1946–2017

Threats

Threats reported in the listing petition are similar to those reported for other salmon populations, including dams, water diversions, migration barriers, and habitat degradation due to logging and roads. Habitat effects noted include reduced stream shade, increased fine sediment levels, reduced levels of in-stream large wood, and altered watershed hydrology. The petition notes that logging can reduce summer and fall flows, which can be particularly harmful to spring Chinook during the summertime holding period of their reproduction cycle (Jones and Post 2004).

The petition also notes that hatchery spring Chinook released into the Rogue River are inadvertently mixing with the wild spring stock on the spawning grounds, thereby reducing the fitness.

Literature Cited

- Davis, C.D., J.C. Garza, and M.A. Banks. 2017. Identification of Multiple Genetically Distinct Populations of Chinook Salmon (*Oncorhynchus tshawytscha*) in a Small Coastal Watershed. *Environmental Biology of Fishes* 100:923–933.
- Ford, M., E. Anderson, J. Carlos Garza, J. Myers, T. H. Williams, and R. Waples. 2021. *Report on a Review of the Oregon Coast and Southern Oregon Northern California Coastal Spring Chinook Salmon ESU Configuration*. National Marine Fisheries Service.
- Healey M.C. 1991 Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). Pages 313–393 in C. Groot and L. Margolis (eds.), *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver.

- Jones, J. A., and Post, D. A. 2004. Seasonal and Successional Streamflow Response to Forest Cutting and Regrowth in the Northwest and Eastern United States. *Water Resources Research* 40(5):W05203, doi:10.1029/2003WR002952.
- Moyle, P.B. 2002. *Inland Fishes of California*. University of California Press. 502pp.
- Moyle, P.B., R. M. Quiñones, J. V. Katz, and J. Weaver. 2015. *Fish Species of Special Concern in California*. Sacramento: California Department of Fish and Wildlife.
- Narum, S. R., A. Di Genova, S.J. Micheletti, and A. Maass. 2018. Genomic Variation Underlying Complex Life-History Traits Revealed by Genome Sequencing in Chinook Salmon. *Proceedings of the Royal Society B: Biological Sciences* 285(1883):20180935.
- Native Fish Society, Center for Biological Diversity, and Umpqua Watersheds. 2019. Petition to List the Oregon Coast ESU of Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) under the Endangered Species Act. September 24.
- Native Fish Society, Center for Biological Diversity, and Umpqua Watersheds. 2022. Petition to List the Oregon Coast, Southern Oregon and Northern California Coastal ESUs of Chinook Salmon (*Oncorhynchus tshawytscha*) under the Endangered Species Act. August 4.
- Nawa, Richard K. 2020. Petition to List the Southern Oregon and Northern California Coastal ESU of Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) under the Endangered Species Act. May 4.
- NMFS (National Marine Fisheries Service). 1999. Endangered and Threatened Species; Threatened Status for Three Chinook Salmon Evolutionarily Significant Units (ESUs) in Washington and Oregon, and Endangered Status for One Chinook Salmon ESU in Washington. *Federal Register*, 64 FR 14308. March 24.
- NMFS (National Marine Fisheries Service). 2021. Listing Endangered and Threatened Wildlife; 12-Month Findings on Petitions To List Spring-Run Oregon Coast Chinook Salmon and Spring-Run Southern Oregon and Northern California Coastal Chinook Salmon as Threatened or Endangered Under the Endangered Species Act. *Federal Register*, 86 FR 45970. August 17.
- NMFS (National Marine Fisheries Service). 2023. Endangered and Threatened Wildlife; 90-Day Finding on a Petition To List Oregon Coast and Southern Oregon and Northern California Coastal Chinook Salmon as Threatened or Endangered Under the Endangered Species Act. *Federal Register*, 88 FR 00214. January 10.
- ODFW (Oregon Department of Fish and Wildlife). 2000. *Effects of Lost Creek Dam on Spring Chinook Salmon in the Rogue River. Phase II Completion Report*. Oregon Department of Fish and Wildlife, Fish Research Project DACW 57-77-C-0033, Completion Report, Portland.
- ODFW (Oregon Department of Fish and Wildlife). 2005. *Oregon Native Fish Status Report, Volume II: Assessment Methods & Population Results*. ODFW Fish Division, Salem, OR.
- ODFW (Oregon Department of Fish and Wildlife). 2007. *Rogue Spring Chinook Salmon Conservation Plan*. ODFW Fish Division, Salem, OR.
- ODFW (Oregon Department of Fish and Wildlife). 2014. *Coastal Multi-Species Conservation and Management Plan*. ODFW Fish Division, Salem, OR.

- ODFW (Oregon Department of Fish and Wildlife). 2019. *Rogue Spring Chinook Salmon Conservation Plan Comprehensive Assessment and Update*. ODFW Fish Division, Salem, OR.
- Prince, D.J., S.M. O'Rourke, T.Q. Thompson, O.A. Ali, H.S. Lyman, I.K. Saglam, T.J. Hotaling, A.P. Spidle, and M.R. Miller. 2017. The Evolutionary Basis of Premature Migration in Pacific Salmon Highlights the Utility of Genomics for Informing Conservation. *Science Advances* 3, August 16, 2017.
- Quinn, Thomas P. 2018. *The Behavior and Ecology of Pacific Salmon and Trout*. University of Washington Press. Seattle, WA.
- Thompson T.Q., R.M. Bellinger, S.M. O'Rourke, D.J. Prince, A.E. Stevenson, A.T. Rodrigues, M.R. Sloat, C.F. Speller, D.Y. Yang, V.L. Butler, M.A. Banks, and M.R. Miller. 2019. Anthropogenic Habitat Alteration Leads to Rapid Loss of Adaptive Variation and Restoration Potential in Wild Salmon Populations. *Proceedings of the National Academy of Sciences* 116 (1), 177–186.
- Waples, R., D.J. Teel, J.M. Myers and A.R. Marshall. 2004. Life-History Divergence in Chinook Salmon; Historic Contingency and Parallel Evolution. *Evolution* 58(2):386–403.

C10 Eulachon (*Thaleichthys pacificus*)

The southern distinct population segment (DPS) of pacific eulachon or smelt is listed as threatened under the federal Endangered Species Act (ESA). Critical habitat was designated in 2011 and includes 16 creeks and rivers within Washington, Oregon, and California.

Legal Status

State: Oregon Nearshore Strategy Species (Oregon Department of Fish and Wildlife [ODFW] 2006)

Federal: Threatened (National Marine Fisheries Service [NMFS] 2009, final rule 2010; 75 *Federal Register* [FR] 13012)

Critical Habitat: Designated (NMFS final rule 2011; 76 FR 65324)

Recovery Planning: Recovery plan approved (NMFS 2017; 81 FR 72572)

Status Review: 5-year status review (NMFS 2016; 81 FR 33468)

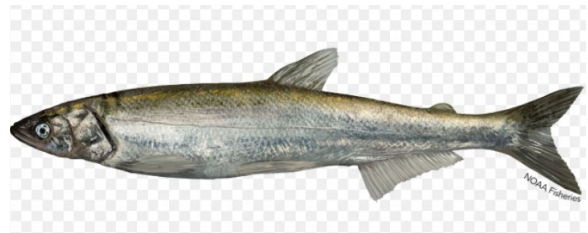


Photo: NOAA Fisheries

Taxonomy

Eulachon are anadromous smelt in the family Osmeridae. The genus *Thaleichthys* has only one species; subspecies have not been described (NMFS 2017).

Distribution

General

Eulachon range from Northern California to the southeastern Bering Sea in Bristol Bay, Alaska. The southern DPS includes four subpopulations: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers of the Nass River (NMFS 2017). Their distribution coincides closely with the distribution of the coastal temperate rain forest ecosystem on the west coast of North America. South of the U.S.-Canada border most eulachon production originates in the Columbia River Basin, with the Columbia and Cowlitz rivers having the largest and most consistent spawning returns. Spawning also occurs in other tributaries to the Columbia River, including the Grays, Elochoman, Kalama, Lewis, and Sandy rivers. The only other larger river basins in the contiguous U.S. with historically large, consistent spawning runs of eulachon are the Umpqua River in Oregon and Klamath River in northern California (NMFS 2011). Eulachon have also historically occurred in the following coastal creeks and rivers: Tenmile Creek, Siuslaw River, Winchuck River, Chetco River, Rogue River, Pistol River, Elk River, Sixes River, Coquille River, Coos River, Yaquina River, Hunter Creek, and Euchre Creek (NMFS 2017).

Occurrences Within the Plan Area

StreamNet does not report eulachon distribution data so distribution of eulachon in the plan area is based on the NMFS critical habitat extent. Within the DPS, eulachon occur primarily in the mainstem Columbia River and alcoves in the mouths of its tributaries (Figure C10-1). These mainstem rivers are outside the plan area, and eulachon are unlikely to migrate upstream into the streams that occur in the plan area. Key eulachon streams in Oregon are the Columbia, Sandy, and Umpqua Rivers; the two latter rivers do not overlap the plan area. The Washington Department of Fish and Wildlife (WDFW) has maintained a eulachon monitoring location on the Columbia River at river kilometer 55 across the Clifton Channel from the Oregon shore to Tenasillahe Island, which is adjacent to the plan area and overlaps with designated eulachon critical habitats. Sampling of eulachon larvae and eggs using plankton nets by ODFW and WDFW (2014), at this location, suggest lower egg densities compared to the Price Island site on the opposite shoreline. This is likely due to the majority of eulachon spawning tributaries occurring on the Washington shore (Elochman, Cowlitz, Kalama, and Lewis Rivers) as well as eulachon generally spawning farther upstream than the Clifton Channel and Price Island sites (ODFW and WDFW 2014, 2023 and WDFW 2020). Based on what is known about eulachon distribution throughout their range it is unlikely that they will occur in the plan area.

Natural History

Life History and Habitat Requirements

Eulachon are a short lived, high fecundity, high mortality forage fish, and tend to have extremely large population sizes. Eulachon abundance exhibits considerable year-to-year variability. Eulachon typically spend 3 to 5 years in saltwater before returning to freshwater to spawn from late winter through mid-spring.

Early Life History

Eulachon eggs average 1 millimeter in size and are broadcast into the water column, attaching to a variety of substrates from sand to pea-sized gravel. Eggs are fertilized in the water column. After fertilization, the eggs sink and adhere to the river bottom, typically in areas of gravel and coarse sand. Most eulachon adults die after spawning. Eulachon eggs hatch in 20 to 40 days with incubation time depending on water temperature (Howell 2001). Newly hatched young, transparent and 4 to 7 millimeters in length, are carried to the sea with the current (Hay and McCarter 2000). It is not known how long larval eulachon remain in the estuary before entering the ocean (NMFS 2011). Like salmon, juvenile eulachon are thought to imprint on the chemical signature of their natal river basins. However, because juvenile eulachon spend less time in freshwater environments than do juvenile salmon, researchers hypothesize that this short freshwater residence time may cause returning eulachon to stray between spawning sites at higher rates than salmon (Hay and McCarter 2000).

Once juvenile eulachon enter the ocean, they move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters, where they are typically found near the ocean bottom in waters 20 to 150 meters deep (66–292 feet) (Hay and McCarter 2000) and sometimes as deep as 182 meters (597 feet) (Barracough 1964). Despite spending over 95% of their lives in the ocean, little is known about eulachon oceanic distribution and ecology (NMFS 2017).

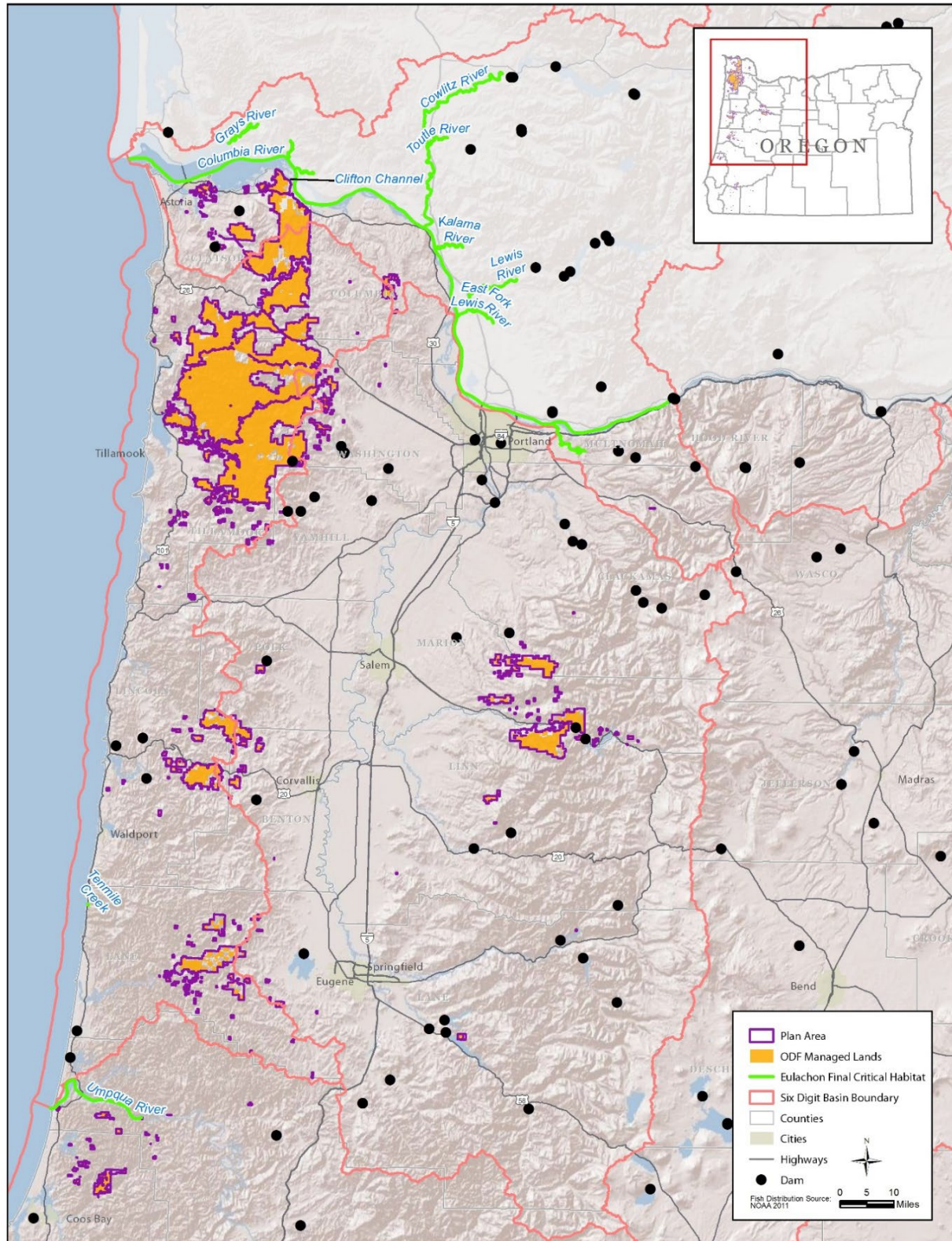


Figure C10-1. Southern DPS Eulachon Critical Habitat Extent

Spawning

Eulachon are semelparous, meaning that they spawn once and then die. Eulachon generally spawn in rivers that are either glacier or snowpack fed and that experience spring freshets (Hay and McCarter 2000, as reported in Willson et al. 2006). Spawning grounds are typically in the lower reaches of larger rivers fed by snowmelt, and spawning typically occurs at night. In many rivers, spawning is limited to the part of the river that is influenced by tides (Lewis et al. 2002).

The Columbia River, below Bonneville Dam, is a very productive and preferred spawning area for eulachon. The mainstem of the Lower Columbia River provides spawning and incubation sites and a migratory corridor to spawning areas in the tributaries.

Spawning substrates can range from silt, sand, or gravel to cobble and detritus, but sand appears to be most common. Eulachon eggs are enclosed in a double membrane; after fertilization in the water, the outer membrane breaks and turns inside out, creating a sticky stalk, which anchors the eggs to the substrate (Hart and McHugh 1944; Hay and McCarter 2000).

Spawning occurs at between 0 and 10°C throughout the range of the species and is largely limited to the part of the river that is tidally influenced (Lewis et al. 2002). Entry into the spawning rivers appears to be related to water temperature and the occurrence of high tides (Ricker et al. 1954; Smith and Saalfeld 1955; Spangler 2002). Spawning generally occurs in January, February, and March in the Columbia River, the Klamath River, and the coastal rivers of Washington and Oregon. It has been argued that because these freshets rapidly move eulachon eggs and larvae to estuaries, it is likely that eulachon imprint and home to an estuary into which several rivers drain rather than to individual spawning rivers (Hay and McCarter 2000). There is some evidence that water velocity greater than 0.4 meters/second (1.3 feet/second) begins to limit the upstream movements of eulachon (Lewis et al. 2002).

Ecological Relationships

Eulachon adults feed on zooplankton, chiefly eating crustaceans such as copepods and euphausiids, including *Thysanoessa* spp. (Hay and McCarter 2000; WDFW and ODFW 2001), unidentified malacostracans (Sturdevant 1999), and cumaceans (Smith and Saalfeld 1955). Eulachon larvae and juveniles eat a variety of prey items, including phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, worm larvae, and eulachon larvae (WDFW and ODFW 2001). Adults and juveniles commonly forage at moderate depths (20–150 meters [66–292 feet]) in nearshore marine waters (Hay and McCarter 2000). Eulachon adults do not feed during spawning (McHugh 1939; Hart and McHugh 1944).

Eulachon are very high in lipids, and their historical large spawning runs made them an important part of the Pacific coastal food web (Gustafson et al. 2010). They have numerous avian predators, including sea birds such as harlequin ducks, pigeon guillemots, common murrelets, mergansers, cormorants, gulls, and eagles (Gustafson et al. 2010). Marine mammals such as baleen whales, orcas, dolphins, pinnipeds, and beluga whales are known to feed on eulachon. Fish that prey on eulachon include white sturgeon, spiny dogfish, sablefish, salmon sharks, arrowtooth flounder, Pacific hake, salmon, Dolly Varden, Pacific halibut, and Pacific cod (Gustafson et al. 2010). Eulachon and their eggs seem to provide a significant food source for white sturgeon in the Columbia and Fraser rivers (Gustafson et al. 2010).

Population Status and Trends

Commercially landed eulachon in the Columbia River has declined from 2.1 million pounds annually from 1938–1989 to 5,000 pounds in 1999 (Gustafson et al. 2010). The current abundance of eulachon is low and declining in all surveyed populations throughout the DPS (NMFS 2011). Eulachon populations spawning in the Klamath River, lower Columbia River Basin, and Fraser River have declined substantially, and the southern DPS will likely become endangered in the foreseeable future if ongoing threats are not addressed (NMFS 2011). Past and ongoing federal, state, and local protective efforts (many of them habitat-based) have contributed to the conservation of the southern DPS, but these efforts alone do not sufficiently reduce the extinction risks faced by the southern DPS (NMFS 2011).

Threats

A federal recovery plan for the southern DPS eulachon was finalized in September 2017 (81 FR 72572). The plan provides guidance to increase the abundance and productivity through its geographical range and improve the viability of the species to the point that it meets the delisting criteria and no longer requires ESA protection. The primary threats identified in the recovery plan are deteriorating ocean, estuarine, and plume conditions as a result of climate change impacts, dams/water diversions; predation; and eulachon as bycatch in offshore shrimp fishery trawls (NMFS 2017).

Habitat loss and degradation threaten eulachon, particularly in the Columbia River basin (NMFS 2011). Hydroelectric dams block access to historical eulachon spawning grounds and affect the quality of spawning substrates through flow management, altered delivery of coarse sediments, and siltation. Freshwater and estuarine migration corridors need to be free of obstructions to support larval and adult movement. Nearshore and offshore marine foraging habitats for juveniles need to be rich with crustaceans such as copepods and euphausiids, mysids, barnacle larvae, and worm larvae for juveniles to feed after they have fully absorbed their yolk sac (NMFS 2011).

Literature Cited

- Barraclough W. E. 1964. Contribution to the Marine Life History of the Eulachon *Thaleichthys pacificus*. *J. Fish. Res. Board Can.* 21:1333–1337.
- Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. *Status Review of Eulachon (Thaleichthys pacificus) in Washington, Oregon, and California*. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-105, 360 p.
- Gustafson, R., Y.-W. Lee, E. Ward, K. Somers, V. Tuttle, J. Jannot, and J. McVeigh. 2017. *Observed and Estimated Bycatch of Eulachon in US West Coast Ocean Shrimp Trawl Fisheries from 2004–2015*.
- Hart, J. L. and J. L. McHugh. 1944. *The Smelts (Osmeridae) of British Columbia*. Fisheries Research Board of Canada Bulletin No. 64.
- Hay, D. E. and P.B. McCarter. 2000. *Status of the Eulachon Thaleichthys pacificus in Canada*. Department of Fisheries and Oceans Canada, Canadian Stock Assessment Secretariat, Research Document 2000-145. Ottawa, Ontario.

- Langer, O. E., B. G. Shepherd, and P. R. Vroom. 1977. *Biology of the Nass River Eulachon* (*Thaleichthys pacificus*). Canadian Fisheries and Marine Service Technical Report 77-10, 56 p.
- _____. Lewis, A.F., M.D. McGurk, and M.G. Galesloot. 2002. Alcan's Kemano River eulachon (*Thaleichthys pacificus*) monitoring program 1988- 1998. Consultant report prepared by Ecofish Research Ltd. for Alcan Primary Metal Ltd., Kitimat, BC. 136 pp.
- McHugh, J.L., 1939. The eulachon. Fish. Res. Board Can. Pac. Progr. Rep. 40:17-22. National Marine Fisheries Service (NMFS). 2011. *Critical Habitat for the Southern Distinct Population Segment of Eulachon. Final Biological Report*. NMFS Northwest Region, Protected Resources Division. Portland, OR. September 2011.
- National Marine Fisheries Service (NMFS). 2016. *5-year review: Summary & Evaluation of Eulachon*. National Marine Fisheries Service, West Coast Region, Portland, Oregon. May 26, 2016.
- National Marine Fisheries Service (NMFS). 2017. *Recovery Plan for the Southern Distinct Population Segment of Eulachon* (*Thaleichthys pacificus*). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, OR, 97232. September.
- Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife (ODFW and WDFW). 2023. *Washington and Oregon Eulachon Management Plan 2nd Edition*. September. 46 pp.
- Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife (ODFW and WDFW). 2014. *Studies of Eulachon Smelt in Oregon and Washington*. Project Completion Report prepared for the National Oceanic and Atmospheric Association. 168 pp.
- Ricker, W.E., D.F. Manzer, and E.A. Neave. 1954. The Fraser River Eulachon fishery, 1941-1953. Fisheries Research Board of Canada, manuscript report no. 583. 35p. Smith, W. E. and R.W. Saalfeld. 1955. Studies on Columbia River Smelt *Thaleichthys pacificus* (Richardson). *Washington Department of Fisheries, Fisheries Research Paper* 1(3):3-26.
- Spangler, Elizabeth A.K., 2002. The ecology of eulachon (*Thaleichthys pacificus*) in twenty mile river, AK.
- Sturdevant, M. V. 1999. Forage Fish Diet Overlap, 1994-1996. APEX Project: Alaska Predator Ecosystem Experiment in Prince William Sound and the Gulf of Alaska. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 98163C), Auke Bay Laboratory, National Marine Fisheries Service, Juneau, Alaska. Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW). 2001. *Washington and Oregon Eulachon Management Plan*.
- Washington Department of Fish and Wildlife (WDFW). 2020. *Status of Eulachon in Washington: Annual Report July 2018 – June 2019*. Report FPA 20-03. February 27. 95pp.
- Willson, M. F., R. H. Armstrong, M. C. Hermans, and K Koski. 2006. *Eulachon: A Review of Biology and an Annotated Bibliography*. Alaska Fisheries Science Center Processed Report 2006-12. Auke Bay Laboratory, Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Juneau, AK.

C11 Columbia Torrent Salamander (*Rhyacotriton kezeri*)

Legal Status

State: Sensitive Species

Federal: Under Review, 2015 (FWS-R1-ES-2015-0083)

Critical Habitat: None

Recovery Planning: None



Photo: Chris Roberts

Coverage is no longer being requested for Columbia torrent salamander. The species was included in the public draft HCP but has since been removed from the requested permit coverage. This species account is retained because the conservation strategy is expected to benefit Columbia torrent salamander through measures that protect and improve stream and riparian habitat conditions.

Taxonomy

Torrent salamanders are in the family Rhyacotritonidae, a small family endemic to the Pacific Northwest that is closely related to the Amphiumidae and Plethodontidae (Frost et al. 2006). The families' four species include the Olympic salamander (*Rhyacotriton olympicus*) (Gaike 1917), Cascade torrent salamander (*R. cascadae*) (Good and Wake 1992), Columbia torrent salamander (*R. kezeri*) (Good and Wake 1992), and southern torrent salamander (*R. variegatus*) (Stebbins and Lowe 1951). Less is known about the biology of Columbia torrent salamanders than of other species of *Rhyacotriton*. However, species of *Rhyacotriton* are likely to be similar in many ways.

Distribution

General

The Columbia torrent salamander is a small, semi-aquatic salamander restricted to coastal and near-coastal regions of northwestern Oregon and southwestern Washington. The species occurs from the Coast Range from just south of the Chehalis River, Grays Harbor County, Washington, south to the Little Nestuca River and the Grande Ronde Valley in Polk, Tillamook, and Yamhill Counties, Oregon (Good and Wake 1992). Across their range, Columbia torrent salamanders occur from near sea level to the highest elevations in the region, up to 3,280 feet. They occur in some upper reaches of the coastal part of the Willamette hydrographic basin (e.g., Upper Grand Ronde system, Oregon [Good et al. 1987]). However, their distribution across the region and their inland distribution in Washington are poorly known (McAllister 1995).

Like other species of *Rhyacotriton*, Columbia torrent salamanders occupy cold, fast-moving streams in forested areas. The larvae generally live in the rocky substrate, while adults occupy the splash zone at the edges of streams. These salamanders may also be found in seeps (Good and Wake 1992;

Petranka 1998). In addition, Hayes et al. (2003) found that Columbia torrent salamander density was significantly greater in splash zones of waterfalls than other reach types.

Occurrences in the Plan Area

Columbia torrent salamander occurrences were derived from recently conducted research led by the USGS and USFS. In 2019, these agencies assessed the distribution and occupancy of torrent salamanders across their range on public lands using visual and eDNA data collection methods (Thurman 2019). Randomly selected stream sites that represented model predicted suitable habitat were distributed throughout the Clatsop and Tillamook State Forests. These surveys documented 184 Columbia torrent salamanders in 15 of 20 (75%) study sites distributed across multiple basins throughout the Tillamook and Clatsop State Forests (Figure C11-1). Additional occurrences have been recorded in Tillamook, Washington, and Yamhill Counties (Figure C11-1).

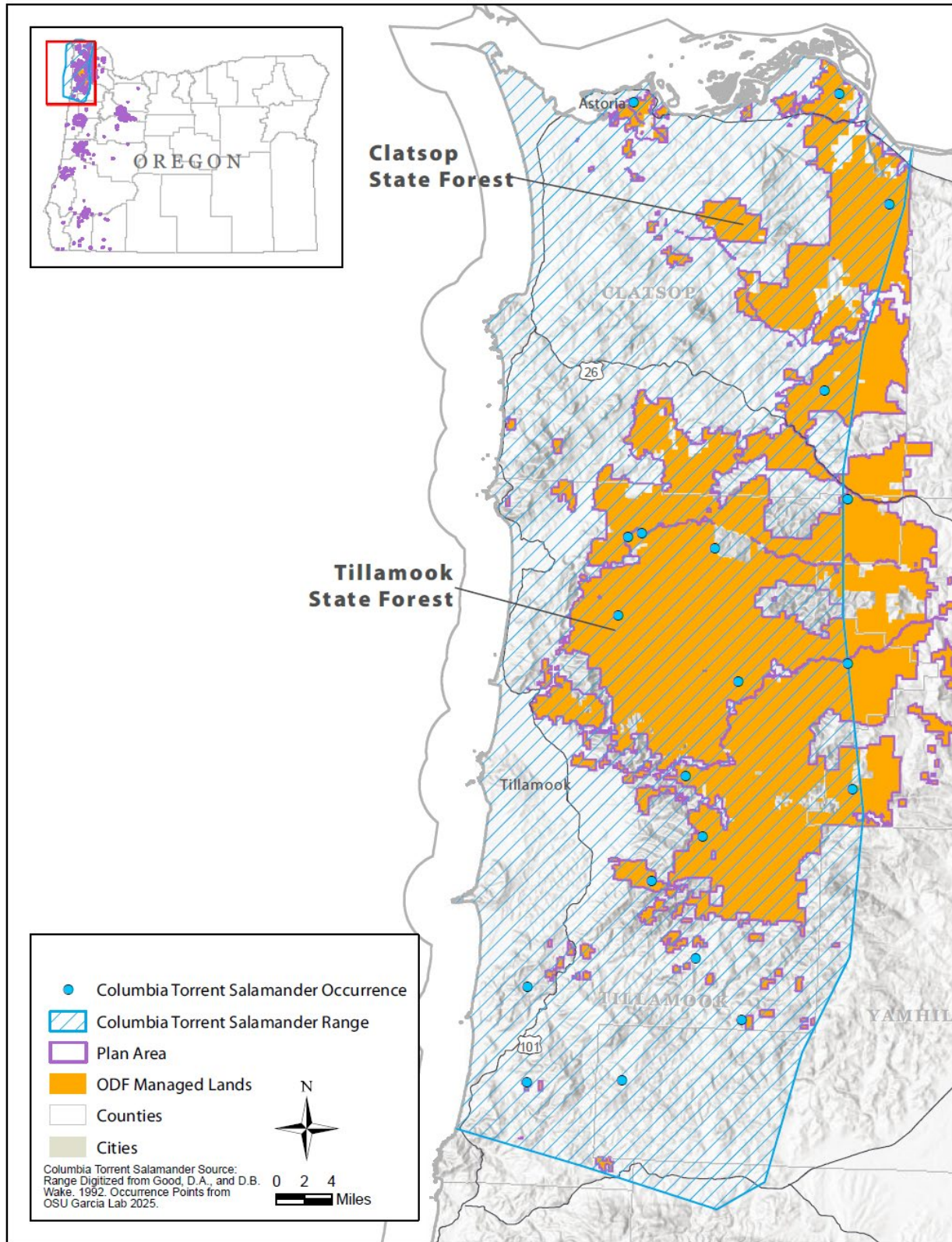


Figure C11-1. Columbia Torrent Salamander Range and Occurrence

Natural History

Habitat Requirements

Descriptions of Columbia torrent salamander habitat requirements are generally limited to landscape and reach scale elements and a few studies on nest-site habitat characteristics.

Stebbins and Lowe (1951) generalize the microhabitat conditions of torrent salamanders as “one of a cold, permanent stream with small water-washed or moss-covered rock, usually rock rubble, in and along running water, seeps and small, trickling tributary streams with rocks of small dimensions.” Torrent salamander are primarily found in older forest sites; however, Russell et al. (2004) found that at the landscape level, site occupancy and relative abundance of the Columbia torrent salamander was not related to age or composition of riparian vegetation, but rather to abiotic landform features (parent geology, elevation, aspect) and that variation in physical features of stream habitats (reach gradient, proximity to stream channel origin) influenced the distribution and abundance of Columbia torrent salamander at multiple spatial scales. Russell et al. (2004) observed higher relative abundance of salamanders in basalt streams compared to marine sediment streams, greater proportion of streams with northerly aspects contained salamanders compared to southerly aspect streams (although the abundance was similar), and streams with salamanders had a higher mean elevation. Of note, forest age was similar between salamander site occupancy and abundance and forest overstory composition was not related to occupancy and abundance. This finding suggests that although disturbance of vegetation (e.g., timber harvest) influences amphibian populations, abiotic habitat features, such as geology, topography, and climate, and the interaction of abiotic and biotic features, should not be discounted.

Wilkins and Peterson (2000) found the likelihood of habitat occupancy by torrent salamander increased as channel gradient increased and basin area decreased. Adjusting for basin area, torrent salamander abundance increased as the proportion of the active channel with flowing water decreased.

In western Oregon, Vesely (1996) found similar abundances of terrestrially occurring torrent salamanders between unmanaged forest and riparian buffer strips along first- to third-order streams; however, Vesely also found amphibian species diversity was lower in buffers than in unmanaged forest, and diversity was correlated with buffer strip width (Vesely 1996). Olson and Burton (2014) examined timber harvest and riparian buffer management approaches on headwater stream habitats and observed densities of *Rhyacotriton* species increased post-harvest in moderate-density thinning with no-entry buffers in wider streams with more pools and narrower streams with more down wood. However, they also found decreased densities along streams with narrow buffers (6 meters).

Reproduction

Due to few nests observed and described for Columbia torrent salamander, the reproductive ecology of the species is not well known. Based on data for other species of *Rhyacotriton*, courtship and mating probably occur over most of the year, concentrated in the fall and spring months. Females may oviposit at any time of the year, but egg laying in *Rhyacotriton* spp. is believed to primarily peak in late spring or early summer (Nussbaum and Tait 1977; Welsh and Lind 1992). The timing of egg deposition in Columbia torrent salamander is estimated as mid-August and late October to early November for the Washington and Oregon clutches described by Nussbaum (1969).

Information on parental care and communal nesting for Columbia torrent salamanders is unclear; both have been observed, but observations have not been consistent (Nussbaum 1969; Russell et al. 2002; Washington Department of Fish and Wildlife 2019). Egg deposition is assumed to occur in seeps and at the heads of springs (Nussbaum 1969). In 2002, Russell et al. described three nest sites of Columbia torrent salamander in Oregon; physical characteristics of the nests were similar to the nests described by Nussbaum (1969)—nest sites were within seeps of cold (8.3 to 9.1 °C) clear water flowing under and between rocky substrates, but were below the stream origin, and near the center of the stream channel. Russell et al.'s (2002) finding of singly laid, unattached eggs, and clutch size are also consistent with previous findings made by Nussbaum (1969). The lithology of nests described by Russell et al. (2002) consisted of unspecified marine sedimentary formation. Clutch frequency is once per year (Nussbaum and Tait 1977; Nussbaum et al. 1983). Based on data for other species of torrent salamanders (Nussbaum and Tait 1977), fecundity in Columbia torrent salamanders is likely low with clutch size range from 2 to 16 eggs (AmphibiaWeb 2019).

The incubation period of eggs is long and eggs laid in spring hatch 5 to 6 months later (Nussbaum 1969). Likewise, the larval period of Columbia torrent salamander is long and can take more than 2 years (Washington Department of Fish and Wildlife 2019). Columbia torrent salamanders likely have a long interval to reproductive maturity (4 years) with a moderately long lifespan (>10 years) (AmphibiaWeb 2019).

Movement

Data from other species of *Rhyacotriton* suggest that Columbia torrent salamanders are highly sedentary (Nussbaum and Tait 1977; Welsh and Lind 1992; Nijhius and Kaplan 1998) and have limited dispersal capabilities, with movements typically limited to distances of 10 to 15 feet. Limited dispersal may be related to adults being sensitive to desiccation and larvae being vulnerable to changes in streamflow (Ray 1958). Surface movement is likely reduced during late summer and early autumn when surface conditions are driest (AmphibiaWeb 2019). Although the species is closely associated with its water source, in times of heavy rainfall, torrent salamanders may move away from and be found away from streams in the nearby forest floor.

Torrent salamanders have limited dispersal abilities and small home ranges (Nussbaum et al. 1983). Available data on closely related Cascade torrent salamanders indicate high densities and restricted movements (Nussbaum and Tait 1977; Nijhius and Kaplan 1998), in which case, territorial behavior is unlikely.

Foraging Habitat

Based on data for other *Rhyacotriton*, Columbia torrent salamanders are opportunistic feeders and probably feed on invertebrates dwelling in moist forested habitats, especially amphipods, fly larvae, springtails, and stonefly nymphs (Bury and Martin, 1967; Bury, 1970). Larvae feed on aquatic invertebrates and adults feed on aquatic and semi-aquatic invertebrates. These taxa occur in semi-aquatic and aquatic microhabitats.

Ecological Relationships

Over their range, Columbia torrent salamanders are sympatric with 12 different amphibian species: northwestern salamanders (*Ambystoma gracile*), long-toed salamanders (*A. macrodactylum*), Cope's giant salamanders (*Dicamptodon copei*), coastal giant salamanders (*D. tenebrosus*), rough-skinned

newts (*Taricha granulosa*), ensatinas (*Ensatina eschscholtzii*), Van Dyke's salamanders (*Plethodon vandykei*), western red-backed salamanders (*P. vehiculum*), Dunn's salamanders (*P. dunni*), coastal (Pacific) tailed frogs (*Ascaphus truei*), Pacific treefrogs (*Pseudacris regilla*), and northern red-legged frogs. However, degree of syntropy with each of these taxa has not yet been detailed (Amphibiaweb 2019)

Predators of Columbia torrent salamanders are unknown. However, the occurrence of giant salamander larva correlates with a lower abundance of torrent larva, which may be attributed to a predator avoidance response (Amphibiaweb 2019).

Population Status and Trends

No historical data on abundance are available, but some recent studies provide relative abundance data. In the Willapa Hills, Columbia torrent salamanders made up 21% of the individuals across eight amphibian species and ranked second only to giant salamanders (*Dicamptodon* sp.) in relative abundance (Wilkins and Peterson 2000). In two other unpublished studies conducted in the Willapa Hills, Columbia torrent salamanders ranked first in abundance among the 9 and 13 (unpublished data) amphibian species recorded; in both cases they represented > 60% of individuals of all species (AmphibiaWeb 2019). In the Russell et al. (2004) study, Columbia torrent salamander densities ranged from 0 to 68.3 individuals per square meter; the upper end is the highest recorded for any torrent salamander species.

Relative abundance of Columbia torrent salamanders is not always among the highest in amphibian assemblages. In a Kilchis River study, Columbia torrent salamanders ranked fourth in relative abundance among the 10 amphibian species recorded (AmphibiaWeb 2019). At least part of the reason for this disparity in relative abundance patterns across studies may depend on how sampling locations were selected within hydrographic basins, as Russell et al. (2004) indicated that Columbia torrent salamander density increases with proximity to the headwater channel origin.

Threats

The main threats to Columbia torrent salamanders include factors that degrade habitat quality, particularly those that result in increased water temperatures and sedimentation (Lannoo 2005). Also, any event that influences the inner-channel gorge of an occupied stream with the potential for destabilizing the geomorphology and hydrology of a stream (e.g., debris flow, altered peak flow from rain-on-snow event, or loss of upland canopy cover) may be problematic for Columbia torrent salamanders (Crisafulli et al. 2005). The primary anthropogenic threats to headwater stream and seep habitats include timber harvest and road construction/maintenance activities. In addition, stream-crossing culverts may fragment populations (Howell and Maggiulli 2011).

Timber Harvest

Torrent salamanders are among one of the stream amphibians reported to be at risk from timber harvest (Bury and Corn 1988; Bury and Corn 1989; Good and Wake 1992; Welsh and Lind 1996).

Timber harvests have been shown to have impacts on Columbia torrent salamander. These impacts include reduced abundances of salamanders in young age classes of managed timber stands (i.e., clear-cut stands). In a study of the effects of timber harvest on terrestrial salamanders in southwest

Washington, Columbia torrent salamanders were only captured in older forests (forested areas between 45 to 60 years old) and not in adjacent forests that were clear cut 2 to 5 years previously (Grialou et al. 2000). Similar results have been found for other *Rhyacotriton* spp. on managed lands in Oregon and Washington with species occupancy being lowest in youngest and oldest sampled forest stands (Kroll et al. 2008).

In general, timber harvest removes riparian canopy cover resulting in increased stream temperatures, deposits sediments that degrade microhabitats, and possibly alters peak flow events (Bury and Corn 1988; Bury and Corn 1989; Welsh and Lind 1996). Based on where Columbia torrent salamanders have been documented (steep gradient systems with high flushing capacity), it is presumed that sediment input from ground-disturbing activities would have a negative effect on individuals. Likewise, in areas where timber harvesting causes increases in water temperature, decreases in oxygen, or increases in siltation, *Rhyacotriton* spp. have been rare or absent (Leonard et al. 1993). Likewise, stream sedimentation may result in degradation of overwintering habitat and asphyxiation of embryos and larvae (McAllister 1992). Some studies suggest riparian buffers offer protection to the salamanders (USFWS 2011).

Roads and Culverts

Culverts and roads may be sources of erosion that result in stream sedimentation. Roads may pose barriers to amphibian movement, and in the context of roads crossing streams, their culverts may pose barriers to species movement. An inability to disperse puts populations at risk because it limits gene flow and the ability to recolonize after disturbance (Jackson 2003). Specifically, perched culverts are problematic due to loss of substrate continuity and increased velocity of water above a surface that does not present any natural characteristics, such as instream structures, substrate, or quiet pools, which would facilitate animal movement. Given its close association to the stream channel and adjacent, saturated ground, Columbia torrent salamanders likely may not move upland to navigate around such barriers. These types of culverts have long been recognized as problems for fish and have only recently become a topic of concern for amphibians.

It is not known to what degree culverts and roads fragment habitat for Columbia torrent salamanders, as there have not been any studies on distribution specifically related to road locations. Nonetheless, Hayes et al. (2002) found that coastal tailed frogs (*Ascaphus truei*) engaged in upstream seasonal movements seeking invertebrate-rich intermittent headwater areas, and Olson et al. (2007) speculated that similar environmental situations may exist for post-metamorphic torrent salamanders to do the same.

Chemical Application

Because amphibians breathe through their skin, a variety of chemicals (e.g., pesticides, herbicides, fire retardant, salt, fertilizers) have the potential to negatively affect these animals. Broad-scale herbicide treatments applied to suppress the shrub layer on forest lands after harvest could have a negative impact on Columbia torrent salamanders. In addition, episodic release of chemicals trapped in snowmelt may have some direct and indirect effects on Columbia torrent salamander (Olson pers. comm., as cited in Howell and Maggiulli 2011). Salt and sand, as components of road and ski area management, have the potential to enter the stream channel and affect the species. Though wildfires are relatively rare events west of the Cascades (but could increase as climate patterns change), and the use of prescribed fire (particularly in riparian areas) is minimal, the effects from fire retardants are nevertheless not fully known. Compared to pesticides, herbicides, may pose less risk to

amphibians because the chemical does not target species with a nervous system; however, no data on the specific effects of herbicides on torrent salamanders are available (Howell and Maggiulli 2011).

Climate Change

The effects of climate change on Columbia torrent salamanders are unknown. However, climate change models generally predict warmer temperatures (especially in the summer), increased rainfall, reduced snowpack, more variable temperature and precipitation, changes in snowline and melting, and increased risk of winter flooding in smaller streams west of the Cascades (Mote et al. 2003). Torrent salamanders are tied to aquatic environments due to their intolerance to desiccation (Ray 1958). Because of this physiological limitation coupled with limited dispersal abilities and small home ranges (Nussbaum et al. 1983), changes in water regimes make the Columbia torrent salamander vulnerable to the effects of climate change.

Literature Cited

- AmphibiaWeb. 2019. University of California, Berkeley, Amphibiaweb website. Available: <http://amphibiaweb.org>. Accessed: May 8, 2019.
- Bury, R.B. and M. Martin. 1967. The food of the salamander *Rhyacotriton variegatus*. *Copeia* 1967:487.
- Bury, R.B. 1970. Food similarities in the tailed frog, *Ascaphus truei*, and the Olympic salamander, *Rhyacotriton olympicus*. *Copeia* 1970:170–171.
- Bury, R.B. 1970. Food similarities in the tailed frog, *Ascaphus truei*, and the Olympic salamander, *Rhyacotriton olympicus*. *Copeia* 1970:170–171.
- Bury, R. B. 1983. Differences in Amphibian Populations in Logged and Old Growth Redwood Forest. *Northwest Science* 57: 167–178.
- Bury, R. B., and P. S. Corn. 1988. Responses of Aquatic and Streamside Amphibians To Timber Harvest: A Review. Pages 165-181 in Raedaeke, K., editor. *Streamside Management: Riparian Wildlife and Forestry Interactions*. Univ. Washington.
- Bury, R. B., and P. S. Corn. 1988. Douglas-Fir Forests in the Oregon and Washington Cascades: Relation of the Herpetofauna to Stand Age and Moisture. Pages 11–22. In: R. C. Szaro, K. E. Severon, and D. R. Patton. Eds. *Management of Amphibians, Reptiles, and Mammals in North America: Proceedings of a Symposium*. General Technical Report RM-166. Corvallis, OR, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Crisafulli, C. M., L. S. Trippe, C. P. Hawkins, and J. A. MacMahon. 2005. Amphibian Responses to the 1980 Eruption of Mount St. Helens, Chapter 13 in *Ecological Responses to the 1980 Eruption of Mt. St. Helens*, V. H. Dale, F. J. Swanson, and C. M. Crisafulli, Eds., Springer Science+Business Media, Inc., New York, NY.
- Frost, D. R., T. Grant, J. Faivovich, R. H. Bain, A. Haas, C. F. B. Haddad, R. O. De Sa, A. Channing, M. Wilkinson, S. C. Donnellan, C. J. Raxworthy, J. A. Campbell, B. L. Blotto, P. Moler, R. C. Drewes, R. A. Nussbaum, J. D. Lynch, D. M. Green, and W. C. Wheeler. 2006. The Amphibian Tree of Life. *Bull. Amer. Mus. Nat. Hist.* 297, 370 pp.
- GBIF.org. 2019. *GBIF Occurrence*. Available: <https://doi.org/10.15468/dl.1xixsr>.

- Gaige, H. T. 1917. *Description of a New Salamander from Washington*. Occasional Papers of the Museum of Zoology, Number 40, University of Michigan, Ann Arbor, Michigan.
- Good, D. A., G. Z. Wurst, and D. B. Wake. 1987. Patterns of geographic variation in allozymes of the Olympic salamander, *Rhyacotriton olympicus* (Caudata: Dicamptodontidae). *Fieldiana Zoology* No. 32 (1374). 15 pp.
- Good, D. A., and D. B. Wake. 1992. Geographic Variation and Speciation in the Torrent Salamanders of the Genus *Rhyacotriton* (Caudata: Rhyacotritonidae). *Univ. California Publication Zoology* 126:i-xii, 1-91.
- Grialou, J. A., S. D. West, and R. N. Wilkins. 2000. The Effects of Forest Clearcut Harvesting and Thinning on Terrestrial Salamanders. *Journal of Wildlife Management* 64(1): 105–113.
- Hayes, M. P., T. Quinn, L. V. Diller, L. L. C. Jones, J. G. McCracken, M. J. Raphael, and D. E. Runde. 2002. *Evaluation of Sampling Methods for Amphibians in Headwater Basins of Non-Fishbearing Streams: A Preliminary Analysis*. A final report submitted to the Cooperative Monitoring, Evaluation, and Research Co.
- Hayes, M. P., D. J. Dugger, T. L. Hicks, and T. Quinn. 2003. Headwater Habitat Variation: Its Relationship to Stream Amphibian Distribution. *Northwestern Naturalist* 84(2): 100.
- Howell, B. L., and N. M. Maggiali. 2011. *Conservation Assessment for the Cascade Torrent Salamander (Rhyacotriton cascadae)*. V.1. February 2011. U.S.D.A Forest Service Region 6 and U.S.D.I. Bureau of Land Management Interagency Special Status and Sensitive Species Program. Available: <https://www.fs.fed.us/r6/sfpnw/issssp/species-index/fauna-amphibians.shtml>. Accessed: May 2, 2019.
- Jackson, S. D. 2003. Ecological Considerations in the Design of River and Stream Crossings. Pages 20–29. In: C. L. Irwin, P. Garrett, and K. P. McDermott. Eds. *Proceedings of the International Conference on Ecology and Transportation*. North Carolina State University, Center for Transportation and the Environment, Raleigh, NC.
- Kroll, A. J., K. Risenhoover, T. McBride, E. Beach, B. J. Kernohan, J. Light, and J. Bach. 2008. Factors Influencing Stream Occupancy and Detection Probability Parameters of Stream-Associated Amphibians in Commercial Forests of Oregon and Washington, USA. *Forest Ecology and Management* 255: 3726–3735.
- Lannoo, M., ed. 2005. *Amphibian Declines: The Conservation Status of United States Species*. University of California Press, Berkeley, California.
- Leonard, W. P., H. A. Brown, L. L. C. Jones, K. McAllister, and R. M. Storm. 1993. *Amphibians of Washington and Oregon*. Seattle Audubon Society, Seattle, WA, 168 p.
- McAllister, 1992. *Amphibian Management Standards*. Department of Wildlife, State of Washington.
- McAllister, K. R. 1995. Distribution of Amphibians and Reptiles in Washington State. *Northwest Fauna* 3:81–112.
- Mote, P. W., E. A. Parson, A. F. Hamlet, W. S. Keeton, D. Lettenmaier, N. Mantua, E. L. Miles, D. W. Peterson, D. L. Peterson, R. Slaughter, and A. K. Snover. 2003. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. *Climatic Change* 61:45–88.

- Nijhuis, M. J., and R. H. Kaplan. 1998. Movement Patterns and Life History Characteristics in a Population of the Cascade Torrent Salamander (*Rhyacotriton cascadae*) in the Columbia River Gorge, Oregon. *Journal of Herpetology* 32(2):301–304.
- Nussbaum, R.A. and C. Maser. 1969. Observations of *Sorex palustris* preying on *Dicamptodon ensatus*. *Murrelet* 50:23–24.
- Nussbaum, R. A., and C. K. Tait. 1977. Aspects of the Life History and Ecology of the Olympic Slalmander, *Rhyacotriton olympicus* (Gauge). *American Midland Naturalist* 98:176–199.
- Nussbaum, R. A., E. D. Brodie, Jr., and R. M. Storm. 1983. *Amphibians and Reptiles of the Pacific Northwest*. University Press of Idaho, Moscow, Idaho. 332 pp.
- Olson, D.H., P.D. Anderson, C.A. Frissell, H.H. Welsh, and D. F. Bradford. 2007. Biodiversity management approaches for stream–riparian areas: Perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Mgt* 246(1):81-107.
- Olson, D. H., and J. I. Burton. 2014. *Near-Term Effects of Repeated-Thinning with Riparian Buffers on Headwater Stream Vertebrates and Habitats in Oregon, USA*.
- Oregon Department of Forestry. 2019. GIS data citation needed.
- Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, D.C. Ray, C. 1958. Vital Limits and Rates of Desiccation in Salamanders. *Ecology* 39:75–83
- Russell, K. R., T. J. Mabey, and M. B. Cole. 2004. *Distribution and Habitat of Columbia Torrent Salamanders at Multiple Scales in Managed Forests of Western Oregon*.
- Russell K. R., A. A. Gonyaw, J. D. Strom, K. E. Diemer, and K. C. Murk. 2002. Three New Nests of the Columbia Torrent Salamander, *Rhyacotriton kezeri*, in Oregon with Observations of Nesting Behavior. *Northwestern Naturalist* 83(1): 19–22.
- Stebbins, R. C., and C. H. Lowe, Jr. 1951. Subspecific Differentiation in the Olympic salamander *Rhyacotriton olympicus*. *University of California Publications in Zoology* 50: 465–484.
- Vesely, D. G. 1996. *Terrestrial Amphibian Abundance and Species Richness in Headwater Riparian Buffer Strips, Oregon Coast Range*. MSc thesis, Oregon State University, Corvallis, OR. 48p.
- Washington Department of Fish and Wildlife. 2019. *Species in Washington. Columbia Torrent Salamander*. Available: <https://wdfw.wa.gov/species-habitats/species/rhyacotriton-kezeri>. Accessed: May 8, 2019.
- Welsh, H. H. Jr. 1990. Relictual Amphibians and Old-Growth Forests. *Conservation Biology* 4: 309–19.
- Welsh, H. H., Jr. and A. J. Lind. 1991. *The Structure of the Herpetofaunal Assemblage in the Douglas-Fir/Hardwood Forests of Northwestern California and Southwestern Oregon*. Wildlife and Vegetation of Unmanaged Douglas-fir Forests, USDA Forest Service, General Technical Report PNW-GTR-285. USDA Forest Service, 394-413.
- Welsh, H.H., Jr. and A.J. Lind. 1992. Population ecology of two relictual salamanders from the Klamath Mountains of northwestern California. Pp. 419–437. In McCullough, D.R. and R.H. Barrett (Eds.), *Wildlife 2001: Populations*. Elsevier Applied Science, London.

- Welsh Jr., H. H. and A. J. Lind. 1996. Habitat Correlates of the Southern Torrent Salamander, *Rhyacotriton variegatus* (Caudata: Rhyacotritonidae), in Northwestern California. *Journal of Herpetology* 30(3):385–398.
- Wilkins, R. N., and N. P. Peterson. 2000. Factors Related to Amphibian Occurrence and Abundance in Headwater Streams Draining Second-Growth Douglas-Fir Forests in Southwestern Washington. *Forest Ecology and Management* 139: 79–91.

C12 Cascade Torrent Salamander (*Rhyacotriton cascadae*)

Legal Status

State: Sensitive Species

Federal: Under Review, 2015 (*FWS-R1-ES-2015-0080*)

Critical Habitat: None

Recovery Planning: None



Photo: Chris Roberts

Coverage is no longer being requested for Cascade torrent salamander. The species was included in the public draft HCP but has since been removed from the requested permit coverage. This species account is retained because the conservation strategy is expected to benefit Cascade torrent salamander through measures that protect and improve stream and riparian habitat conditions.

Taxonomy

Torrent salamanders are in the family Rhyacotritonidae, a small family endemic to the Pacific Northwest that is closely related to the Amphiumidae and Plethodontidae (Frost et al. 2006). The families' four species include the Olympic salamander (*Rhyacotriton olympicus*) (Gage 1917), Cascade torrent salamander (*R. cascadae*) (Good and Wake 1992), Columbia torrent salamander (*R. kezeri*) (Good and Wake 1992), and southern torrent salamander (*R. variegatus*) (Stebbins and Lowe 1951).

Cascade torrent salamanders occupy cold, fast-flowing headwater streams, seeps, and waterfall splash zones in forested areas. They typically occur in reaches and off-channel habitat with gravel or cobble substrate and persistent, shallow water.

Distribution

General

The range of the Cascade torrent salamander includes Washington counties of Thurston, Lewis, Cowlitz, Skamania, and Clark, and the Oregon counties of Multnomah, Hood River, Clackamas, Marion, Linn, and Lane (Howell and Maggilli 2011). Cascade torrent salamanders are restricted to the west slope of the Cascade mountains from the west bank of the Skookumchuck River in central Washington 0.4 mile north of the Thurston–Lewis County line; (Wilson and Larsen 1992; McAllister 1995) south to the Middle Fork of the Willamette River in central western Oregon Lane County; (Good et al. 1987; Good and Wake 1992). Within this area, the species is patchily distributed.

Cascade torrent salamanders are known to range in elevation to over 4,000 feet, but the real extent of their geographic range is ambiguous largely because upper- and lower-elevation limits, and how these change with latitude, are poorly understood. A watershed-wide study of the Blue River hydrographic basin near the southern end of their geographic range (Willamette River hydrographic basin, Oregon) revealed Cascade torrent salamanders at 52 of 273 (19%) sites, with the probability of occurrence peaking at an elevation of around 2,854 feet (Hunter 1998).

Known locations of Cascade torrent salamanders include state lands (39%), National Forests (37%), private lands (industrial and nonindustrial, 14%), and Bureau of Land Management lands (10%). These numbers may or may not reflect indicators of habitat availability or quality, but rather, the effort and emphasis on previous and current survey efforts (Howell and Maggiulli 2011).

Occurrences in the Plan Area

Cascade torrent salamander occurrences were derived from recently conducted research led by the USGS and USFS. In 2019, they assessed the distribution and occupancy of torrent salamanders across their range on public lands using visual and eDNA data collection methods (Thurman 2019). Randomly selected stream sites that represented model predicted suitable habitat were distributed throughout the north cascades and included the Santiam State Forest. Cascade torrent salamanders were not detected at the single study site surveyed on Santiam State Forest. However, the frequency of occurrence of Cascade torrents salamanders was 33% for all study sites distributed across multiple basins on public lands throughout the north Cascades and adjacent to Santiam State Forest. Additional occurrences in the vicinity of the plan area have been recorded in Marion, Clackamas, and Lane Counties (Figure C12-1).

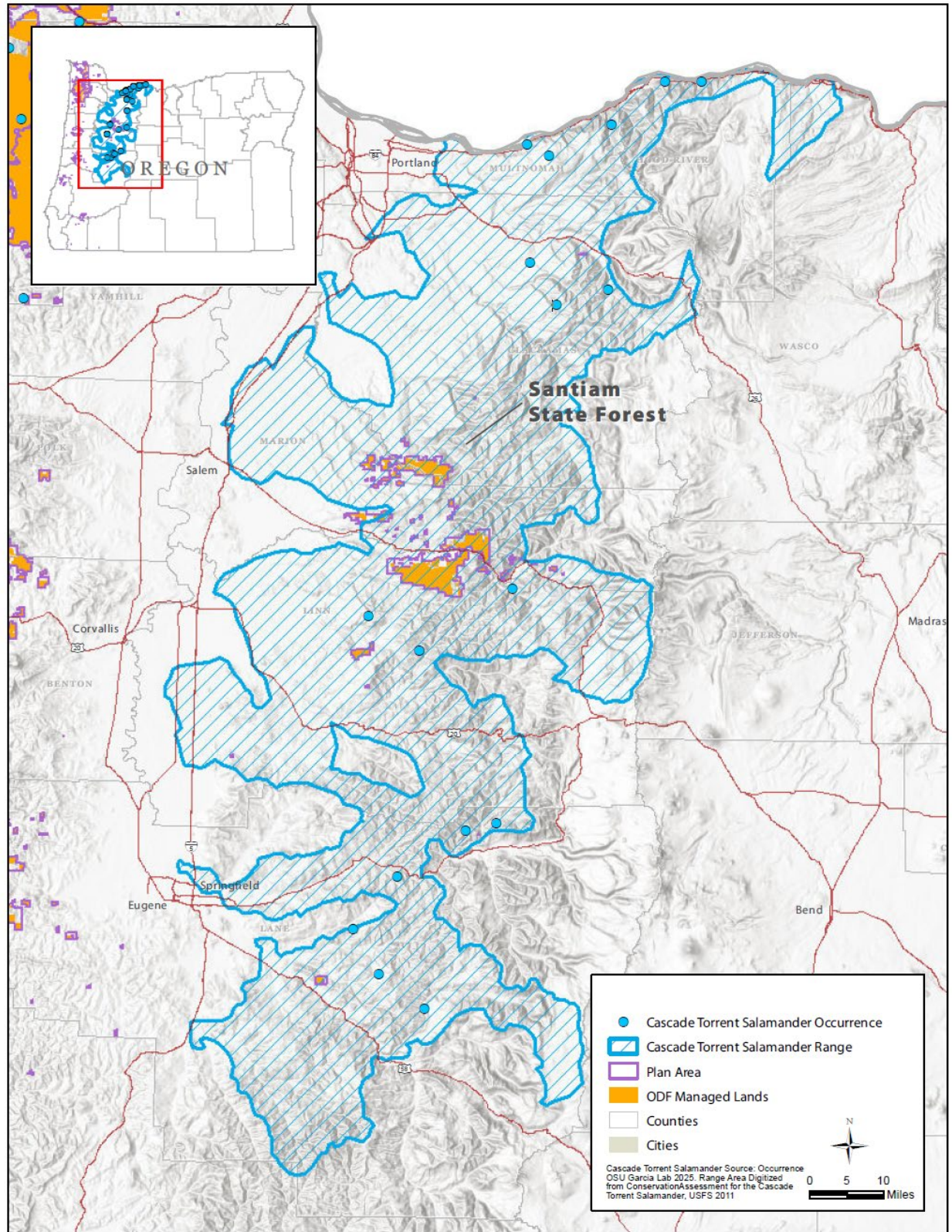


Figure C12-1. Cascade Torrent Salamander Range and Occurrence

Natural History

Habitat Requirements

Cascade torrent salamanders are associated with high-gradient,¹ permanent, cool or cold-water sources, such as seeps, waterfalls, headwaters, and edges of larger streams. They typically occur in reaches and off-channel habitat with gravel or cobble substrate and persistent, shallow water. Individuals may be located beneath rocks in the splash zone or on stream banks under rock, moss, or wood, but may favor rock cover (Jones et al. 2005; Lannoo 2005). This species requires continuous access to cold, silt-free water and moist adjacent forests. During heavy rains, Cascade torrent salamanders may be found far from the stream (potentially several hundred meters) under leaf litter, branches, and small logs (Rombough and Corkran pers. comm; Palazzotto pers. comm. 2019).

In the Blue River Watershed of the west-central Cascade Range of Oregon, which is managed primarily by the Willamette National Forest, Cascade torrent salamander larvae were encountered in 19% of 15-foot stream reaches surveyed ($n=273$ sites) (Hunter 1998). At the watershed scale, the species was associated with small, high-gradient streams, with a maximum basin size of 350 acres, and was most abundant at about 2,850 feet elevation. Hunter (1998) also found Cascade torrent salamanders were associated with an average stream depth of 4 to 5 centimeters; streams had limited amounts of riffle in channel units; the channel substrate consisted of cobbles and boulders; and streams had high canopy cover and mid-story cover was present along the stream.

In managed forests of western Oregon, Russell et al. (2005) found the occurrence and abundance of Cascade torrent salamanders at the stream-reach scale was associated with headwaters. Abiotic factors, such as cobble and gravel substrates with low percentages of fine sediment and sand, were associated with Cascade torrent salamander presence. Cascade torrent salamander occupancy and relative abundance at the landscape scale was also greater in streams with northerly aspects, as compared to southerly aspects, and increased with adjacent riparian forest age. In southern Washington, Pollett et al. (2010) found an abundance of the species to be lower in unbuffered streams than in streams with buffers or in second-growth forests. In privately managed forests of southwestern Washington, Steele et al. (2003) found a relative higher abundance of Cascade torrent salamanders in streams adjacent to older forest stands. In both studies (Russell et al. 2005; Steele et al. 2003), salamanders were found in forests between 0 and 90 years old, with the highest abundance occurring in those areas containing streams surrounded by forests between 43 and 59 years old. The lost abundance, in occupied stands, occurred in younger forest between 0 and 22 years old (Steele et al. 2003).

Habitat requirements for larval and juvenile stages of Cascade torrent salamanders have not been distinguished from adults in studies to date. Larval *Rhyacotriton* spp. may be associated with stable, low-flow volume areas with loose gravel and cobble with limited fine sediments (Nussbaum and Tait 1977; Diller and Wallace 1996; Welsh and Lind 1996).

Because torrent salamanders are adapted for life in cold water, stream water temperature is a critical factor for habitat requirement. Among amphibians, the thermal tolerances of *Rhyacotriton* spp. are among the lowest (Bury 2008). Pollett et al. (2010) found Cascade torrent salamanders

¹ Bed slope greater than 2%.

were almost absent from streams where water temperatures were $\geq 14^{\circ}\text{C}$ for greater than 35 consecutive hours. Due to the species' intolerance of warm water temperature, susceptibility to desiccation (Ray 1958), and possessing reduced lung capacity (resulting in the need for high oxygen absorption through moist skin) (Whitford and Hutchison 1966), inferences about the habitat characteristics of streams utilized by Cascade torrent salamanders have been made. Stebbins and Lowe (1951) infer streams utilized by the species have presence of leaf canopy and abundant understory vegetation.

Reproduction

Cascade torrent salamanders are likely a relatively long-lived amphibian, although longevity has not been determined. Larvae take approximately 4 to 5 years to reach metamorphosis (Nussbaum and Tait 1977) and presumably another year or so to reach sexual maturity, with animals living several years as adults.

Torrent salamanders likely have a prolonged courting season, as sperm caps of spermatophores have been found in the vents of *Rhyacotriton* spp. females every month of the year except August, September, December, and January (Nussbaum and Tait 1977). Courtship occurs between October and July, and most egg laying occurs during spring and early summer (Nussbaum and Tait 1977). Courtship and sperm transfer are believed to occur on land or in the splash zone. Gravid females in the Columbia River Gorge averaged eight ova per individual (Nussbaum and Tait 1977).

Very few nests or eggs for any species of torrent salamander have been found. Generally, it has been thought that *Rhyacotriton* spp. females deposit their eggs in deep, narrow cracks in rock (Nussbaum et al. 1983). However, recent work by Karraker (1999) and Russell et al. (2002) showed that *R. variegatus* and *R. kezeri* also oviposit in mid-channel under boulders and logs. The Cascade torrent salamander, similar to other torrent salamanders, lays large eggs in seeps with coarse substrate, eggs are singly deposited, and are surrounded by a jelly layer. Based on breeding sites that have been observed in other *Rhyacotriton* species, torrent salamanders may nest communally (Russell et al. 2002).

Movement

Torrent salamanders are not known to be territorial (Marangio 1988). Recapture studies of *Rhyacotriton* spp. indicated larval movement is minimal, with more movement upstream than downstream (Nussbaum and Tait 1977). *Rhyacotriton* spp. in western Oregon are relatively sedentary (Corn and Bury 1989) and *Rhyacotriton variegatus*, the southern torrent salamander, does not disperse widely through streams (Diller and Wallace 1996). Additionally, the torrent salamanders are apparently unable to disperse overland through dry forests (Bury and Corn 1988; Bury et al. 1991), which may limit connectivity between populations in different streams.

In a population of Cascade torrent salamanders in the Columbia River Gorge of Oregon, Nijhuis and Kaplan (1998), demonstrated behavioral hydro- and thermoregulation and the species moved parallel to streams more often than perpendicular to streams; however, overall movements were minor. Additionally, the average range length (distance between the furthest points of capture for an individual animal) was 2.4 meters (7.8 feet), and the mean distance traveled per day was 0.359 meter (1.1 feet). Despite these minor movements, Nijhuis and Kaplan (1998) acknowledged that because of the small sample size of the study, longer-distance movement may have gone undetected. Likewise, Nussbaum and Tait (1977), in an earlier study in the Columbia River Gorge, found that of

191 recaptures of uniquely marked larvae, 134 (70%) had no net movement since the previous capture (i.e., they were found in the same 2-meter (6.6-foot) section where they were originally marked). Thirty-nine of these recaptures (20%) demonstrated net movement upstream and 18 (10%) moved downstream; the farthest distance traveled during the summer was 22 meters (72 feet).

Foraging Habitat

Based on data for other *Rhyacotriton* species, Columbia torrent salamanders probably feed on invertebrates dwelling in moist forested habitats, especially amphipods, fly larvae, springtails, and stonefly nymphs (Bury and Martin 1967; Bury 1970). These taxa occur in semi-aquatic and aquatic microhabitats.

Ecological Relationships

Olson and Weaver (2007) found amphibian assemblages with Cascade torrent salamanders to be associated with spatially intermittent streams at managed forest sites where year-round hyporheic flows and moist bank habitat exist. Spatially intermittent streams were the most commonly detected in the headwaters sampled from Mt. Hood to Coos Bay, Oregon. Consistent with other studies, the assemblages were also associated with higher gradient reaches and reaches with larger substrate.

Cascade torrent salamanders are preyed upon by a variety of predators. Pacific giant salamanders (*Dicamptodon* spp.) are commonly cited as a predator, as well as, northwestern salamanders (*Ambystoma gracile*), red-legged frogs (*Rana aurora*), ringneck snakes (*Diadophis punctatus*), garter snakes (*Thamnophis* spp.), American robin (*Turdus migratorius*), American dipper (*Cinclus mexicanus*), and ground beetles (Rombough pers. comm., as cited in Howell and Maggiulli 2011). Other predators may include weasels (*Mustela* spp.), mink (*Mustela vison*), and water shrews (*Sorex* spp.).

Torrent salamanders consume a variety of aquatic and semi-aquatic invertebrates, including larval and adult beetles, flies, stoneflies, snails, millipedes, amphipods, and earthworms (Nussbaum et al. 1983; Marangio 1988). Nussbaum et al. (1983) documented the predominant food of larval Cascade torrent salamanders in the Columbia River Gorge was immature caddisflies. Cudmore and Bury (2014) documented differences in microhabitat use in creeks that may contribute to salamander diet differences, with Cascade torrent salamanders being more selective or gape-limited as compared to Coastal giant salamanders (*Dicamptodon tenebrosus*). The coastal giant salamander larvae were found to be opportunistic, dietary generalists, and most commonly found in pools and riffles, while Cascade torrent salamander diets were not closely tied to food availability and were found in riffles, splash zones, and seeps (Cudmore and Bury 2014).

Population Status and Trends

No long-term population data exist for Cascade torrent salamanders. The species is assigned a decreasing population trend on the International Union for Conservation of Nature (IUCN) Red List (Geoffrey Hammerson 2004), and it is possible that numbers are decreased from historical levels due to anthropogenic influences on both public and private lands.

Threats

The main suspected threats to Cascade torrent salamanders include factors that degrade habitat quality, particularly those that result in increased water temperatures and sedimentation (Lannoo 2005). Also, any event that influences the inner-channel gorge of an occupied stream with the potential for destabilizing the geomorphology and hydrology of a stream (e.g., debris flow, rain-on-snow event, or loss of upland canopy cover) may be problematic for Cascade torrent salamanders (Crisafulli et al. 2005). The primary anthropogenic threats to headwater stream and seep habitats include some timber harvest and road construction/maintenance. In addition, stream-crossing culverts may fragment populations. Additional potential threats include chemical applications, mining, recreation, fire, volcanism, disease, and climate change.

Timber Harvest

Timber harvests have been shown to affect Cascade torrent salamanders. These impacts include reduced abundances in young age classes of managed forest stands (i.e., clear-cut stands), through impact mechanisms that affect stream habitats, such as increasing stream temperatures, sedimentation, and changes to peak flow events. Also, interactions between timber harvest and some physical habitat parameters have been detected (Howell and Maggiulli 2011).

However, not all timber harvest practices have the same kind of effects on torrent salamanders. For example, Olson and Rugger (2007) did not find a negative effect from thinning on Cascade torrent salamander abundance with four different stream buffer widths ranging from 6 to 145 meters (19.7 to 475.7 feet) on federally managed lands in western Oregon in the first 2 years post-harvest. In Washington, Pollett (2005) found lower density of Cascade torrent salamanders in high gradient streams ($>10^{\circ}\text{C}$) of managed forest stands than in unmanaged forests and the presence of the species did not differ among the forested stream buffer treatments (unbuffered, buffered 5 to 23 meters [16.4 to 75.5 feet] wide, buffered 200 meters [656.2 feet] wide, unmanaged).

Other studies suggest riparian buffers offer protection to the salamanders (Pollett et al. 2010; Howell and Maggiulli 2011). Maintaining stream-side buffers during clear cut operations reduces the negative impact of timber harvest to Cascade torrent salamanders. The salamander was nearly absent from streams with temperatures $\geq 14^{\circ}\text{C}$. Additionally, the species was less abundant in unbuffered streams than in streams with buffers or streams located in second-growth forests. Pollett et al. (2010) suggested stream buffers had a positive ecological effect on the density of torrent salamanders.

In general, the harvest of timber in riparian areas can affect the stream by increasing water temperatures (from canopy removal) and by depositing sediment. Based on where Cascade torrent salamanders have been documented (steep gradient systems with high flushing capacity), it is presumed that sediment input from ground-disturbing activities would have a negative effect on individuals. Likewise, in one study, where timber harvesting caused increases in water temperature, decreases in oxygen, or increases in siltation, *Rhyacotriton* spp. have been rare or absent (Leonard et al. 1993).

Roads and Culverts

Culverts and roads can have multiple effects on Cascade torrent salamanders. They may be sources of erosion that result in stream sedimentation. Roads may also pose barriers to amphibian

movement, and in the context of roads crossing streams, their culverts may pose barriers. An inability to disperse puts populations at risk because it limits gene flow and the ability to recolonize after disturbance (Jackson 2003). Specifically, perched culverts are problematic due to the loss of substrate continuity and increased velocity of water above a surface that does not present any natural characteristics, such as instream structures, substrate, or quiet pools, which would facilitate animal movement. Given its close association to the stream channel and adjacent, saturated ground, Cascade torrent salamanders likely may not move any significant distance upland to navigate around such barriers. These types of culverts have long been recognized as problems for fish and have only recently become more of a topic of concern for amphibians.

It is not known to what degree culverts and roads fragment habitat for Cascade torrent salamanders as there have not been any studies on distribution specifically related to road locations. Nonetheless, Hayes et al. (2002) found that coastal tailed frogs (*Ascaphus truei*) engaged in upstream seasonal movements seeking invertebrate-rich intermittent headwater areas and Olson et al. (2007) speculated that similar environmental situations may exist for post-metamorphic torrent salamanders to do the same.

Chemical Application

Because amphibians breathe through their skin, a variety of chemicals (e.g., pesticides, herbicides, fire retardant, salt, fertilizers) have the potential to negatively affect these animals. Broad-scale herbicide treatments applied to suppress the shrub layer on forest lands after harvest could negatively affect Cascade torrent salamanders. In addition, episodic release of chemicals trapped in snowmelt may have some direct and indirect effects on Cascade torrent salamanders, particularly where they may accumulate in the foothills of the Cascade Range (Olson pers. comm., as cited in Howell and Maggiulli 2011). Though wildfire is a relatively rare event west of the Cascades (but could increase as climate patterns change), and the use of prescribed fire (particularly in riparian areas) is minimal, the effects from fire retardants are nevertheless not fully known. Salt and sand, as components of roads and ski area management, have the potential to enter the stream channel and affect the species. Compared to pesticides, herbicides, may pose less risk to amphibians because the chemical does not target species with a nervous system; however, no data on the specific effects of herbicides on Cascade torrent salamanders are available (Howell and Maggiulli 2011).

Climate Change

The effects of climate change on Cascade torrent salamanders are unknown. However, climate change models generally predict warmer temperatures (especially in the summer), increased rainfall, reduced snowpack, more variable temperature and precipitation, changes in snowline and melting, and increased risk of winter flooding in smaller streams west of the Cascades (Mote et al. 2003). Climate change may affect suitable headwater habitat for the species. Because torrent salamanders are tied to aquatic environments and tolerate a narrow range of water temperatures, change water regime has the potential to affect the species.

Literature Cited

- Bury, R.B. and M. Martin. 1967. The food of the salamander *Rhyacotriton variegatus*. *Copeia* 1967:487. Bury, R.B. 1970. Food similarities in the tailed frog, *Ascaphus truei*, and the Olympic salamander, *Rhyacotriton olympicus*. *Copeia* 1970:170–171. Bury, R. B., and P. S. Corn. 1988.

- Douglas-Fir Forests in the Oregon and Washington Cascades: Relation of the Herpetofauna to Stand Age and Moisture. Pages 11–22. In: R. C. Szaro, K. E. Severon, and D. R. Patton. Eds. *Management of Amphibians, Reptiles, and Mammals in North America: Proceedings of a Symposium*. General Technical Report RM-166. Corvallis, OR, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Bury, R. B., P. S. Corn, K. B. Aubry, F. F. Gilbert, and L. L. C. Jones. 1991. Aquatic Amphibian Communities in Oregon and Washington. Pages 352–362. In: L. F. Ruggiero, K. B. Aubry, A. B. Carey and M. H. Huff. Eds. *Wildlife and Vegetation of Unmanaged Douglas-fir Forests*, General Technical Report PNW-GTR-285. Portland, OR, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Bury, R. B. 2008. Low Thermal Tolerances of Stream Amphibians in the Pacific Northwest: Implications for Riparian and Forest Management. *Applied Herpetology* 5:63–74.
- Crisafulli, C. M., L. S. Tripp, C. P. Hawkins, and J. A. MacMahon. 2005. Amphibian Responses to the 1980 Eruption of Mount St. Helens, Chapter 13 in *Ecological Responses to the 1980 Eruption of Mt. St. Helens*, V. H. Dale, F. J. Swanson, and C. M. Crisafulli, Eds., Springer Science+Business Media, Inc., New York, NY.
- Corkran, C. C. 2009. Personal communication. Naturalist/Wildlife Consultant, Northwest Ecological Research Institute, 130 NW 114th Avenue, Portland, OR 97229
- Corn, P. S., and R. B. Bury. 1989. Logging in Western Oregon: Responses of Headwater Habitats and Stream Amphibians. *Forest Ecology and Management* 29:39–57.
- Cudmore, W. W., and R. B. Bury. 2014. Resource Partitioning in Two Stream Salamanders, *Dicamptodon tenebrosus* and *Rhyacotriton cascadae*, from the Oregon Cascade Mountains. *The American Midland Naturalist* 172(1):191–199.
- Diller, L. V., and R. L. Wallace. 1996. Distribution and Habitat of *Rhyacotriton Variegatus* in Managed, Young Growth Forests in North Coastal California. *Journal of Herpetology* 30(2):184–191.
- Frost, D. R., T. Grant, J. Faivovich, R. H. Bain, A. Haas, C. F. B. Haddad, R. O. De Sa, A. Channing, M. Wilkinson, S. C. Donnellan, C. J. Raxworthy, J. A. Campbell, B. L. Blotto, P. Moler, R. C. Drewes, R. A. Nussbaum, J. D. Lynch, D. M. Green, and W. C. Wheeler. 2006. The Amphibian Tree of Life. *Bull. Amer. Mus. Nat. Hist.* 297, 370 pp.
- Gaige, H.T. 1917. Description of a new salamander from Washington. Occasional Papers of the Museum of Zoology, Number 40, University of Michigan, Ann Arbor, Michigan.
- Geoffrey Hammerson 2004. *Rhyacotriton cascadae*. In International Union for Conservation of Nature (IUCN) 2009. IUCN Red List of Threatened Species. Version 2009.2. Available: www.iucnredlist.org. Accessed: February 9, 2010.
- Good, D.A., G.Z. Wurst and D.B. Wake. 1987. Patterns of geographic variation in allozymes of the Olympic salamander, *Rhyacotriton olympicus* (Caudata: Dicamptodontidae). Fieldiana, Zoology, New Series, Number 32, Field Museum of Natural History, Chicago, Illinois.
- Good, D. A., and D. B. Wake. 1992. Geographic Variation and Speciation in the Torrent Salamanders of the Genus *Rhyacotriton* (Caudata: Rhyacotritonidae). *University of California Publication in Zoology* 126:1–91.

- Hayes, M. P., T. Quinn, L. V. Diller, L. L. C. Jones, J. G. McCracken, M. J. Raphael, and D. E. Runde. 2002. *Evaluation of Sampling Methods for Amphibians in Headwater Basins of Non-Fishbearing Streams: A Preliminary Analysis*. A final report submitted to the Cooperative Monitoring, Evaluation, and Research Co.
- Howell, B.L, and N.M. Maggiulli. 2011. Conservation assessment for the Cascade torrent salamander (*Rhyacotriton cascadae*). USDA Forest Service Region 6 and U.S.D.I. Bureau of Land Management Interagency Special Status and Sensitive Species Program.
- Hunter, M. G. 1998. *Watershed-Level Patterns Among Stream Amphibians in the Blue River Watershed, West-Central Cascades of Oregon*. Master's thesis, Oregon State University, Corvallis.
- Hutchison, Victor & Whitford, Walter. (1966). Pulmonary and Cutaneous Gas Exchange in Ambystomatid Salamanders. *Copeia*. 1966. 573–577. 10.2307/1441084.
- Jackson, S. D. 2003. Ecological Considerations in the Design of River and Stream Crossings. Pages 20–29. In: C. L. Irwin, P. Garrett, and K. P. McDermott. Eds. *Proceedings of the International Conference on Ecology and Transportation*. North Carolina State University, Center for Transportation and the Environment, Raleigh, NC.
- Jones, L. C., W. P. Leonard, and D. H. Olson, eds. 2005. *Amphibians of the Pacific Northwest*. Seattle Audubon Society, Seattle, Washington.
- Karraker, N.E. 1999. Natural history notes: *Rhyacotriton variegatus* (southern torrent salamander). Nest site. *Herpetological Review* 30:160–161. Karraker, N. E., L. M. Ollivier, and G. R. Hodgson. 2005. Oviposition Site of the Southern Torrent salamander (*Rhyacotriton variegates*) in Northwestern California. *Northwestern Naturalist* 86:34–36.
- Lannoo, M., ed. 2005. *Amphibian Declines: The Conservation Status of United States Species*. University of California Press, Berkeley, California.
- Leonard, W. P., H. A. Brown, L. L. C. Jones, K. McAllister, and R. M. Storm. 1993. *Amphibians of Washington and Oregon*. Seattle Audubon Society, Seattle, WA, 168 p.
- MacCracken, J. G. 2004. *Rhyacotriton cascadae* (Cascade torrent salamander) Nest. *Herpetological Review* 35(4):367.
- Marangio, M. 1988. Olympic Salamander. In: D.C. Zeiner, W.F. Laudenslayer, Jr., K.E. Mayer, and M.L. White. Eds. *California's Wildlife, Vol. I. Amphibians and Reptiles*. California Statewide Wildlife Habitat Relationship System. Sacramento, CA, Department of Fish and Game, The Resources Agency. 272 p.
- McAllister, K.R. 1995. Distribution of amphibians and reptiles in Washington State. *Northwest Fauna* 3:81-112.
- Mote, P. W., E. A. Parson, A. F. Hamlet, W. S. Keeton, D. Lettenmaier, N. Mantua, E. L. Miles, D. W. Peterson, D. L. Peterson, R. Slaughter, and A. K. Snover. 2003. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. *Climatic Change* 61:45–88.
- Nijhuis, M. J., and R. H. Kaplan. 1998. Movement Patterns and Life History Characteristics in a Population of the Cascade Torrent Salamander (*Rhyacotriton cascadae*) in the Columbia River Gorge, Oregon. *Journal of Herpetology* 32(2):301–304.

- Nussbaum, R. A., and C. K. Tait. 1977. Aspects of the Life History and Ecology of the Olympic Slalmander, *Rhyacotriton olympicus* (Gaike). *American Midland Naturalist* 98:176–199.
- Nussbaum, R. A., E. D. Brodie, Jr. and R. M. Storm. 1983. *Amphibians and Reptiles of the Pacific Northwest*. The University Press of Idaho, Moscow, ID, 332 p.
- Olson, D. H. 2007. Personal communication. Research Ecologist. USDA Forest Service—Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331.
- Olson, D. H., and K. M. Burnett. 2009. Design and Management of Linkage Areas Across Headwater Drainages to Conserve Biodiversity in Forest Ecosystems. *Forest Ecology and Management* 258S:S117–S126.
- Olson, D. H. and C. Rugger. 2007. Preliminary Study of the Effects of Headwater Riparian Reserves with Upslope Thinning on Stream Habitats and Amphibians in Western Oregon. *Forest Science* 53(2):331–342.
- Olson, D. H., and G. Weaver. 2007. Vertebrate Assemblages Associated with Headwater Hydrology in Western Oregon Managed Forests. *Forest Science* 53:343–355.
- Oregon Department of Forestry. 2019. GIS data citation needed.
- Palazzotto, N. 2019. Personal communication. State Forests Wildlife Biologist, Oregon Department of Forestry.
- Pollett, K. L. 2005. *Responses of Stream-Breeding Amphibians to Riparian Buffers in Headwater Streams: Ameliorating the Effects of Regeneration Harvest*. Master's Thesis, Utah State University.
- Pollett, K. L., J. G. MacCracken, and J. A. MacMahon. 2010. Stream Buffers Ameliorate the Effects of Timber Harvest on Amphibians in the Cascade Range of Southern Washington, USA. *Forest Ecology and Management* 260:1083–1087.
- Ray, C. 1958. Vital Limits and Rates of Desiccation in Salamanders. *Ecology* 39:75–83.
- Rombough, C. 2009. Personal communication. Herpetologist, Rombough Biological, P.O. Box 365, Aurora, OR 97002.
- Russell, K. R. A. A. Gonyaw, J. D. Strom, K. E. Diemer, and K. C. Murk. 2002. Three New Nests of the Columbia Torrent Salamander, *Rhyacotriton kezeri*, in Oregon with Observations of Nesting Behavior. *Northwestern Naturalist* 83:19–22.
- Russell, K. R., T. J. Mabey, M. B. Cole, and M. J. Rochelle. 2005. Evaluating Biotic and Abiotic Influences on Torrent Salamanders in Managed Forests of Western Oregon. *Wildlife Society Bulletin* 33(4):1413–1424.
- Stebbins, R. C., and C. H. Lowe, Jr. 1951. Subspecific Differentiation in the Olympic Salamander, *Rhyacotriton olympicus*. *University of California Publications of Zoology* 50:465–484.
- Steele, C. A., E. D. Brodie, and J. G. MacCracken. 2003. Relationships Between Abundance of Cascade Torrent Salamanders and Forest Age. *Journal of Wildlife Management* 67(2):447–453.
- Welsh Jr., H. H. and A. J. Lind. 1996. Habitat Correlates of the Southern Torrent Salamander, *Rhyacotriton variegatus* (Caudata: Rhyacotritonidae), in Northwestern California. *Journal of Herpetology* 30(3):385–398.

Whitford, W.G. and V.H. Hutchison. 1966. Cutaneous and pulmonary gas exchange in ambystomatid salamanders. *Copeia* 1966:573–577. Wilson, A.G. and J.H. Larsen Jr. 1992. Geographic distribution: *Rhyacotriton olympicus* (Olympic salamander). *Herpetological Review* 23:85

C13 Oregon Slender Salamander (*Batrachoseps wrighti*)

Legal Status

State: Sensitive Species

Federal: Species of Concern. In 2015, FWS published a 90~Day Finding on a Petition to List the Oregon Slender Salamander as a Threatened or Endangered Species (Federal Docket No. FWS-RI- ES-2015-0057). The FWS found substantial scientific or commercial information indicating that the petitioned action may be warranted

Critical Habitat: N/A

Recovery Planning: N/A



Oregon Slender Salamander. Photo credit OSU via ODFW Oregon Conservation Strategy

Taxonomy

There is a high level of genetic divergence within Oregon slender salamander (*Batrachoseps wrighti*). Wagner (2000) and Miller et al. (2005) found evidence of two major lineages, a northern and southern population, and a pattern of isolation by distance. The northern population includes sites east of the Cascade crest and western sites from the Columbia River south to near Estacada, Oregon, in Multnomah, Clackamas, Hood River, and Wasco Counties. The southern population, in Marion, Linn, and Lane Counties, includes sites west of the Cascade crest north to near Silver Creek Falls.

Distribution

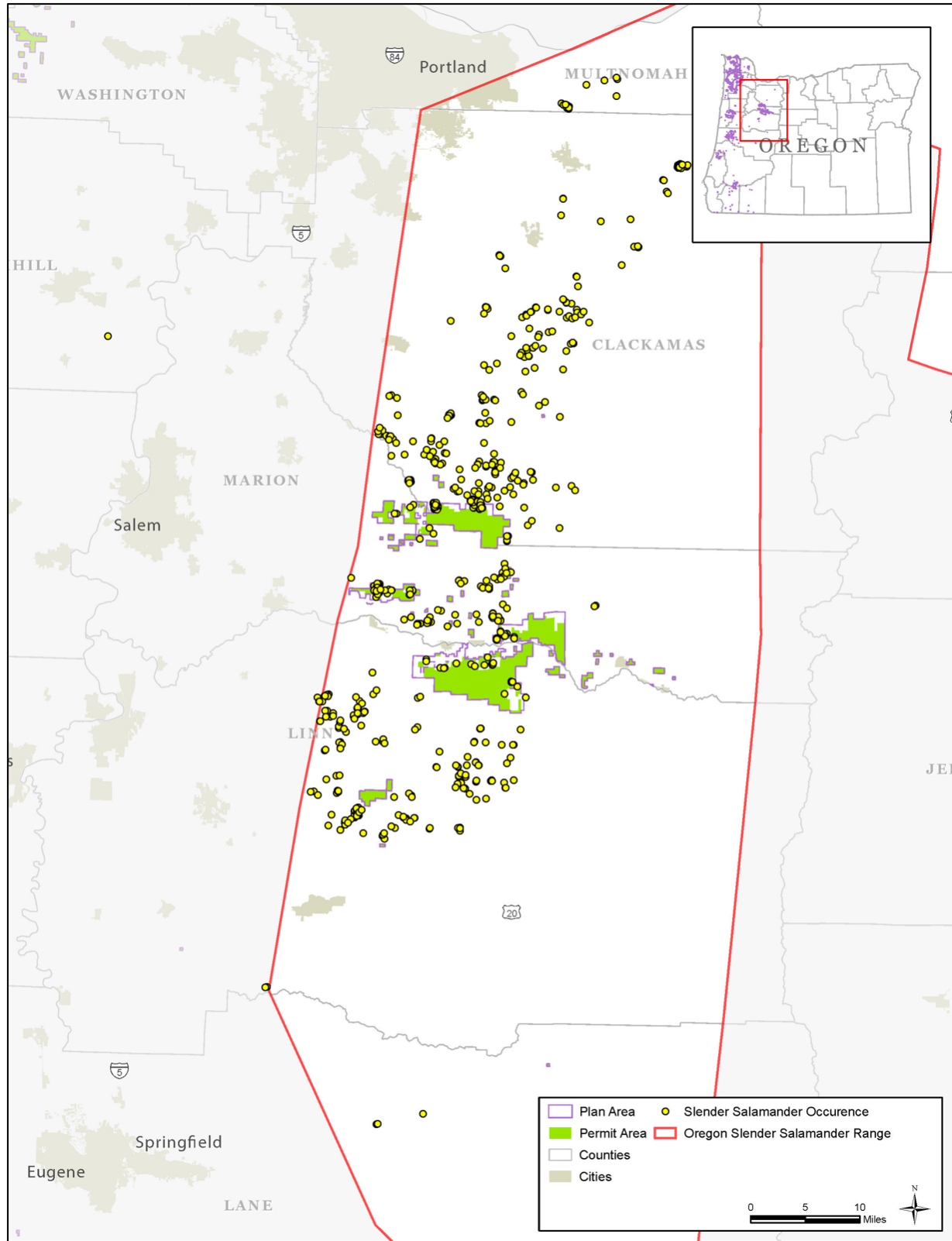
General

The Oregon slender salamander occurs in the northwestern Oregon Cascade Range and the foothills, from the Columbia River Gorge National Scenic Area, in the Multnomah and Hood River Counties southward in the Cascade Mountains, from Mt. Hood and Willamette National Forests, to southern Lane County (Clayton and Olson 2009) (Figure C13-1). The species is also found in northeast Oregon Cascade Range foothills from the Gorge to the Warm Springs Indian Reservation. Most of the species' range is on the western slopes of the Cascades, but several sites are on the eastern slope in Hood River and Wasco Counties (Stebbins 2003; Jones et al. 2005).

Clayton and Olson (2009) report the species occurring across a north-south range of close to 233 kilometers (145 miles), from approximately 24 meters (79 feet) in elevation (at the northern end of

the species range in the Columbia Gorge) to approximately 1,700 meters (5,577 feet) (at the southern end of the species range on the west side of the Cascade Range crest).

Guderyahn et al. (2010) documented a breeding population of Oregon slender salamander among non-native plant species and small debris in a riparian buffer in the suburban residential development of Gresham, Oregon (Multnomah County). High densities of salamanders were found within soil layers, under small deciduous logs on soil, within fine woody debris, and within decaying deciduous logs and coniferous stumps. The finding suggests Oregon slender salamander need specific microhabitat conditions that may occur in other habitats apart from the species' primary association with late-successional forests.



The range shown in red from Clayton and Olson (2009).

Figure C13-1. Range Map of the Oregon Slender Salamander

Occurrences Within the Plan Area

Oregon slender salamander occurs in the Western Cascades of the plan area in Clackamas, Marion, and Linn Counties. Their occupancy has been documented across private and public lands, including Santiam State Forest within the permit area. Data records for BLM and Forest Service lands were collected from 1980 to 2016, and represent sightings recorded during project area surveys or paired sites for research purposes. From 2013-2020, Garcia et al. (2020) conducted a 7-year Before-After Control-Impact cooperative study between Oregon State University, ODF, and private landowners. This study quantified OSS pre and post-harvest occupancy and abundance in randomly selected harvest units in the west Cascades, including areas within the Santiam State Forest. All survey plots had positive detections for Oregon slender salamander over the course of this research effort, and there was no statistical evidence of harvest effects on the abundance of Oregon slender salamanders (Garcia et al. 2020). This work was extended to include a post-wildfire resurvey at the original study sites that overlapped the 2020 Beachie Creek fire perimeter to compare pre and post-fire changes in salamander occupancy and abundance.

Natural History

The ecology and status of Oregon slender salamander are described in the Conservation Assessment for the Oregon Slender Salamander (Clayton and Olson 2009) and more recently summarized in Garcia et al. (2020).

Habitat Requirements

The Oregon slender salamander primarily occurs in old forests (generally older than 76 years) of Douglas-fir, bigleaf maple, hemlock, and western red cedar forests (Blaustein et al. 1995; Bury and Corn 1988; Gilbert and Allwine 1991; Vesely et al. 1999; Center for Biological Diversity 2012). Primary habitat characteristics include moisture, dead wood, and older forest (Clayton and Olson 2009).

Oregon slender salamander is highly associated with decayed large logs (Vesely et al. 1999; Clayton and Olson 2009; Kroll et al. 2015; Garcia et al. 2020). In the western Cascades, Oregon slender salamander density is positively correlated with large diameter (50 to 75 centimeters [20 to 30 inches]) logs and snags in forests with closed canopies, and negatively correlated with small (10 to 25 centimeters [4 to 10 inches]) logs and logs in intermediate levels of decay (Clayton and Olson 2009). This pattern is believed to reflect the species' selection of microhabitats that have a greater abundance of snags and large down logs in advanced decay stages. In surveys of 56 stands of 13 forest types, Vesely et al. (1999) found Oregon slender salamander to be more abundant in old growth than second growth stands; they did not find Oregon slender salamander in clear-cuts, possibly due to canopy removal and the low abundance of woody material. Large logs (50 to 75 centimeters), canopy closure, aspect, and snags were positively correlated with presence of Oregon slender salamander. Overall, canopy closure (median of 93% in old growth stands and 92% in second growth stands) and west- and east-facing slopes were the best predictors of relative density of salamanders. Vesely et al. (1999) suggest that mortality exceeds reproduction in intensively managed forests on short harvest rotations and cannot sustain populations of Oregon slender salamander in the long term. Forest practices that remove legacy down wood are most likely the cause of reduced abundances in harvested forests (Clayton and Olson 2009).

Oregon slender salamander may occur in younger forest stands, however, particularly if legacy downed wood has been retained (Clayton and Olson 2009). For example, Oregon slender salamander have been found in stands on the Cascades Resource Area clear-cut prior to 1960 with higher down wood (S. Dowlan, pers. comm., as cited in Clayton and Olson 2009), and volumes of large down, decayed wood in some of these stands are relatively high (Olson et al. 2006). Similarly, Oregon slender salamander abundance may not be significantly affected by thinning old clear-cuts, as long as legacy down wood is retained (Rundio and Olson 2007; Wessell 2005; Clayton and Olson 2009). Kroll et al. (2015) showed Oregon slender salamander occupancy was strongly associated with the amount of coarse wood debris, whereas *Ensatina* was not. Garcia et al. (2020) found a strong negative harvest effect on *Ensatina* but a lack of clear evidence for harvest effect on Oregon slender salamander. The study found the mean odds of occupancy for Oregon slender salamander was 20% lower in the post-harvest period (clear-cut units managed under standard practices including planting of Douglas-fir seedlings and herbicide applications) compared with pre-harvest period and 23% reduced mean abundance (Garcia et al. 2020). However, they did not find evidence of higher capture probabilities for slender salamanders than *Ensatina* in either control or treatment units (Garcia et al. 2020). Garcia et al. (2020) observed treatment differences for within structure temperatures and found evidence of positive association between occupancy and abundance of Oregon slender salamanders and *Ensatina* with downed wood count.

Suzuki (2009) developed habitat suitability models for Oregon slender salamander on federal lands in the west slope of the Oregon Cascade Range. The model that best classified salamander habitat as suitable or unsuitable included precipitation, minimum daily temperature, forest stand height, and basal area of Pacific fir. Analysis of the individual habitat attributes used to develop the models indicated that Oregon slender salamanders are more likely to occur at lower elevations, warmer temperatures, moderately lower precipitation, and taller, older forest stands with large basal areas and tree diameters. While studies have documented a strong association between downed wood and Oregon slender salamander occupancy or abundance (Vesely et al. 1999; Kroll et al. 2015; Garcia et al. 2020), downed wood was not significantly associated with presence of Oregon slender salamander. This is likely because amount and distribution of downed wood was not captured well by the landscape-level geographic information system (GIS) data used in the model (Suzuki 2008). East of the Cascades crest, the habitat associations for the species are not well known; the salamander has been reported using a variety of ground cover ranging from down logs to sloughed bark, and can occur in younger and older forests (Clayton and Olson 2009). The Oregon slender salamander also occurs under moss-covered rocks in the Columbia River Gorge and in stabilized talus and lava flows elsewhere (Jones et al. 2005).

Reproduction

Reproduction is terrestrial and mating occurs when the male transfers a spermatophore to the female. The species exhibits delayed onset of female oviposition until 4–5 years of age (Tanner 1953). Female Oregon slender salamanders have been found with clutches during April, May, and June (Blaustein et al. 1995). Based on gravid females observed, the clutch size ranges from 3 to 11 eggs. Oviposition likely occurs in spring and eggs hatch within 4 to 5 months (Storm 2005). Nests have been found under subsurface objects such as bark and in crevices in logs (Clayton and Olson 2009).

Diet

Oregon slender salamander consume a variety of small invertebrates such as springtails, mites, flies, spiders, snails, beetles, centipedes, and earthworms (Storm 2005).

Movement

Batrachoseps are thought to be sedentary. Oregon slender salamander is most active at the ground surface during wet periods (i.e., fall and spring) and when temperatures are cool (10–14°C) (Nussbaum et al. 1983). The movement capability of the Oregon slender salamander is indicated from genetic analysis studies. Wagner (2000) and Miller et al. (2005) documented divergence patterns suggestive of two discrete populations, which could be retained through time only as a result of limited gene flow between populations; this may be attributed to limited dispersal capabilities among other factors such as low reproductive rates, specific habitat requirements, and habitat fragmentation. Studies also suggest males disperse while females do not (Wagner 2000; Miller et al. 2005). Studies of the California slender salamander (*B. attenuates*), a close relative to the Oregon slender salamander, documented the salamander remaining in proximity to cover items at which they were discovered and moving approximately 1.5 meters from where they were originally found (Hendrickson 1954, as cited by Clayton and Olson 2009). Oregon slender salamander has been detected in forest stands that were clear-cut in the 1950s and 1960s, indicating the salamander either persisted after disturbance or dispersed into the area from nearby stands (Clayton and Olson 2009).

Ecological Relationships

Although, the predators of Oregon slender salamander are not well known or are undocumented (Clayton and Olson 2009), they likely include amphibians, reptiles, birds, and small mammals. Eggs and hatchlings are susceptible to cannibalism by adult salamanders even from the same species. The role of Oregon slender salamander in community or ecosystem processes has not been studied, though Plethodontid salamanders can comprise a large portion of the forest vertebrate biomass in some areas (e.g., Burton and Likens 1975).

Population Status and Trends

There is no information about population trends in this species (Clayton and Olson 2009). However, the International Union for Conservation of Nature (IUCN) Red List considers the Oregon slender salamander vulnerable to extinction.

Threats

The Oregon slender salamander is threatened by land-use activities that affect forest conditions, surface substrate/ground cover including down wood, soil compaction, fire, chemical application, changes in microhabitat and microclimate regimes that may impact individuals or populations at occupied site(s), and global climate change. Habitat loss and habitat degradation are the primary threats to the species (Clayton and Olson 2009). Clayton and Olson (2009) suggest short rotation clear-cut timber harvest, which removes canopy closure, disturbs substrates, and has potential to alter microhabitat refuges and microclimates, is the primary immediate threat to the salamander.

The removal of large down wood and limited down wood recruitment decrease the availability of habitat and change habitat conditions, thereby negatively affecting the salamander. There is uncertainty about the effect of partial timber harvest or regeneration harvest with green tree and down wood retention on Oregon slender salamander (Clayton and Olson 2009), although most studies in the region of forest thinning indicate a decline in abundance of terrestrial salamanders. Habitat loss from development (e.g., urbanization, large recreation areas) resulting in loss of habitat connectivity leading to isolated populations, also poses a threat to the species (Clayton and Olson 2009).

The effect of fire (prescribed fire vs. natural fire) on Oregon slender salamander is poorly understood. Low intensity fires that retain large down wood and occur during the seasons when these salamanders are not active at the surface may not have adverse effects on the species. A high intensity fire could remove overstory canopy that moderates surface microclimates and reduce decayed down wood, and represents a larger disturbance to flora and fauna (Clayton and Olson 2009).

Although it is not known how chemical applications affect Oregon slender salamander, the species breathes through its skin. Contact with chemicals such as herbicides, pesticide, fungicides, fertilizers, and fire retardant may have a direct negative impact on the species.

While disease has not been implicated for Oregon slender salamander, chytrid fungus has recently been detected in a plethodontid salamander (Cummer et al. 2005).

The species' range includes habitat that is vulnerable to the effects of predicted climate change (Clayton and Olson 2009). West of the Cascade crest, warming could increase the elevational limits of the species and restrict Oregon slender salamander distribution at lower elevations. Foothills may become less suitable for the species. Habitat for the species may become restricted east of the Cascade crest.

Roads create direct and indirect threats to Oregon slender salamander. Roads can cause mortality, loss and modification of suitable habitat, and habitat fragmentation. Development can impact the species through loss of habitat and disturbance of habitat.

A landscape-level multivariate risk assessment (Suzuki 2008) showed the central-western portion of the species' range has high cumulative risk due to high concentrations of actively managed federal timber and private lands, as well as roads. The southwestern portion of the species' range has high potential cumulative risk due to high fire risk, and the northwestern corner of the species' range has the highest potential risk due to actively managed federal timber land, private lands, roads, and wildland-urban interface.

Literature Cited

- Anderson, P. K. 1960. Ecology and Evolution in Island Populations of Salamanders in the San Francisco Bay Region. *Ecological Monographs* 30:359–386.
- Blaustein, A., J. Beatty, D. Olson, and R. M. Storm. 1995. *Biology of Amphibians and Reptiles in Old-Growth Forests in the Pacific Northwest*. Forest Service general technical report.
- Burton, TM, Likens GE. 1975. Salamander Populations and Biomass in the Hubbard Brook Experimental Forest, New Hampshire. *Copeia* 1975;3:541–546.

- Bury, R. B., and P. S. Corn. 1988. Responses of Aquatic and Streamside Amphibians to Timber Harvest: a Review. Pages 165–166: *Streamside Management: Riparian Wildlife and Forestry Interactions*. College of Forest Resources, University of Washington, Seattle, WA.
- Center for Biological Diversity. 2012. Petition to list 53 amphibians and reptiles in the United States as threatened or endangered species under the Endangered Species Act. Center for Biological Diversity, Tucson, Arizona. Prepared by C.L.A., Giese, D.N. Greenwald and T. Curry.
- Clayton, D. R., and D. H. Olson. 2009. *Conservation Assessment for the Oregon Slender Salamander*. Page 76. version 2, USDA Forest Service Region 6 and USDI Bureau of Land Management.
- Cummer, M.R.; Green, D.E.; O'Neill, E.M. 2005. Aquatic Chytrid Pathogen Detected in Terrestrial Plethodontid Salamander. *Herpetological Review* 36:248–249.
- Garcia, T.S., J. Johnson, J. Jones, and A. J. Kroll. 2020. *Experimental evidence indicates variable responses to forest disturbance and thermal refugia by two plethodontid salamanders*. *Forest Ecology and Management* 464. <https://doi.org/10.1016/j.foreco.2020.118045>.
- Gilbert, F.F.; Allwine, R. 1991. Terrestrial Amphibian Communities in the Oregon Cascade Range. Pages 319–324 in L.F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff (technical coordinators). *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests*. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 533 p 285.
- Guderyahn, L., C. Musson, A. Smithers, B. Wishnek, and C. Corkran. 2010. Observations of Oregon Slender Salamanders (*Batrachoseps wrighti*) in Suburban Landscapes. *Northwestern Naturalist* 91:325–328.
- Jones, L.L.C., W. P. Leonard, and D. H. Olson, editors. 2005. *Amphibians of the Pacific Northwest*. Seattle Audubon Society, Seattle, Washington. xii + 227 pp.
- Kroll AJ, Garcia TS, Jones JE, Dugger K, Murden B, Johnson J, et al. (2015) Evaluating Multi-Level Models to Test Occupancy State Responses of Plethodontid Salamanders. *PLoS ONE* 10(11): e0142903. doi:10.1371/journal.pone.0142903
- Miller, M. P., S. M. Haig, and R. Steven. Wagner. 2005. Conflicting Patterns of Genetic Structure Produced by Nuclear and Mitochondrial Markers in the Oregon Slender Salamander (*Batrachoseps wrighti*): Implications for Conservation Efforts and Species Management. *Conservation Genetics* 6:275–287.
- Olson, D.H., Nauman, R.H., Ellenburg, L.L., Hansen, B.P., Chan, S.S. 2006. *Ensatina eschscholtzii* Nests at a Managed Forest Site in Oregon. *Northwestern Naturalist* 87:203–208.
- Ruggiero, L. F., K. B. Aubry, A. B. Carey, and M. H. Huff. 1991. *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests*. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 533 p 285.
- Rundio, D.E., Olson, D.H., 2007. Influence of Headwater Site Conditions and Riparian Buffers on Terrestrial Salamander Response to Forest Thinning. *Forest Science* 53(2):320–330.
- Stebbins, R. C. 2003. *A Field Guide to Western Reptiles and Amphibians*. Third edition. Houghton Mifflin Company, Boston.

- Suzuki, N., and D. H. Olson. 2012. *Validation of the Oregon Slender Salamander Habitat Suitability Model and Map for the West Slope of the Oregon Cascade Range*. Available: <https://www.fs.fed.us/r6/sfpnw/issssp/documents3/inv-rpt-ha-bawr-habitat-model-validation-20120726.pdf>.
- Suzuki, N., D. Olson, and E. C. Reilly. 2008. Developing Landscape Habitat Models for Rare Amphibians with Small Geographic Ranges: A Case Study of Siskiyou Mountains Salamanders in the Western USA. *Biodiversity and Conservation* 17:2197–2218.
- Storm, R.M. 2005. Oregon Slender Salamander: *Batrachoseps wrighti* Bishop. In Jones, L.L.C.; Leonard, W.P.; Olson, D.H. (eds.). 2005. *Amphibians of the Pacific Northwest*. Seattle Audubon Society, Seattle, WA.
- Tanner, W. 1953. Notes on the Life History of *Plethopsis wrightii* Bishop. *Herpetologica* 9:139–140. As cited in Clayton and Olson 2009.
- Vesely, D.G., 1999. *Habitat Selection by Oregon Slender Salamanders (Batrachoseps wrighti) in Western Oregon Cascades*. Pacific Wildlife Research, Corvallis, OR, USA, pp. 16.
- U.S. Forest Service. 2008. *2008 ISSSSP Surveys for Oregon Slender Salamander (Batrachoseps wrightorum)* on Federal Lands Managed by the Eugene Bureau of Land Management and the Willamette National Forest. Page 15. U.S. Department of Agriculture, Forest Service.
- Wagner, R.S. 2000. *Phylogeny, Evolution, and Conservation in Forest-Associated Pacific Northwest Salamanders*. Ph.D. dissertation. Oregon State University, Corvallis, Oregon
- Walcott, P. 2010. *Inventory for Oregon Slender Salamander, Batrachoseps wrightorum, on the Mt. Hood National Forest*. Report to the Interagency Special Status Sensitive Species Program FY 2009. Page 8. Mt. Hood National Forest.
- Wessell, S.J., 2005. *Biodiversity in Managed Forests of Western Oregon: Species Assemblages in Leave Islands, Thinned, and Unthinned Forests*. M.Sc. Thesis, Oregon State Univ., Corvallis, Oregon, U.S.A., p. 161.

C14 Northern Spotted Owl (*Strix occidentalis caurina*)

Legal Status

State: Threatened

Federal: Threatened

Critical Habitat: Original designation in 1992 (57 *Federal Register* [FR] 1796–1838); revised in 2008 (73 FR 47326–47522); December 4, 2012 (77 FR 71875–72068); and January 15, 2021 (86 FR 4820–4860)

Recovery Planning: 2008; revised on June 28, 2011.



Photo: USFWS

Taxonomy

The northern spotted owl (*Strix occidentalis caurina*) is the largest of the three subspecies of spotted owls. The taxonomic separation of these three subspecies is supported by genetic, morphological, and biogeographical information (USFWS 2011). The distribution of the Mexican subspecies (*S.o. lucida*) is disjunct from those of the northern and California (*S.o. occidentalis*) subspecies (Gutierrez et al. 1995). Mitochondrial DNA and microsatellite studies also support the subspecies designation for northern and California spotted owls (Henke 2005; Barrowclough et al. 2005). A narrow hybridization zone between northern and California spotted owls is located in the southern Cascades and northern Sierra Nevada.

Distribution

General

Spotted owls are believed to have inhabited most old-growth forests or stands throughout the Pacific Northwest, including northwestern California, prior to the mid-1800s (USFWS 1989).

The current range of the northern spotted owl extends from southwest British Columbia through the Cascade Mountains, coastal ranges, and intervening forested lands in Washington, Oregon, and California, as far south as Marin County (USFWS 2011). The range of northern spotted owl is partitioned into 12 provinces based on landscape subdivisions with different physical and environmental features. The provinces are distributed across the species' range as follows.

- Four provinces in Washington: Eastern Washington Cascades, Olympic Peninsula, Western Washington Cascades, Western Washington Lowlands.

- Five provinces in Oregon: Oregon Coast Range, Willamette Valley, Western Oregon Cascades, Eastern Oregon Cascades, Oregon Klamath.
- Three provinces in California: California Coast, California Klamath, California Cascades.

Occurrences Within the Plan Area

Northern spotted owl occurs in the plan area in the Coast Range counties of Clatsop, Tillamook, Washington, Yamhill, Polk Lincoln, Benton, Lane, Douglas, Coos, Curry, Josephine, and Jackson and the Western Cascade counties of Clackamas, Marion, and Linn.

The permit area includes 20 “active” northern spotted owl activity centers confirmed to be occupied by pairs. For this HCP, active activity centers are defined as those activity centers that have been confirmed at one point and have had less than 6 consecutive years of surveys with no observations. Activity centers that have not been surveyed consistently were assumed to have their same status as of their most recent survey history.

There are 142 northern spotted owl sites with activity centers located outside of the permit area but within the provincial radius of permit area lands. Using the provincial radius, “owl circles” that overlap the permit area include 119 sites with confirmed pairs, 5 sites with unconfirmed pairs, and 18 sites with resident single owls. Because northern spotted owl numbers continue to decline throughout the species’ range, not all of these sites are believed to currently support owls. However, for this HCP, sites with historic confirmed pair status but no confirmed absence (i.e., 6 consecutive years with no observations) were assumed to be occupied to minimize the potential for take.

Table C14-1. Northern Spotted Owl Active Sites Within the Permit Area, by ODF District.

District	Location	Pair	Unconfirmed Pair	Resident Single	Total
Astoria	Permit Area	2	--	--	2
	Adjacent	--	--	--	--
Coos	Permit Area	3	--	--	3
	Adjacent	24	--	3	27
Forest Grove	Permit Area	2	--	--	2
	Adjacent	1	--	--	1
North Cascade	Permit Area	3	2	--	5
	Adjacent	9	1	2	12
Southwest	Permit Area	3	--	2	5
	Adjacent	47	2	3	52
Tillamook	Permit Area	3	2	3	8
	Adjacent	4	1	--	5
West Oregon	Permit Area	2	--	2	4
	Adjacent	2	--	2	4
Western Lane	Permit Area	2	--	--	2
	Adjacent	32	1	8	41

District	Location	Pair	Unconfirmed Pair	Resident Single	Total
	Total	139	9	25	173
	Total Permit Area	20	4	7	31
	Total Adjacent	119	5	18	142

Natural History

Habitat Requirements

The most recent and comprehensive review of northern spotted owl status and threats is in Chapter 4 of the 2018 Forest Service Science Synthesis Report (Lesmeister et al. 2018). The ecology of northern spotted owl is addressed in the 2012 designation of critical habitat for northern spotted owl (USFWS 2012).

Northern spotted owls generally occupy late-seral forest but may also use younger forests for foraging, movement, and dispersal. Northern spotted owl habitat requirements are commonly ascribed to the specific essential behaviors of nesting and roosting, foraging, and dispersal. Habitat associations for each of these essential behaviors is described in this section.

Nesting and Roosting Habitat

Nesting and roosting habitat provides structural features for nesting, protection from adverse weather conditions, and cover to reduce predation risks for adults and young. Stand structure at nest sites tends to vary little across the northern spotted owl's range. The U.S. Fish and Wildlife Service (USFWS) considers the following components important to nesting and roosting habitat (USFWS 2012).

- Moderate to high canopy cover (60% to over 80%).
- Multilayered, multispecies canopies with large (20- to 30-inch or greater diameter at breast height [dbh]) overstory trees.
- High basal area (greater than 240 square feet per acre).
- High diversity of tree diameters.
- High incidence of large live trees with various deformities (e.g., large cavities, broken tops, mistletoe infections).
- Large snags and large accumulations of fallen trees and other woody material on the ground.
- Sufficient open space below the canopy for northern spotted owls to fly.

Northern spotted owls do not construct nests, but instead rely on platforms provided by tree cavities, mistletoe brooms, and abandoned nests of other predatory birds such as northern goshawks (*Accipiter gentilis*) (Buchanan et al. 1993). Such nest sites are found in large snags or large live trees with structurally diverse crowns (e.g., broken tops or large cavities), features typically found in late-seral forest or in younger forest that retains residual large trees and snags.

Prey Species

Northern spotted owls are mostly nocturnal but will forage opportunistically during the day (USFWS 2011). The composition of the northern spotted owl's diet varies geographically and by forest type.

- Flying squirrels (*Glaucomys sabrinus*) are the most prominent prey for northern spotted owls in Douglas-fir and western hemlock (*Tsuga heterophylla*) forests in Oregon and Washington (Forsman et al. 1984; Hamer et al. 2001),
- Dusky-footed wood rats (*Neotoma fuscipes*) are a major part of the diet in the Oregon Klamath, California Klamath, and California Coastal provinces (Forsman et al. 1984, 2004; Ward et al. 1998).
- Depending on location, other important prey include deer mice (*Peromyscus maniculatus*), tree voles (*Arborimus longicaudus*, *A. pomo*), red-backed voles (*Clethrionomys* sp.), gophers (*Thomomys* sp.), snowshoe hare (*Lepus americanus*), bushy-tailed wood rats (*Neotoma cinerea*), birds, and insects, although these comprise a small portion of the northern spotted owl diet (Forsman et al. 1984, 2004; Ward et al. 1998; Hamer et al. 2001).

Foraging Habitat

Foraging habitat varies widely across the northern spotted owl's range. Within the West Cascades/Coast Ranges of Oregon and Washington, the USFWS defines foraging habitat as follows (USFWS 2012).

- Stands of nesting and roosting habitat; additionally, owls may use younger forests with some structural characteristics (legacy features) of old forests, hardwood forest patches, and edges between old forest and hardwoods.
- Moderate to high canopy cover (60 to over 80%).
- A diversity of tree diameters and heights.
- Large accumulations of fallen trees and other woody debris on the ground.
- Sufficient open space below the canopy for northern spotted owls to fly.

Reproduction

Northern spotted owls are monogamous, form long-term pair bonds, have a long reproductive life span (6–9 years) and provide extended parental care (USFWS 2011). There are no known examples of polygyny in this owl, although associations of three or more birds have been reported (Gutiérrez et al. 1995). Spotted owls are sexually mature at 1 year of age, but rarely start breeding until 2 to 5 years of age (Forsman et al. 2002). Females lay one to four eggs per clutch, with an average clutch size of two eggs. Most spotted owl pairs do not nest every year, nor are nesting pairs successful every year (Forsman et al. 1984; USFWS 1990; Anthony et al. 2006). The species has low fecundity due to its small clutch size, nesting success variability, and delayed onset of breeding (Gutierrez 1996).

Timing of nesting and fledging varies with elevation and latitude (Forsman et al. 1984). Courtship behavior usually begins in February or March, and eggs are typically laid in late March or April. Juveniles leave the nest in late May or June and are dependent upon their parents until they are able

to fly and hunt on their own. Adults continue to provide parental care from fledging into September (Forsman et al. 1984; USFWS 1990). Adults will roost during the day with fledged young for the first few weeks, but by late summer the adults rarely roost with their young and only visit the juveniles at night to feed them (Forsman et al. 1984).

Territory and Home Range

Territory

Northern spotted owls are territorial; however, home ranges of adjacent pairs may overlap (Solis and Gutierrez 1990), suggesting that the territorial area is smaller than the area used for foraging. Northern spotted owls will actively defend their nests and young from predators (Gutierrez et al. 1995). Territorial defense is primarily achieved by hooting, barking and whistle type calls. Some northern spotted owls are not territorial but either remain as residents within the territory of a pair or move among territories (Gutiérrez 1996). These birds are referred to as “floaters.”² Floaters have special significance in northern spotted owl populations because they may buffer the territorial population from decline (Franklin 1992). Little is known about floaters other than that they exist and typically do not respond to calls as vigorously as territorial birds (Gutiérrez 1996).

Home Range

A home range is the area in which a spotted owl conducts its activities during a defined period of time (USFWS 1992) that provides important habitat elements for nesting, roosting, and foraging. Home ranges vary geographically, generally increasing in size from south to north, which is likely a response to differences in habitat quality (USFWS 1990,).

The presence of barred owl has also been shown to influence the home range of spotted owls (Wiens et al. 2014). Estimates of median size of the annual home range (the area traversed by an individual or pair during normal activities) varies by province and range from 2,955 acres in the Oregon Cascades to 14,211 acres on the Olympic Peninsula in Washington (USFWS 2011). Within the home range is a smaller area of concentrated use during the breeding season, often referred to as the core use area.³

Spotted owl core use areas vary in size geographically and provide habitat elements that are needed for reproduction, such as the nest tree, roost sites, and foraging areas. Spotted owl home ranges contract during the breeding season and expand during fall and winter. Home range size is also influenced by stand characteristics, availability of prey, and presence of barred owls (Wiens et al. 2014).

² Floaters are referred to as “SU” for administrative purposes.

³ Core Use Area: An area of concentrated use within a home range that receives disproportionately high use (Bingham and Noon 1993), and commonly includes nest sites, roost sites, and foraging areas close to the activity center. Core use areas vary geographically, and in relation to habitat conditions. This is a biological definition of core use area and is not the same as a 70-acre core as defined by the Oregon Forest Practices Act nor is it equivalent to the 100-acre LSRs referred to as NSO cores on federal lands. The 70-acre core area has been expanded to 250-acre on the North Coast under the SOC policy.

Activity Centers and Provincial Radii

Spotted owls have been characterized as central-place foragers, where individuals forage over a wide area and subsequently return to a nest or roost location that is often centrally-located within the home range (Rosenberg and McKelvey 1999, in USFWS 2011). Activity centers are location or point within the core use area that represent this central location. Nest sites are typically used to identify activity centers, or in cases where nests have not been identified, breeding season roost sites or areas of concentrated nighttime detections may be used to identify activity centers.

The FWS has identified “provincial home ranges” as a management tool for northern spotted owls (USFWS 2011). The “provincial radius” is that of a circle centered on the activity center that represents the approximate home range for an owl in a given geographic location. Based on guidance from the USFWS, ODF uses the following provincial radii:

- Klamath Province (Southwest Unit), 1.3 miles;
- Oregon Cascades (North Cascade District), 1.2 miles;
- Oregon Coast Ranges (all other Districts), 1.5 miles.

Using the provincial radius, a circle is drawn around each activity center, creating an “owl circle” in which habitat effects may occur.

Dispersal Biology

Dispersal habitat is habitat through which young owls disperse from their parents’ territory to establish a new territory. Young owls generally begin to disperse in September and October, with a few individuals dispersing in November and December (Forsman et al. 2002). Natal dispersal occurs in stages. Young owls tend to disperse widely, often in a series of steps (Forsman et al. 2002), so that dispersing juveniles may occupy temporary home ranges for up to several months (Forsman et al. 2002). Studies have shown that spotted owls can disperse through highly fragmented forest landscapes (Forsman et al. 2002); however, owls are not able to disperse through large, non-forested valleys (such as the Willamette Valley) and may move around large water bodies rather than crossing them (Forsman et al. 2002).

USFWS defines dispersal habitat as follows (USFWS 2012).

- Stands with adequate tree size and canopy cover to provide protection from avian predators and minimal foraging opportunities; in general this may include, but is not limited to, trees that are at least 11 inches dbh and have a minimum 40% canopy cover.
- Younger and less diverse forest stands than foraging habitat, such as even-aged, pole-sized stands, if such stands contain some roosting structures and foraging habitat to allow for temporary resting and feeding during dispersal.
- Habitat supporting the colonization phase of dispersal, which is generally similar to nesting, roosting and foraging habitat, but may be smaller in area than habitat needed to support nesting pairs.

Dispersing juvenile northern spotted owls experience high mortality rates from starvation, predation, and accidents (Forsman et al. 2002). Dispersal distances have been reported to be in the range of 8 to 17 miles from natal areas to eventual home range (Courtney et al. 2004); the median

natal dispersal distance is about 10 miles (16 kilometers) for males and 15.5 miles (25 kilometers) for females (Forsman et al. 2002).

Successful juvenile dispersal may depend on locating unoccupied suitable habitat in proximity to other occupied sites (LaHaye et al. 2001). Dispersing juveniles may be attracted to calls of other northern spotted owls and may look for suitable sites preferentially in the vicinity of occupied territories. When all suitable territories are occupied, dispersers may temporarily pursue a nonresident (nonbreeding) strategy as floaters (Forsman et al. 2002). Floaters prospect for territorial vacancies created when residents die or leave their territories.

Ecological Relationships

Known predators of northern spotted owls include great horned owls (Forsman et al. 1984) and possibly barred owls (Leskiw and Gutiérrez 1998). Other suspected predators include northern goshawks, red-tailed hawks, and other raptors (Courtney et al. 2004). Barred owls are also known to compete with northern spotted owls for habitat and resources for breeding, feeding and sheltering; evidence of a negative relationship between barred owl occurrence and population characteristics of northern spotted owl have been well documented and include declines in occupancy of historical northern spotted owl territories where barred owls are detected (Dugger et al. 2011; Lesmeister et al. 2018). Hybridization of northern spotted owls with barred owls and California spotted owls has also been confirmed (Lesmeister et al. 2018).

Population Status and Trends

Meta-analysis has documented the progressive and ongoing decline of spotted owl populations throughout their range (Anthony et al. 2006; Dugger et al. 2016; Forsman et al. 2011), with pronounced declines in annual survival, rate of population change, and site occupancy (Dugger et al. 2016). Dugger et al. (2016) reported the rate of decline was increasing in many areas, including southern Oregon and northern California. Dugger et al. (2016) reported a 3.8% annual rate of decline, which was higher than the 2.9% annual rate of decline reported by Forsman et al. (2011).

Threats

The northern spotted owl was listed as threatened throughout its range “due to loss and adverse modification of northern spotted owl habitat as a result of timber harvesting and exacerbated by catastrophic events such as fire, volcanic eruption, and wind storms” (USFWS 2008). Additional threats included limited habitat, declining habitat, inadequate distribution of habitat or populations, isolation of populations within physiographic provinces, predation and competition, lack of coordinated conservation measures, inadequacy of regulatory mechanisms, and vulnerability to natural disturbance (USFWS 1992).

U.S. Fish and Wildlife Service Revised Recovery Plan for the Northern Spotted Owl (2011) identifies past habitat loss, current habitat loss, and competition from barred owls as the most pressing threats to the spotted owl. Davis et al. (2011) report spotted owl habitat loss on federal lands resulting from harvest and natural disturbances from 1994/1996 to 2006/2007 in Oregon as follows.

- Oregon Coast Range – 611,200 acres with a total habitat loss of 3,300 acres (0.5% total percent loss).
- Oregon Klamath – 985,000 acres with a total habitat loss of 100,700 (10.2% total percent loss).
- Eastern Oregon Cascades – 402,900 acres with a total habitat loss of 25,900 (6.4% total percent loss).
- Western Oregon Cascades – 2,258,700 acres with a total habitat loss of 43,900 (1.9% total percent loss).
- Willamette Valley – 3,400 acres with a total habitat loss of 100 (2.9% total percent loss).

Additional threats to northern spotted owl include climate change, regulatory mechanisms, and disease. Glenn et al. (2010) noted that the potential consequences of global climate change on the Pacific Northwest forests remain unclear with models predicting warmer, wetter winters, and hotter drier summers. Climate change has the potential to cause fundamentally different patterns in weather, which may have unpredictable consequences for northern spotted owl populations.

One of the original reasons for listing the northern spotted owl was the inadequacy of applicable regulatory mechanisms that existed in 1990; since 1994 the Northwest Forest Plan has been implemented on federal lands throughout the northern spotted owl range, and as of 2016 Bureau of Land Management (BLM) lands in western Oregon are being managed under the Proposed Resource Management Plan (BLM 2016). State and private lands are regulated under various state authorities, and timber harvest within each state is governed by rules that provide varying degrees of protection of northern spotted owls or their habitat. In Oregon, the State Forest Practices Act regulates state and private lands. Various research indicates that habitat conservation measures on state and private lands may not be sufficient to maintain the northern spotted owl (Buchanan 2004; Sovern et al. 2015; Glenn et al. 2004). The *Revised Recovery Plan for the Northern Spotted Owl* (USFWS 2011) and *Northern Spotted Owl Habitat and Populations: Status and Threats* (Leismeister et al. 2018) identify a more important recovery role for state and private lands.

USFWS identified disease as a potential stressor for northern spotted owls in 1992 and in 2011. This stressor includes both avian disease (such as West Nile virus, avian flu, avian malaria, and trichomonosis) that may affect northern spotted owls directly and forest pathogens (such as sudden oak death) that may disturb or alter spotted owl habitat.

Literature Cited

- Anthony, R. G., E. D. Forsman, A. B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. D. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, L. S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P. Gerhardt, S. A. Gremel, R. J. Gutiérrez, P. J. Happe, D. R. Herter, J. M. Higley, R. B. Horn, L. L. Irwin, P. J. Loschl, J. A. Reid, and S. G. Sovern. 2006. Status and Trends in Demography of Northern Spotted Owls, 1985–2003. *Wildlife Monographs* 163:1–48.
- Barrowclough, G. F., J. G. Groth, L. A. Mertz, and R. J. Gutierrez. 2005. Genetic Structure, Introgression, and a Narrow Hybrid Zone Between Northern and California Spotted Owls (*Strix occidentalis*). *Molecular Ecology* 14:1109–1120.

- Buchanan, J. B. 2004. In My Opinion: Managing Habitat for Dispersing Northern Spotted Owls—Are the Current Management Strategies Adequate? *Wildlife Society Bulletin* 32:1333–1345.
- Buchanan, J. B., L. L. Irwin, and E. L. McCutchen. 1993. Characteristics of Spotted Owl Nest Trees in the Wenatchee National Forest. *Journal of Raptor Research* 27:1–7.
- Bureau of Land Management. 2016. *Proposed Resource Management Plan/Final Environmental Impact Statement for the Resource Management Plans for Western Oregon—Coos Bay, Eugene, Medford, Roseburg, and Salem Districts, and the Klamath Falls Field Office of the Lakeview District. Vol. I–IV*. Bureau of Land Management, Portland, OR.
- Courtney, S. P., J. A. Blakesley, R. E. Bigley, M. L. Cody, J. P. Dubmacher, R. C. Fleischer, J. F. Franklin, R. J. Gutiérrez, J. M. Marzluff, and L. Sztukowski. 2004. *Scientific Evaluation of the Status of the Northern Spotted Owl*. Sustainable Ecosystems Institute, Portland, OR.
- Davis, R. J., K. M. Dugger, S. Mohoric, L. Evers, and W. C. Aney. 2011. *Northwest Forest Plan—The First 15 Years (1994–2008): Status and Trends of Northern Spotted Owl Populations and Habitats*. Page 147. Gen. Tech. Rep., U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station., Portland, OR.
- Dugger, K. M., E. D. Forsman, A. B. Franklin, R. J. Davis, G. C. White, Carl J. Schwarz, Kenneth P. Burnham, James D. Nichols, James E. Hines, Charles B. Yackulic, Paul F. Doherty, Larissa Bailey, Darren A. Clark, Steven H. Ackers, Lawrence S. Andrews, B. Augustine, Brian L. Biswell, Jennifer Blakesley, Peter C. Carlson, Matthew J. Clement, Lowell V. Diller, Elizabeth M. Glenn, Adam Green, Scott A. Gremel, Dale R. Herter, J. Mark Higley, Jeremy Hobson, Rob B. Horn, Kathryn P. Huyvaert, Christopher McCafferty, Trent McDonald, Kevin McDonnell, Gail S. Olson, Janice A. Reid, Jeremy Rockweit, Viviana Ruiz, Jessica Saenz, and Stan G. Sovern. 2016. The Effects of Habitat, Climate, and Barred Owls on long-Term Demography of Northern Spotted Owls. *The Condor* 118:57–116.
- Forsman, E. D., R. G. Anthony, K. M. Dugger, E. M. Glenn, A. Franklin, G. White, C. J. Schwartz, K. P. Burnham, D. R. Anderson, J. D. Nichols, J. Hines, J. B. Lint, R. J. Davis, S. H. Ackers, L. Andrews, B. L. Biswell, P. C. Carlson, L. Diller, S. A. Gremel, and S. Sovern. 2011. *Population Demography of Northern Spotted Owls*.
- Forsman, E. D., R. G. Anthony, E. C. Meslow, and C. J. Zabel. 2004. Diets and Foraging Behavior of Northern Spotted Owls in Oregon. *Journal of Raptor Research* 38:214–230.
- Forsman, E. D., R. G. Anthony, J. A. Reid, P. J. Loschl, S. G. Sovern, M. Taylor, B. L. Biswell, A. Ellingson, E. C. Meslow, G. S. Miller, K. A. Swindle, J. A. Thrailkill, F. F. Wagner, and D. E. Seaman. 2002. Natal and Breeding Dispersal of Northern Spotted Owls. *Wildlife Monographs*:1–35.
- Forsman, E. D., E. C. Meslow, and H. M. Wright. 1984. Distribution and Biology of the Spotted Owl in Oregon. *Wildlife Monographs* 48:1–64.
- Franklin, A.B. 1992. Population Regulation In Northern Spotted Owls: Theoretical Implications for Management. Pages 815–827 in D.R. McCullough and R.H. Barrett (eds.), *Wildlife 2001: Populations*. New York: Elsevier Press: 815–827.
- Glenn, E. M., M. C. Hansen, and R. G. Anthony. 2004. Spotted Owl Home-Range and Habitat Use in Young Forests of Western Oregon. *The Journal of Wildlife Management* 68:33–50.

- Glenn, E. M., R. G. Anthony, and E. D. Forsman. 2010. Population Trends in Northern Spotted Owls: Associations with Climate in the Pacific Northwest. *Biological Conservation* 143:2543–2552.
- Gutierrez, R. J. 1996. Biology and Distribution of the Northern Spotted Owl. *Studies in Avian Biology* 17:2–5.
- Gutierrez, R. J., A. B. Franklin, and W. S. Lahaye. 1995. Spotted Owl (*Strix occidentalis*), version 2.0. Page in A. F. Poole and F. B. Gill (eds.). *Birds of North America*. Cornell Lab of Ornithology, Ithaca, New York.
- Hamer, T. E., D. L. Hays, C. M. Senger, and E. D. Forsman. 2001. Diets of Northern Barred Owls and Northern Spotted Owls in an Area of Sympatry. *Journal of Raptor Research* 35:221–227.
- Henke, A. L. 2005. *Spotted Owl (Strix occidentalis) Microsatellite Variation in California*. M.S. thesis, San Jose State University.
- Lahaye, W. S., R. J. Gutiérrez, and J. R. Dunk. 2001. Natal Dispersal of the Spotted Owl in Southern California: Dispersal Profile of an Insular Population. *The Condor* 103:691–700.
- Leskiw, T., and R. J. Gutiérrez. 1998. Possible Predation of a Spotted Owl by a Barred Owl. *Western Birds* 29:225–226.
- Lesmeister, D. B., R. J. Davis, P. H. Singleton, and J. D. Wiens. 2018. Chapter 4: Northern Spotted Owl Habitat and Populations: Status and Threats. In *Volume 2 – Synthesis of Science to Inform Land Management within the Northwest Forest Plan Area* 2:56.
- Lorenz, T.J.; M.R. Raphael, T.D. Bloxton, P.G. Cunningham. 2017. Low Breeding Propensity and Wide-Ranging Movements by Marbled Murrelets in Washington. *Journal of Wildlife Management* 81:306–321.
- M Dugger, K., R. G Anthony, and L. Andrews. 2011. *Transient Dynamics of Invasive Competition: Barred Owls, Spotted Owls, Habitat, and the Demons of Competition Present*.
- Sovern, S. G., E. D. Forsman, K. M. Dugger, and M. Taylor. 2015. Roosting Habitat Use and Selection by Northern Spotted Owls During Natal Dispersal. *The Journal of Wildlife Management* 79:254–262.
- Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. *A Conservation Strategy for the Northern Spotted Owl*. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. National Park Service, Portland, OR.
- U.S. Fish and Wildlife Service (USFWS). 1989. *The Northern Spotted Owl: A Status Review Supplement*.
- U.S. Fish and Wildlife Service (USFWS). 1990. Endangered and Threatened Wildlife and Plants: Determination of Threatened Status for the Northern Spotted Owl. *Federal Register* 55: 26114–26194.
- U.S. Fish and Wildlife Service (USFWS). 1992. Endangered and threatened wildlife and plants: Determination of Critical Habitat for the Northern Spotted Owl. *Federal Register* 57:1796–1838.
- U.S. Fish and Wildlife Service (USFWS). 2008. Endangered and Threatened Wildlife and Plants: Revised Designation of Critical Habitat for the Northern Spotted Owl. *Federal Register* 73(157): 47326–47522.

- U.S. Fish and Wildlife Service (USFWS). 2011. *Revised Recovery Plan for the Northern Spotted Owl* (*Strix occidentalis caurina*). Page xvi + 258 pp. U. S. Fish and Wildlife Service, Portland, OR.
- U.S. Fish and Wildlife Service (USFWS). 2012. Endangered and Threatened Wildlife and Plants; Designation of Revised Critical Habitat for the Northern Spotted Owl. Final Rule. *Federal Register* 77: 71875-72068.
- Ward Jr., J. W., R. J. Gutierrez, and B. R. Noon. 1998. Habitat Selection by Northern Spotted Owls: The Consequences of Prey Selection and Distribution. *The Condor* 100:79-92.
- Weathers, W. W., P. J. Hodum, and J. A. Blakesley. 2001. Thermal Ecology and Ecological Energetics of the California Spotted Owl. *The Condor* 103:678-690.
- Wiens, J. D., Anthony, R. G. and Forsman, E. D. 2014. Competitive Interactions and Resource Partitioning Between Northern Spotted Owls and Barred Owls in Western Oregon. *Wildlife Monographs* 185:1-50.

C15 Coastal Marten (*Martes caurina*)

Legal Status

State: Threatened

Federal: Threatened, listed in 2020 (FWS-R8-ES-2018-0076,

Critical Habitat: 2024 (89 Federal Register [FR] 46576)

Recovery Planning: N/A



Photo: Mark Linnell/USDA Forest Service

Taxonomy

The coastal distinct population segment (DPS) of the Pacific marten (*Martes caurina*) is commonly called, and referred to herein as, the coastal marten. The DPS includes populations in the Coast Range of Oregon and northern coastal California. Historically, two subspecies of Pacific marten have been recognized in coastal western Oregon and northwestern California: *M. caurina* along the Coast Range and Cascade Mountains in western and central Oregon and *M. c. humboldtensis* in the coastal coniferous forests in northwestern California. Genetic analysis indicates that populations of *M. c. caurina* in the Coast Range are more closely related to *M. c. humboldtensis* (Humboldt marten) than to populations of *M. c. caurina* in the Cascade Mountains (Slauson et al. 2009; Schwartz et al. 2016, unpublished report, as cited in USFWS 2023a) and may represent a single subspecies. At the time of the proposed rule (October 9, 2018; USFWS 2023) a taxonomic change to a subspecies status had not been published, so the U.S. Fish and Wildlife Service (USFWS) identifies the coastal marten as a DPS.

Distribution

General

Coastal martens historically occurred in the coastal forests of Oregon and California (USFWS 2023). Coastal martens have not been detected recently (since 1980) throughout much of the species' historic range, despite extensive surveys (USFWS 2023).

Coastal martens have been documented in four small (<100 individuals) populations and are absent from the northern and southern extents of their historical range (USFWS 2023). The populations were mapped by USFWS (2023) as Extant Population Areas, two of which occur in Oregon and in the region of the plan area (Moriarty et al. 2016a) (Figure C15-1).

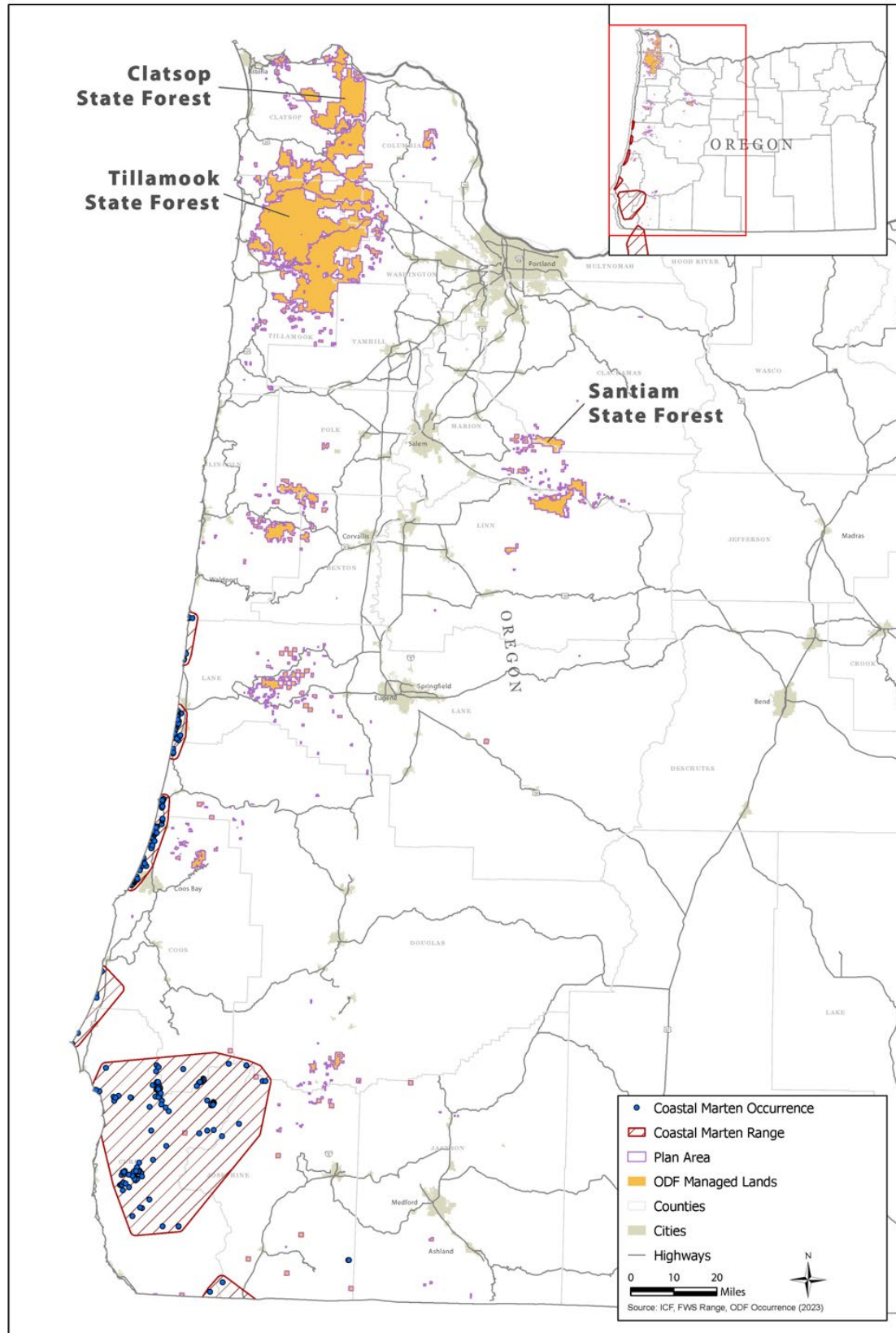


Figure C15-1. Range of the Coastal Marten within the Permit Area Shown in Red.

Two of the four populations are located in the vicinity of the plan area:

- **Central Coastal Oregon Extant Population Area** covers 403 square kilometers (km²) in coastal forest in the Oregon Dunes Recreational Area, managed by the Siuslaw National Forest. The occupied area is less than 500 meters wide in coastal forest. This Extant Population Area is divided by the Umpqua River, a relatively large barrier to movement.
- **Southern Coastal Oregon Extant Population Area** covers 2,420 km² in Coos and Curry Counties. Land in this Extant Population Area is managed by Cape Blanco State Park, Siskiyou National Forest, the U.S. Department of the Interior Bureau of Land Management (BLM), and private landowners. Most detections in this Extant Population Area occurred on the Rogue River–Siskiyou National Forest. The occupied area is bisected by the Rogue River, which is likely a strong barrier to movement.

USFWS also verified two detection locations in Jackson County in southwestern Oregon, outside of the four Extant Population Areas. These locations did not meet USFWS criteria for inclusion in an Extant Population Area (i.e., there were less than five detections in an area buffered 2 kilometers around each detection and connected using a minimum convex polygon tool, or detections were separated by greater than 5 kilometers from other verified detections). Coastal martens have not been detected recently in this area over the past 4 to 8 years (USFWS 2023).

The overall range for the coastal marten stretches across western Oregon, with potential habitat identified in portions of the Plan Area under the jurisdiction of the Department of State Lands and Department of Forestry, including in Coos, Josephine, Douglas, Lane, Jackson, and Curry counties. Critical habitat within the Plan Area is identified in northwestern Douglas County, eastern Curry County, and northern Josephine County, all of which are under the jurisdiction of the Department of State Lands.

Occurrences in the Plan Area

The coastal marten extant population areas depicted in Figure 2-24 are based on the USFWS Species Status Assessment (2026) and include species occurrences (up to 2023) located inside and outside the permit area. ODF detected this species on multiple trail cameras deployed at two survey sites within one survey area on ODF managed lands located south of Winchester Bay in the Central Coastal Oregon Extant Population Area (Douglas County). ODF trail cameras did not detect this species at the other survey area located in the permit area in the Upper West Fork Cow Creek Basin (Coos County; outside of the Southern Coastal Extant Population Area). Beyond surveys, a roadkill marten was located adjacent to ODF managed lands near highway 101 in 2015. The roadkill location is within 500 meters of the 2023 trail camera locations that detected marten presence.

Natural History

This section includes information on closely related Pacific marten and American marten when information is not available for coastal marten, as provided in the USFWS Species Status Summary (2023). In those cases, natural history is described for “martens” to distinguish from data on coastal marten.

Martens have three life stages (Strickland et al. 1982):

- Kits from birth until approximately 6 months of age when they begin dispersing from their natal habitat.
- Juveniles from approximately 6 months until 2 years of age when they begin reproducing.
- Adults after they become reproductive, with a lifespan generally less than 5 years.

These terms are applied in the following sections to describe life stage-specific natural history.

Habitat Requirements

Pacific and American martens have been shown to select habitat at four spatial scales (USFWS 2018). USFWS characterizes habitat for coastal martens at these primary spatial scales, including the microhabitat, stand, home range, and landscape scales.

Microhabitat-Scale

At the microhabitat scale, martens select habitat with suitable resting and denning structures. Structures used by coastal martens for resting include large-diameter trees with large horizontal limbs, cavities in snags, and downed hollowed logs (Slauson and Zielinski 2009; Moriarty et al. 2017; Tweedy 2018). Coastal martens in the dune habitat of the Central Coastal Oregon Extant Population Area use squirrel nests in trees, branches, and basal hollows from overturned trees for resting habitat (Moriarty pers. comm., as cited in USFWS 2023).

Kits are born in a natal den and are subsequently moved to maternal dens (Buskirk and Ruggiero 1994). Dens provide shelter from weather and predators. Coastal martens tend to den in cavities in large, live and dead trees, as well as hollow logs, under rocks, log piles and squirrel nests (Slauson and Zielinski 2009; Thompson et al. 2012; Moriarty et al. 2017).

Stand-Scale

At the stand scale, martens select forest stands that provide structural features adequate to support one or more life-history requirements, such as enough food, large logs to run along when foraging for prey, and cavities.

Coastal martens in the Southern Coastal Oregon Extant Population Area use conifer-dominated forests with large, live trees (>51 centimeters diameter at breast height [dbh]) and extensive, ericaceous shrub cover dominated by evergreen huckleberry (*Vaccinium ovatum*) and salal (*Gaultheria shallon*) and large to very large snags and logs (e.g., >51 and >76 centimeters, respectively, and dbh for snags and trees) (Moriarty et al. 2019). Douglas-fir, Sitka spruce (*Picea sitchensis*), and western hemlock (*Tsuga heterophylla*) tend to dominate the overstory (Moriarty et al. 2019).

A coastal marten habitat distribution model for the Southern Coastal Oregon Extant Population Area predicts that stands with the highest value are neither young nor old, and predict highest habitat values for moderate tree diameter, height, diversity indices, and expected number of large trees. Based on their findings, Moriarty et al. (2019) recommend harvest practices that retain and recruit large trees and snags, encourage dense growth of salal and evergreen huckleberry shrubs, and retain or increase large downed woody material.

Coastal martens in the Southern Coastal Oregon Extant Population Area also occur in forests and shrub-dominated habitats on serpentine soils interspersed among more productive, non-serpentine soil, conifer-dominated habitats (Moriarty et al. 2019). Serpentine soils are derived from weathered ultramafic rock such as serpentinite, dunite, and peridotite, and are characterized by low plant growth and productivity, and generally have lower amounts of vegetation cover (McNaughton 1968). Serpentine habitats are more common in the California Extant Population Areas; there is little information on their use in Oregon. In California, serpentine habitats where coastal martens occur have conifer-dominated overstories, including lodgepole pine (*Pinus contorta* spp. *murrayana*), western white pine (*P. monticola*), and Douglas-fir. Serpentine habitat stands used by coastal martens can be of any seral stage and generally have a low basal area of trees and a high density of shrubs (Zielinski et al. 2001).

Coastal martens in the Central Coastal Oregon Extant Population Area occupy shore pine (*Pinus contorta* spp. *contorta*) and transitional shore pine—Douglas-fir hemlock forests less than 70 years old. These forests grow on nutrient-poor, sandy soils dominated by stands of Sitka spruce and shore pine less than 70 years old. Stands are composed of small-diameter trees and have few snags or downed logs (Moriarty et al. 2019). Occupied stands have a dense understory dominated by willow (*Salix hookeri*), Pacific waxmyrtle (*Myrica californica*), evergreen huckleberry, and salal (USFWS 2018; Moriarty et al. 2019). Compared to the Southern Coastal Oregon Extant Population Area, the Central Coastal Oregon Extant Population Area has more variable canopy cover, smaller trees, and fewer and smaller snags and downed logs. Occupied sites in the Central Coastal Oregon Extant Population Area have high shrub cover, though lower than the occupied sites in the Southern Coastal Oregon Extant Population Area, but higher fruit-bearing shrub cover than the Southern Coastal Extant Population Area (Moriarty et al. 2019).

Home-Range-Scale

At the home-range-scale, martens select enough habitat to meet their year-round life-history needs, such as home ranges with enough sources of seasonally available food to ensure food is available year-round, den sites, and access to mates while not overlapping with same-sex individuals (Karnik et al. 1994; Powell 1994). Types of structures needed for resting, denning, and foraging can vary within season, so a diversity of resting structures in a home range is important. Because only females raise young, they must have access to enough prey to support the nutrition and energetic demands of lactation and provide food for kits (USFWS 2023).

Landscape-Scale

The distribution of habitat patches large enough to support multiple home ranges in the landscape affects habitat selection and the ability of martens to disperse to new, suitable home ranges. Dispersal habitat is habitat that improves connectivity between larger habitat patches while providing adequate prey and cover from predators to facilitate successful movement between habitat patches (USFWS 2023).

Martens are susceptible to habitat loss and fragmentation; populations can become extirpated locally when as little as 25–33% of forest cover in a landscape is removed (Hargis et al. 1999; Potvin et al. 2000; Fuller 2006). There are little data on the effects of habitat distribution at the landscape-scale for coastal martens in Oregon; however, other North American martens select habitat based on the amount of habitat available in the landscape (e.g., Potvin et al. 2000; Kirk and Zielinski 2009) and size of available patches (e.g., Chapin et al. 1998; Slauson et al. 2007).

Diet

Coastal martens are dietary generalists, with types of food eaten depending on seasonal availability. Analysis of coastal marten diet is limited to scats collected in central coastal Oregon and northern coastal California populations. In central coastal Oregon populations, coastal martens were found to primarily consume mammals (mostly voles), birds, and berries. Berries were found in most scats collected in fall and winter (100% and 86% of the 90 scats collected, respectively), and mammals were found in scats collected throughout the sampling period (Eriksson et al., in review, as cited in USFWS 2023). Analysis of a larger number of scats (420) in northern coastal California from July to November found mammals in most scats, as well as berries, birds, insects, and reptiles (93%, 85%, 21%, 20%, and 7% of the scats, respectively). Squirrels (*Sciuridae*) and mice (*cricketid*) were the primary mammals consumed (Slauson and Zielinski, in press, as cited in USFWS 2018).

Many of the important prey species are at highest densities in structurally complex forests characteristic of older forests. For example, dense shrub layers provided by ericaceous shrubs are positively correlated with chipmunk density in coastal Oregon and other coastal marten prey species in Oregon coastal dune forests (Hayes et al. 1995; Eriksson et al., in review, as cited in USFWS 2023).

Reproduction

North American martens are polygamous, with only females responsible for raising young. Information on the timing of mating is primarily from captive martens, but mating is believed to occur from late June to early August, peaking in July (Markley and Bassett 1942, as cited in USFWS 2023). Delayed implantation results in females giving birth the following March and April.

Females do not mate until they are 15 months old, and with delayed implantation, do not give birth to their first litter until they are at least 24 months old. Not all female martens of reproductive age give birth in a year (Thompson and Colgan 1987; Slauson 2017). The limited data for coastal martens indicate that 80% of females are reproducing, with a mean litter size of 1.8 kits (USFWS 2023). Due to delayed implantation, and with a life span of generally less than 5 years, approximately 10% of a marten population is reproducing for more than 3 years, contributing to a slow reproductive output (USFWS 2023).

Movement

American martens disperse from their natal home range at around 6 months of age. Juvenile Humboldt martens in northern California disperse as early as August and can continue through the following summer (Slauson and Zielinski, unpublished data, as cited in USFWS 2018). The timing of juvenile dispersal in coastal martens in Oregon is likely similar to coastal martens in northern coastal California. Once juveniles disperse and settle into new habitat, they tend to remain in their home ranges (USFWS 2018).

Most studies have found juvenile martens disperse less than 15 kilometers (e.g., Broquet et al. 2006; Pauli et al. 2012; Slauson 2017), though martens have been reported to disperse more than 70 kilometers (e.g., Fecske and Jenks 2002). Limited dispersal data on coastal martens suggest similar dispersal distances (Slauson pers. comm., as cited in USFWS 2023).

Habitat quality and the spatial distribution of higher-quality habitat affects marten movement. For example, forest thinning to reduce fuel load affected habitat selection and movement by Pacific martens in the Lassen National Forest in California. Martens generally avoided thinned stands with simplified structure and openings. When martens used thinned stands, they tended to move faster and more directly; movements consistent with predator avoidance or low resource availability (Moriarty et al. 2016b). Martens tend to travel faster and longer in unlogged versus logged forests in Canada and have higher mortality in logged forests (Johnson 2008). Martens in Canada have also been shown to have greater foraging efficiency (Andruskiw et al. 2008), longer dispersal distances, and higher likelihood of surviving to adulthood in unlogged landscapes (Johnson et al. 2009).

Ecological Relationships

Coastal martens exhibit intrasexual territoriality, where dominant males maintain home ranges that moderately overlap one or more female's home range (Moriarty et al. 2017). Coastal martens move regularly within their home range, maintaining the boundaries of their territories (Moriarty et al. 2017). Males have larger home ranges than females (Moriarty et al. 2017). Individuals in the Central Coastal Oregon Extant Population Area have the smallest home ranges reported for martens in North America. Three females were found to have a mean territory size of 0.84 km² and three males had a mean territory size of 3.06 km² (Moriarty et al. 2017). In a different study in the same Extant Population Area, seven females had a mean home range of 0.8 km² and four males had a mean home range of 1.5 km² (Linnell et al. 2018). Home ranges in the Southern Coastal Oregon Extant Population Area and northern California include large patches (median >1.5 km²) of older forests and serpentine habitats and a high amount of vegetation cover (Slauson 2003; Slauson et al. 2007; Linnell et al. 2018). In the Northern Coastal California Extant Population Area, coastal martens have been found to select the largest available patches with old-growth, late-mature, or serpentine habitat (Slauson et al. 2007).

Martens are susceptible to predation by animals such as bobcat (*Felis rufus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), fishers (*Pekania pennant*), and great horned owl (*Bubo virginianus*) (Thompson 1994; Lindstrom et al. 1995; Bull and Heater 2001; McCann et al. 2010).

Competition with other carnivores such as fisher, bobcat, gray fox (*Urocyon cinereoargenteus*), and coyote can restrict marten habitat use. In the Sierra Nevada in California for example, competition with fisher affects marten activity and access to parts of their home range (Zielinski et al. 2017). The effects of competition are likely greater in areas with moderate-high severity fires or intensive logging has removed structural complexity necessary for foraging and cover by martens (USFWS 2023).

Population Status

As described above, coastal martens exist in four small (<100 individuals) populations. A landscape habitat suitability model predicts that there is little habitat connectivity between the Oregon populations, though there is some potential habitat connectivity between the Southern Coastal Oregon and Northern Coastal California populations (Slauson et al. in review, and Slauson et al. in press, as cited in USFWS 2023).

The following is a summary of the population status for the DPS.

- **Central Coastal Oregon Extant Population Area.** There are approximately 71 adults in this Extant Population Area, with approximately 30 adults each in the two subpopulations separated by the Umpqua River (Linnell et al. 2018). There is no information on long-term trends in population size (USFWS 2018). This population has the highest density (1.13 martens/1 km²) reported for North American martens (Linnell et al. 2018).
 - Using a population viability analysis, Linnell et al. (2018) assessed extinction risk for a subpopulation of 30 coastal martens. Extinction risk ranged from 32% to 99% within 30 years assuming two or three annual human-caused mortalities, such as vehicle strikes or trapping. The authors concluded that, other than efforts to expand the population, reducing human-caused mortalities would have the greatest impact on conservation.
 - The mature forest to the east of the Central Coastal Oregon Extant Population Area does not support a population of coastal martens and factors limiting coastal martens from expanding a population into these forests is unknown (Moriarty et al. 2016a; Linnell et al. 2018).
- **Southern Coastal Oregon Extant Population Area.** This Extant Population Area likely contains 100 or fewer individuals (Slauson pers. comm., as cited in USFWS 2018; Moriarty pers. comm., as cited in USFWS 2023). Most detections occurred on the Rogue River–Siskiyou National Forest (Moriarty et al. 2016a).
- **California–Oregon Border Extant Population Area.** There is no estimate of the size of this population, though given the small size of the Extant Population Area the area likely supports fewer than 100 individuals (Slauson pers. comm., as cited in USFWS 2023).
- **Northern Coastal California Extant Population Area.** This is the most surveyed Extant Population Area. The Extant Population Area includes approximately 60 to 80 individuals as of 2012, fewer than the greater than 100 individuals estimated in the area in 2008 (USFWS 2023).

Threats

Small home range, population size, and restricted distribution make coastal martens vulnerable to events that could severely reduce population size. USFWS identified threats directly and indirectly affecting coastal martens (USFWS 2023). Direct effects are those that cause direct mortality, including trapping, vehicle collisions, poisoning from rodenticides, predation, and disease. Indirect effects are those primarily affecting coastal marten habitat, including wildfire, disturbances to vegetation from causes other than wildfire (e.g., timber harvest), climate change, and tsunamis.

Trapping

Trapping in the early 20th century is considered the primary reason for initial coastal marten range contraction (Zielinski et al. 2001). A small number of trappers currently pursue martens (around four to eight each year), with most martens harvested in the Cascades. Harvest of coastal martens in Oregon is infrequent: 35 martens were harvested in coastal Oregon between 1969 and 1995 (USFWS 2015) and 13 were harvested in coastal Oregon from 1989 to 2016 (Broman pers. comm., as cited in USFWS 2023). However, as described above, as few as two to three human-caused mortalities per year can lead to a high risk of extinction for a small population of coastal martens (Linnell et al. 2018).

Vehicle Strikes

Coastal martens are susceptible to mortality from vehicle strikes. Since 1980, 19 deaths caused by vehicles have been documented, all in Oregon, and most in or adjacent to the central coastal Oregon population or the general central Oregon coast area along U.S. Highway 101 (USFWS 2023). The central coastal Oregon population remains the most susceptible to vehicle strikes due to the proximity of U.S. Highway 101. USFWS considers traffic on forest roads to be a low risk to martens due to slow travel speeds and low levels of traffic (USFWS 2023).

Rodenticides

Exposure to rodenticides results from direct ingestion or by eating prey that consumed rodenticides. Coastal martens may ingest rodenticides such as strychnine and zinc phosphides, which are the rodenticides most commonly used in forest lands. In Oregon, a special use label on the anticoagulant chlorophacinone allows the use of chlorophacinone to control mountain beavers (*Aplodontia rufa*). Illegal marijuana cultivation is another source of the rodenticide (USFWS 2023).

Landscape-level changes in forest composition within the range of coastal martens has likely caused an increase in the species' depredation (USFWS 2023). Bobcats are the primary predator of coastal martens, and bobcats prefer regenerating harvest stands less than 30 years old and are almost absent from unfragmented conifer forest landscapes comprised preferred by martens (Powell et al. 2003; Linnell et al. 2018; Slauson et al., in press, as cited in USFWS 2023).

Disease

Martens are susceptible to diseases, including canine distemper viruses, rabies, viruses, parvoviruses, and the protozoan *Toxoplasma gondii*. Given the small size of the coastal marten populations, disease could have a catastrophic effect. Most of what is known about the presence or exposure to pathogens in coastal martens comes from 19 blood samples taken from the Central Coastal Oregon Extant Population Area. None of the samples taken were positive for canine distemper viruses, 5 had antibodies for canine parvovirus, and 14 had antibodies for *T. gondii* (Moriarty 2017, unpublished data, as cited in USFWS 2023).

Wildfire

Wildfire is a natural disturbance that helps maintain structural features and conditions of coastal marten habitat (e.g., snags, down logs, canopy structure). Low severity fire regimes are most prevalent in the southwestern portion of the coastal marten range in Oregon. This type of wildfire occurs every 5 to 25 years (Arno 2000), does not kill the overstory trees, and causes little structural damage to dominant vegetation, though it can reduce shrub cover important for coastal martens (USFWS 2023).

Moderate to high-severity wildfire regimes affect stand structure and can eliminate important structural habitat features that provide cavities and resting platforms (e.g., snags, downed logs, large trees). These types of fires occur infrequently (200 to 500 years in wetter forests [Arno 2000]). This type of fire regime occurs in much of the central coastal Oregon portion of the coastal marten range. The two Oregon Extant Population Areas have been subject to fewer large fires between 1987 and 2016 than the two California Extant Population Areas (USFWS 2023). Relatively recent fires that reduced habitat include the 2002 Biscuit Fire and the 2017 Chetco Bar Fire.

Timber Harvest

Changes in forest vegetation composition, age, and structure from timber harvest affects the quality, quantity, and distribution of coastal marten habitat. Timber harvests that reduce conifer forest structural complexity or the extent of the shrub layer increase fragmentation of habitat and reduce size of forest patches, affecting habitat quality or eliminating habitat entirely. While shrub cover develops post-harvest, the simple structure and species composition of post-harvest shrub cover is often not representative of the complex shade-tolerant shrub cover characteristic of coastal marten forest or coastal dune forest habitat (Slauson et al. 2007; USFWS 2023).

Intensively managed regenerating stands generally lack key habitat elements in great enough quantity to support coastal martens. Those habitat elements include resting and denning structures and dense ericaceous shrub cover (Slauson and Zielinski 2007; Slauson et al. 2010; USFWS 2023). Vegetation management practices in addition to harvest, such as thinning and fuel reduction, can also reduce habitat quality if they reduce structural complexity and remove key habitat features. Thinning, fuel reduction, and forest habitat restoration, however, can improve habitat quality in the long term if managed to accelerate development of late seral forest characteristics (Moriarty et al. 2016b; USFWS 2023).

Climate Change

Climate change is projected to cause warmer temperatures and a slight increase in precipitation in coastal Oregon; summers are expected to be warmer and dryer, with more extreme heat and precipitation events. With a changing climate, the distribution and type of vegetation communities are predicted to change. In coastal Oregon, the range and extent of temperate conifer forests is projected to shrink and be replaced by mixed evergreen forests. Coastal martens occupy both forest types, so the region is expected to continue to support suitable habitat conditions (Lenihan et al. 2008; Shafer et al. 2010; Dalton et al. 2017; USFWS 2023).

Climate change is also projected to affect other disturbance regimes that could, in turn, affect coastal martens. For example, warmer, drier summers and longer fire seasons could result in more frequent large fires that could burn large swaths of habitat. Warmer temperatures and more frequent drought could increase susceptibility of trees to insects and pathogens, resulting in an increase in damage to trees, which can affect forest structure and composition, and possibly reduce habitat quality and quantity for coastal martens (USFWS 2023).

Martens in North America are projected to shift ranges northward over the next century in response to climate change (Lawler et al. 2012). Fragmentation and landscape-level loss of coastal marten habitat could make dispersal to shifting habitats challenging (USFWS 2023).

Literature Cited

- Andruskiw, M., J. M. Fryxell, I. D. Thompson, and J. A. Baker. 2008. Habitat-Mediated Variation in Predation Risk by the American Marten. *Ecology* 89:2273–2280.
- Arno, S. F. 2000. Fire in Western Forest Ecosystems. Pages 97–120 in J. K. Brown and J. K. Smith (eds.), *Wildland Fire in Ecosystems: Effects of Fire on Flora*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

- Broquet, T., C. A. Johnson, E. Petit, I. Thompson, F. Burel, and J. M. Fryxell. 2006. Dispersal and Genetic Structure in the American Marten, *Martes americana*: Marten Dispersal and Genetic Structure. *Molecular Ecology* 15:1689–1697.
- Bull, E. L., and T. W. Heater. 2001. Survival, Causes of Mortality, and Reproduction in the American Marten in Northeastern Oregon. *Northwestern Naturalist* 82:1–6.
- Buskirk, Steven W.; Ruggiero, Leonard F. 1994. Chapter 2: American marten. Pages 7–37 in Leonard F. Ruggiero, Keith B. Aubry, Steven W. Buskirk, L. Jack Lyon, and William J. Zielinski (tech. eds.), *The Scientific Basis for Conserving Forest Carnivores: American Marten, Fisher, Lynx, and Wolverine in the Western United States*. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.
- Chapin, T. G., D. J. Harrison, and D. D. Katnik. 1998. Influence of Landscape Pattern on Habitat Use by American Marten in an Industrial Forest. *Conservation Biology* 12:1327–1337.
- Dalton, M. M., K. D. Dello, L. Hawkins, P. W. Mote, and D. E. Rupp. 2017. *The Third Oregon Climate Assessment Report*. Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR.
- Fecske, D. M., and J. Jenks. 2002. *Dispersal by a Male American Marten, Martes americana*.
- Fuller, A. K. 2006. *Multi-Scalar Responses of Forest Carnivores to Habitat and Spatial Pattern: Case Studies with Canada Lynx and American Martens*. Dissertation, University of Maine, Orono, Maine.
- Hargis, C. D., J. A. Bissonette, and D. L. Turner. 1999. The Influence of Forest Fragmentation and Landscape Pattern on American Martens. *Journal of Applied Ecology* 36:157–172.
- Hayes, J. P., E. G. Horvath, and P. Hounihan. 1995. Townsend's Chipmunk Populations in Douglas-fir Plantations and Mature Forests in the Oregon Coast Range. *Canadian Journal of Zoology* 73:67–73.
- Johnson, C. A. 2008. *Mammalian Dispersal Behavior and its Fitness Correlates*. Ph.D. dissertation, University of Guelph, Guelph, ON, Canada.
- Johnson, C. A., J. M. Fryxell, I. D. Thompson, and J. A. Baker. 2009. Mortality Risk Increases with Natal Dispersal Distance in American Martens. *Proceedings of the Royal Society B: Biological Sciences* 276:3361–3367.
- Katnik, D. D., D. J. Harrison, and T. P. Hodgman. 1994. Spatial Relations in a Harvested Population of Martens in Maine. *Journal of Wildlife Management* 58:600–607.
- Kirk, T. A., and W. J. Zielinski. 2009. Developing and Testing a Landscape Habitat Suitability Model for the American Marten (*Martes americana*) in the Cascades Mountains of California. *Landscape Ecology* 24:759–773.
- Lawler, J., H. D. Safford, and E. H. Girvetz. 2017. *Martens and Fishers in a Changing Climate. Biology and Conservation of Martens, Sables, and Fishers: A New Synthesis*.
- Lawler, J. J., H. D. Safford, and E. H. Girvetz. 2012. Martens and Fishers in a Changing Climate. Pages 371–397 in K. B. Aubry, W. J. Zielinski, M. G. Raphael, G. Proulx, and S. W. Buskirk (eds.), *Biology*

and Conservation of Martens, Sables, and Fishers: A New Synthesis. Cornell University Press, Ithaca, New York, USA.

- Lenihan, J. M., D. Bachelet, R. Neilson, and Drapek. 2008. Simulated Response of Conterminous United States Ecosystems to Climate Change at Different Levels of Fire Suppression, CO₂ Emission Rate, and Growth Response to CO₂. *Global Planetary Change* 64:16–25.
- Lindstrom, E. R., S. M. Brainerd, J. O. Helldin, and K. Overskaug. 1995. Pine Marten - Red Fox Interactions: A Case of Intraguild Predation? *Annales Zoologici Fennici* 32:123–130.
- Linnell, M. A., K. Moriarty, D. S. Green, and T. Levi. 2018. Density and Population Viability of Coastal Marten: A Rare and Geographically Isolated Small Carnivore. *PeerJ* 6:e4530.
- Markley, M. H., and C. F. Bassett. 1942. Habits of Captive Marten. *The American Midland Naturalist* 28:604–616.
- McCann, N. P., P. A. Zollner, and J. H. Gilbert. 2010. Survival of Adult Martens in Northern Wisconsin. *Journal of Wildlife Management* 74:1502–1507.
- McNaughton, S. J. 1968. Structure and Function in California Grasslands. *Ecology* 49:962–972.
- Moriarty, K. M., J. D. Bailey, S. E. Smythe, and J. Verschuyt. 2016a. Distribution of Pacific Marten in Coastal Oregon. *Northwestern Naturalist* 97:71–81.
- Moriarty, K. M., C. W. Epps, and W. J. Zielinski. 2016b. Forest Thinning Changes Movement Patterns and Habitat Use by Pacific Marten: Marten Behavior Affected by Structure. *The Journal of Wildlife Management* 80:621–633.
- Moriarty, K. M., M. A. Linnell, B. E. Chasco, C. W. Epps, and W. J. Zielinski. 2017. Using High-Resolution Short-Term Location Data to Describe Territoriality in Pacific Martens. *Journal of Mammalogy* 98:679–689.
- Moriarty KM, Verschuyt J, Kroll AJ, Davis R, Chapman J, Hollen B. 2019. Describing Vegetation Characteristics Used by Two Rare Forest-Dwelling Species: Will Established Reserves Provide for Coastal Marten in Oregon? *PLoS ONE* 14(1): e0210865.
<https://doi.org/10.1371/journal.pone.0210865>
- Pauli, J. N., W. P. Smith, and M. Ben-David. 2012. Quantifying Dispersal Rates and Distances in North American Martens: A Test of Enriched Isotope Labeling. *Journal of Mammalogy* 93:390–398.
- Potvin, F., L. Bélanger, and K. Lowell. 2000. *Marten Habitat Selection in a Clearcut Boreal Landscape* 14.
- Powell, R. A. 1994. Structure and Spacing of *Martes* Populations. Pages 101–121 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell (eds.), *Martens, Sables and Fishers: Biology and Conservation*. Cornell University Press, Ithaca, NY.
- Powell, R. A., S. W. Buskirk, and W. J. Zielinski. 2003. Fisher and Marten (*Martes pennanti* and *Martes americana*). Pages 635–649 in G. Feldhamer, B. Thompson, and J. Chapman (eds.), *Wild Mammals of North America*, 2nd Edition. Johns Hopkins University Press, Baltimore, MD, USA.
- Schwartz et al. 2016

- Shafer, S. L., M. E. Harmon, R. P. Neilson, R. Seidl, B. St. Clair, and A. Yost. 2010. The Potential Effects of Climate Change on Oregon's Vegetation. Pages 173–208 in K. D. Dello and P. W. Mote (eds.), *Oregon Climate Assessment Report*. Oregon Climate Change Research Institute. College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR.
- Slauson, K. M. 2003. *Habitat Selection by American Martens (Martes americana) in Coastal Northwestern California*. M.S. thesis, Oregon State University, Corvallis, OR.
- Slauson, K. M. 2017. *Linking Landscape Pattern to Population Processes in a Carnivorous Mammal*. Ph.D. dissertation, University of Montana, Missoula, MT.
- Slauson, K. M., and W. J. Zielinski. 2007. The Relationship Between the Understory Shrub Component of Coastal Forests and the Conservation of Forest Carnivores. Pages 241–243 in G. A. Standiford, G. A. Giusti, Y. Valachovic, W. J. Zielinski, and W. J. Furniss (eds.), *Proceedings of the Redwood Region Forest Science Symposium: What Does the Future Hold?* U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. Albany, CA.
- Slauson, K. M., and W. J. Zielinski. 2009. Characteristics of Summer and Fall Diurnal Resting Habitat Used by American Martens in Coastal Northwestern California. *Northwest Science* 83:35–45.
- Slauson, K. M., W. J. Zielinski, and J. P. Hayes. 2007. Habitat Selection by American Martens in Coastal California. *Journal of Wildlife Management* 71:458–468.
- Slauson, Keith M.; Zielinski, William J.; Stone, Karen D. 2009. Characterizing the Molecular Variation Among American Marten (*Martes americana*) Subspecies from Oregon and California. *Conservation Genetics* 10(5):1337–1341.
- Slauson, K. M., W. J. Zielinski, and T. A. Kirk. 2010. *Effects of Forest Restoration on Mesocarnivores in the Northern Redwood Region of Northwestern California*. Unpublished final report. On file with U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521.
- Strickland, M. A., C. W. Douglas, M. Novak, and N. P. Hunzinger. 1982. Marten (*Martes americana*). Pages 599–612 in J. A. Chapman and G. A. Feldhamer (eds.), *Wild Mammals of North America: Biology, Management and Economics*. Johns Hopkins University Press, Baltimore, MD, USA.
- Thompson, C., and P. W. Colgan. 1987. Numerical Responses of Martens to a Food Shortage in North-Central Ontario. *Journal of Wildlife Management* 51:824–835.
- Thompson, I. D. 1994. Marten Populations in Uncut and Logged Boreal Forests in Ontario. *Journal of Wildlife Management* 58:272–280.
- Thompson, I. D., J. Fryxell, and D. J. Harrison. 2012. Improved Insights into Use of Habitat by American Martens. Pages 209–230 in K. Aubry, W. Zielinski, M. Raphael, G. Proulx, and S. W. Buskirk (eds.), *Biology and Conservation of Martens, Sables, and Fishers: A New Synthesis*. Cornell University Press, Ithaca, NY.
- Tweedy, P. J. 2018. *Diel Rest Structure Selection and multiscale Analysis of Pacific Marten Resting Habitat in Lassen National Forest, California*. M.S. thesis, Oregon State University, Corvallis, OR.
- U.S. Fish and Wildlife Service (USFWS). 2015. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition To List Humboldt Marten as an Endangered or Threatened Species. *Federal Register* 80:18742–18772.

- U.S. Fish and Wildlife Service (USFWS). 2023. *Species Status Assessment for the Coastal Marten (Martes caurina) Version 2.2*. U.S. Fish and Wildlife Service, Arcata, CA.
- U.S. Fish and Wildlife Service (USFWS). 2026. Species Status Assessment for the Coastal Marten (*Martes caurina*). Version 3.0. January 2026. U.S. Fish and Wildlife Service. Region 8. Arcata, CA.
- Zielinski, W. J., K. M. Slauson, C. R. Carroll, C. J. Kent, and D. G. Kudrna. 2001. Status of American Martens in Coastal Forests of the Pacific States. *Journal of Mammalogy* 82:478–490.
- Zielinski, W. J., J. M. Tucker, and K. M. Rennie. 2017. Niche Overlap of Competing Carnivores Across Climatic Gradients and the Conservation Implications of Climate Change at Geographic Range Margins. *Biological Conservation* 209:533–545.

C16 Marbled Murrelet (*Brachyramphus marmoratus*)

Legal Status

State: Listed as Threatened in 1995.
Reclassified as Endangered in 2021

Federal: Threatened, listed in 1992

Critical Habitat: 2016 (81 *Federal Register* [FR] 51348)

Recovery Planning: September. 24, 1997



Photo: USFWS

Taxonomy

The marbled murrelet (*Brachyramphus marmoratus*) is a small sea bird that belongs to the Alcidae, or auk family. There are three recognized species within the *Brachyramphus* genus: (1) the marbled murrelet, which breeds in the western North America; (2) the long-billed murrelet (*B. perdix*), which breeds in eastern Asia; and (3) the Kittlitz's murrelet (*B. brevirostris*), which breeds in Russia and Alaska.

Researchers have found significant genetic distinction throughout the marbled murrelet's range, and the species appear to be composed of three genetic units: (1) western and central Aleutian Islands, (2) eastern Aleutian Islands to northern California, and (3) central California (Friesen et al. 2007). The U.S. Fish and Wildlife Service (2009) considers the Washington, Oregon, and California population of murrelet to be a valid distinct population segment (DPS) under the 1996 DPS Policy. The population of murrelets in Washington, Oregon, and California are considered discrete based on differences in conservation status, management of habitat, and regulatory mechanisms between the United States and Canada that would result without the federal protective measures afforded by the Endangered Species Act. The U.S. Fish and Wildlife Service also considers the coterminous United States murrelet population as significant in accordance with the criteria of the DPS Policy.

Distribution

General

Marbled murrelet breed along the Pacific coast of North America from the Bering Sea to the Santa Cruz mountains of California (Ralph et al. 1995; Burger 2002; Piatt et al. 2007). The center of population is in the northern part of southeast Alaska (Ralph et al. 1995) with large numbers of murrelets occurring in the Kodiak Archipelago, Prince William Sound, and the Alexander Archipelago, south along the coast to British Columbia (Piatt et al. 2007). The marbled murrelet

population becomes more disjunct and sparse at the northern and southern range limits (Ralph et al. 1995; McShane et al. 2004). Within the range, there are large distribution gaps (Ralph et al. 1995; USFWS 2012). The murrelet winters throughout its breeding range south to southern California or northern Baja California (McShane et al. 2004; Piatt et al. 2007).

The USFWS has designated five recovery zones for marbled murrelet, ranging from San Francisco Bay to the Canada border with Washington State (Figure C16-1). Falxa and Raphael (2016) reported marbled murrelet population estimates in each zone as follows:

- 7,600 marbled murrelets in the Strait of Juan de Fuca, San Juan Islands, and Puget Sound in Washington (Zone 1).
- 2,000 marbled murrelets on the outer coast of Washington (Zone 2).
- 7,600 marbled murrelets from Coos Bay, Oregon, north to the Columbia River (Zone 3, which includes the HCP plan area).
- 6,600 marbled murrelets from Shelter Cove, California, north to Coos Bay, Oregon (Zone 4).
- “few” marbled murrelets remaining from San Francisco Bay north to Shelter Cove, California (Zone 5).

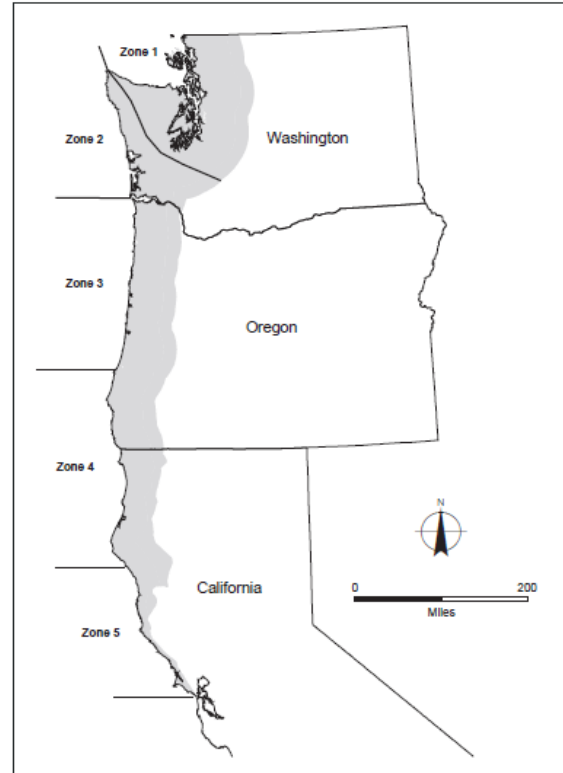


Figure C16-1. Marbled Murrelet Recovery Zones (from Falxa and Raphael 2016)

At the state scale, Falxa and Raphael (2016) found populations to be declining in Washington (4.6% decline per year), but no evidence of a trend in Oregon or California (Zone 4). Based on at-sea data, marbled murrelet populations in Oregon are highest in the central portion of the Coast Range near the Elliott State Research Forest and the Siuslaw National Forest, corresponding closely to the amount of habitat available inland from these at-sea foraging areas.

Occurrences Within the Plan Area

Historical

The marbled murrelet in Oregon is found mainly in the Coast Range and Klamath physiographic provinces (ODFW 2018). The species has been detected up to 80 miles inland in Oregon (Nelson 1997), but most occupancy/nesting behaviors have been detected within 40 miles of the ocean (Mack et al. 2003). During the breeding season in Oregon (generally April through September), foraging murrelets remain within 1.2 miles of the shore (Strong et al. 1995; Falxa et al. 2016).

Recent

Within the permit area, marbled murrelet nesting is concentrated in the northwest portion of the permit area (i.e., the Tillamook and Astoria districts) and in the central Oregon Coast area (West Oregon District) near the Elliott State Forest and Siuslaw National Forest (Figure C16-2 and C16-3).

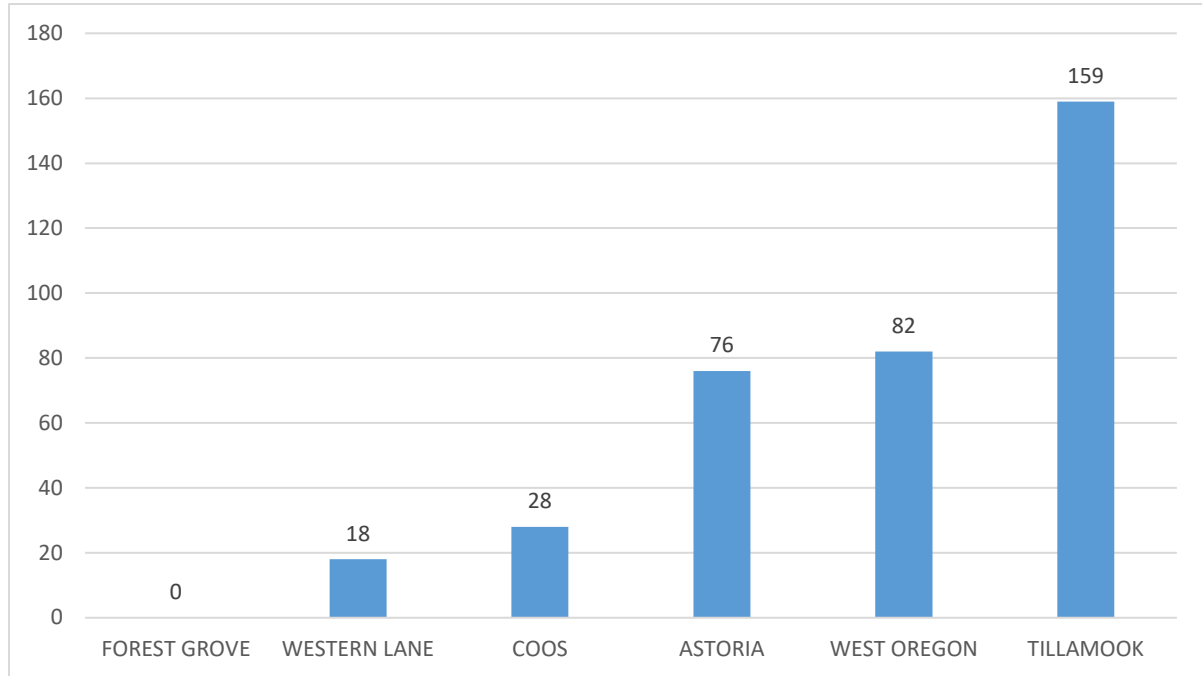


Figure C16-2. Number of Unique Sites with "Significant Observations" of Marbled Murrelets, by ODF District

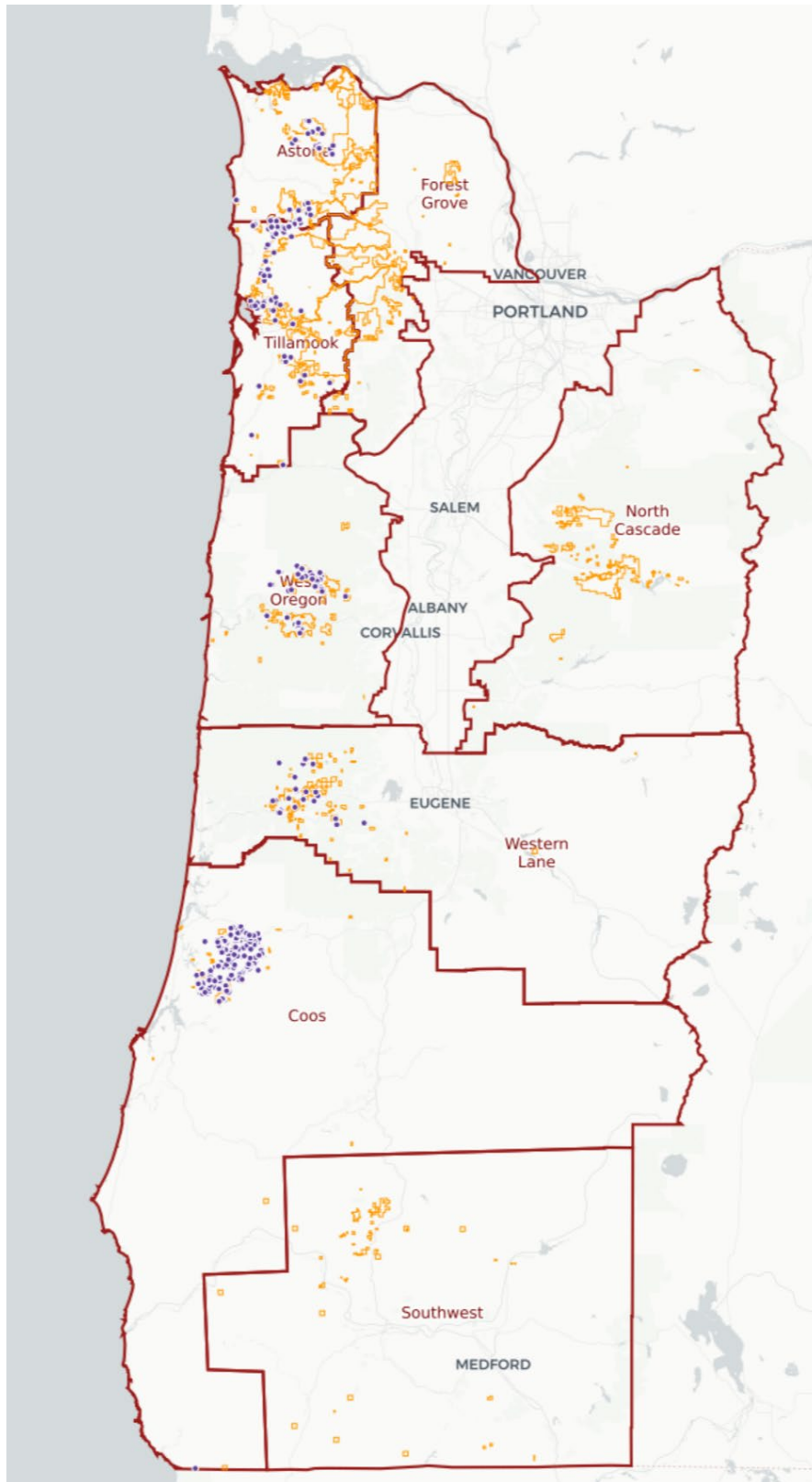


Figure C16-3. Location of Unique Sites with "Significant Observations" of Marbled Murrelets, by ODF District

Natural History

The ecology and status of marbled murrelet are reviewed in the Status Review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Oregon and Evaluation of Criteria to Reclassify the Species from Threatened to Endangered under the Oregon Endangered Species Act (ODFW 2018) and in Chapter 5 of the 2018 Forest Service Science Synthesis Report (Raphael et al. 2018).

Habitat Requirements

Nesting and Roosting Habitat

Unlike other alcids, which nest in dense colonies on the ground, in burrows, on rocky cliffs, and sea stacks at the marine-terrestrial interface, marbled murrelets nest in trees in dispersed locations up to 55 miles inland (Spies et al. 2018). Throughout the forested portion of the species' range murrelets typically nest in large conifers in late-successional forests. Murrelets in Washington, Oregon, and California nest in the major types of conifer forest wherever older forests remain inland of the coast at elevations below 4,000 feet (Raphael et al. 2018; Spies et al. 2018). Murrelets have also been observed nesting in young stands with suitable nesting substrates (e.g., legacy trees with large limbs, and mistletoe brooms) (ODFW 2018). Murrelet nesting habitat characteristics vary throughout its range; however, some general characteristics, such as the presence of nesting platforms, adequate canopy cover over the nest, large patch size of mature forest, and within commuting distance to the marine environment to allow foraging, are present throughout the species' range (McShane et al. 2004; Ralph et al. 1995; Spies et al. 2018).

Marbled murrelets do not construct nests and rely on the availability of platforms formed on large or deformed branches with moss or other thick substrate. In Washington, Oregon, and northern California, platforms usually are found on trees at least 19 inches in diameter at breast height and greater than 98 feet tall (Spies et al. 2018). In Oregon, typical nest trees include Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), or Sitka spruce (*Picea sitchensis*) (Raphael et al. 2018). However, marbled murrelets do not seem to preferentially select any particular tree species, and the nest tree species is usually the dominant species found within the area that provides suitable nest platforms and other preferred characteristics (ODFW 2018). Most nests have foliage cover above or to the side of the nest, and the platform must be large enough to support raising a nestling.

In his review of existing literature on nest trees across their range, Burger (2002) noted that, given a choice, it appears that marbled murrelets select nest trees with the following characteristics.

- Sufficient height to allow stall-landing and jump-off departures.
- Openings in the canopy for unobstructed flight access.
- Sufficient diameter to provide a nest site and landing platform.
- Some soft substrate to support a nest cup.
- Overhead foliage cover.

Between 1995 and 1999, Nelson and Wilson (2002, as cited in Wiekell 2018) studied the characteristics of marbled murrelet nesting habitat on Oregon state lands. This research confirmed that marbled murrelet select large conifer trees with numerous platforms for nesting. Nests were

predominately found in trees more than 200 years old (two or three nests were found in 140- to 170-year-old trees). The presence of platforms is considered the most important characteristic of murrelet nesting habitat (Burger 2002; McShane et al. 2004).

Throughout their range, marbled murrelets nest primarily in low-elevation coniferous forests within 52 miles of the coast (McShane et al. 2004; Nelson et al. 2006). In 1997 the U.S. Fish and Wildlife Service reported that marbled murrelets nest disproportionately on lower slopes and near streams with mean distance to streams in the Pacific Northwest of 509 feet (USFWS 1997); however, more recent studies suggest the slope, aspect, or other topographical features may be equivocal (Pillsner et al. 2015).

Diet

Marbled murrelet primarily forages on small schooling fish and marine invertebrates (e.g., krill) in the nearshore (within 3.1 miles of shore) marine environment. The species is described as a “flexible forager” and will feed on the most abundant, suitable prey items (Burkett 1995; Nelson 1997). Studies suggest there are seasonal and geographic variations in diet across the murrelet range, as well as differences between adult and chick diet. During the breeding season, fish are the dominant prey (Nelson 1997; Piatt et al. 2007). During the winter and spring, invertebrates are the dominant prey (Piatt et al. 2007). Freshwater prey, such as salmonids, are also consumed in inland nesting habitat where large lakes are abundant (McShane et al. 2004). Fish consumed by adults and subadults tend to be small larval or juvenile fish classes, and those fed to nestlings are larger subadults or adult fish (Piatt et al. 2007). Studies show long-term declines in murrelet diet quality in portions of its range in central California, the Salish Sea, northern Washington, and British Columbia (Raphael et al. 2018, as cited in Spies et al. 2018). Becker and Beissinger (2006) present evidence of a decline in the trophic level of the murrelet, suggesting an increased importance of krill in modern, compared with historic, prebreeding diets of marbled murrelets. Other studies suggest that declines in murrelet diet quality may contribute to reduced reproductive success (Raphael et al. 2018, as cited in Spies et al. 2018).

Marbled murrelets have been shown to primarily forage in nearshore marine waters less than 98 feet deep off the Oregon coast, but may be found farther offshore during the non-breeding season (ODFW 2018). Mathews and Burger (1998) estimate, based on the bird’s body size, the maximum diving depth is 154 feet. Marbled murrelet forage during the day, at dawn or dusk, solitarily or in groups; there is little evidence the species feeds at night (reviewed in ODFW 2018). Off the coast of Oregon, small groups of 2–3 murrelets have been observed (Strong et al. 1995), though aggregations comprising thousands of individuals have been observed in northern parts of the species range (Burkett 1995; Strachan et al. 1995).

Reproduction

Marbled murrelets have a long and asynchronous breeding season. In Oregon, Nelson and Hammer (1995) found the breeding period lasts up to 149 days, beginning in April and ending in September. Across the species’ range, timing of breeding varies with latitude and is affected by food availability, weather, and ocean conditions (ODFW 2018). Birds may also breed later or forego breeding altogether when food availability is poor.

Marbled murrelets are monogamous and courtship takes place at sea in early spring, throughout the summer, and in winter (ODFW 2018). In Oregon, pairs have been observed “prospecting” or visiting

potentially suitable nest trees prior to egg laying (Nelson and Wilson 2002). Copulation can take place in trees and on the water (Nelson 1997).

In some portions of the range, marbled murrelets start laying eggs in March, but they generally lay eggs from mid-May to mid-June, with some eggs laid as late as July. The clutch size is one, large egg. Incubation lasts approximately 30 days, with incubation shifts of 24 hours, shared equally by both sexes (Nelson 1997). Hatched chicks are semiprecocial and remain in the nest for approximately 3 weeks. The chick is left alone at the nest for most of the rearing period while both parents feed at sea (McShane et al. 2004). Adults commute to the nest up to 8 times per day, typically bringing one large fish to the chick on each trip (Nelson 1997). Feeding generally takes place at dawn or dusk but can occur during the day.

Young fledge between 27 to 40 days after hatching, from early July through early September. At fledging, young are believed to fly alone directly to the ocean; however, many are found grounded on the forest floor at varying distances from the ocean (as reviewed in ODFW 2018). No evidence of parental care has been documented once the young fledge (Nelson 1997). Renesting after early nest failure has been reported (Barbaree et al. 2014); however, evidence of a second brooding is lacking (McShane et al. 2004).

Site Fidelity

Marbled murrelets show highly variable home range sizes and nest-sea commuting distances; however, larger marine home ranges and commuting distances have been recorded in the federally listed range compared to Alaska (Lorenz et al. 2017).

McShane et al. (2004) suggest that marbled murrelets, like other alcids, show high philopatry (i.e., returning to breed where they hatched) and high site fidelity (i.e., typically breeding at the same location year after year). Strong nest-site fidelity in murrelets has been suggested by Divoky and Horton (1995), based on observations that murrelets have been observed in the same forest stands in California, Oregon, and Washington for over 20 years. Plissner et al. (2015) examined evidence of breeding site fidelity in the species at watershed-, stand-, tree-, and nest platform- levels. The study found consistent evidence of fidelity at the watershed scale and evidence of fidelity at the stand scale, fidelity at the tree scale was indicated from 19 of the 23 studies reviewed, and 13 of the 23 studies reviewed showed fidelity at the smaller scale of branch, nest-platform, or nest cup (Plissner et al. 2015). Plissner et al.'s review suggest areas used for nesting in one year are or can be occupied in subsequent years, but it is unknown whether these are the same birds or different individuals. Studies also suggest that nest site fidelity at the tree or nest platform may be lower in more contiguous habitat where suitable nest sites are more available (Burger et al. 2009).

Habitat Use and Selection

Marbled murrelets spend a lot of time in nearshore waters along exposed coastlines throughout their range, and in sheltered sounds and estuaries in Alaska, British Columbia, and Washington. Foraging, courtship, loafing, molting, and preening occur at sea (ODFW 2018).

Inland, murrelets use large coniferous trees for nesting, often in older forests. In Oregon, some nests have also been found in mature and young trees (66–150 years) containing older forest characteristics, such as platforms created by mistletoe infections or other deformities (Huff et al. 2006). The presence of platforms appears to be the most important stand characteristic for predicting murrelet occupancy of a given forest (Burger et al. 2002; McShane et al. 2004). Nesting in

trees is unique among North American alcids; nesting on open ground (particularly in western Alaska where trees are absent), on cliffs, in rock crevices, or rarely in deciduous trees has been documented in parts of the northern marbled murrelet range, but not in Washington, Oregon, or California (McShane et al. 2004; Piatt et al. 2007).

Predation

Predation, particularly by Steller's jays (*Cyanocitta stelleri*), American crows (*Corvus brachyrhynchos*), and common ravens (*C. corax*), is a leading cause of marbled murrelet nest failure. Piatt et al. (2007) also reports bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), northern goshawk (*Accipiter gentilis*), and sharp-shinned hawk (*A. striatus*) predation on adult murrelets. Other reported predators include mice, squirrels, Western gull (*Larus occidentalis*), and California sea lion (*Zalophus californianus*). The U.S. Fish and Wildlife Service (2009) reports corvids as having the greatest impact on the species, although recovering populations of peregrine falcon and bald eagles are identified as an emerging concern (USFWS 2012).

Higher predation rates and numbers are generally associated with human presence (activities, food sources, etc.). Where parks, trails, and campgrounds overlap with marbled murrelet habitat, it is expected that predation pressures will remain high or increase in the future. Studies have reported behavioral responses of murrelets to boat traffic and boat disturbance can disrupt foraging or resting birds on the water, potentially increasing energetic costs or displacing them from preferred at-sea areas (USFWS 2009).

Ocean Conditions

Oceanic conditions influence the availability, distribution, and timing of prey resources available to murrelets (Piatt et al. 2007). Prey availability and prey quality affect breeding success and survival. A shift in murrelet diet to lower, poor quality trophic levels has been documented in parts of the murrelet range (Lorenz et al. 2017). Lower reproductive success has been correlated to warmer water events and El Niño years.

Population Status and Trends

There is limited information on the historical distribution and numbers of marbled murrelets. Available data suggest major population declines over the last 150 years (McShane et al. 2004; Piatt et al. 2007), with the steepest decline during the period of industrial logging of most murrelet habitat from 1850–1980. Assessments suggest the global murrelet population is on the order of 300,000–400,000 individuals, with roughly 70% in Alaska, 25% in British Columbia, and 5% in Washington, Oregon, and California combined (Committee on the Status of Endangered Wildlife in Canada 2012, Environment Canada 2014). McShane et al. (2004) suggest that Washington, Oregon, and California may have supported a larger population in the past.

Population decline has been attributed to loss of mature and old-growth forest from harvesting, low recruitment of young, and mortality at sea (USFWS 1997). The Oregon Coast Range has been identified by the *U.S. Fish and Wildlife Service Recovery Plan* (1997) as Conservation Zone 3, one of six recovery units or Conservation Zones for the marbled murrelet. Conservation Zone 3 and the northern portion of Conservation Zone 4 (the Siskiyou Coast Range) occur in Oregon. Conservation

Zone 3 extends from the Columbia River south to North Bend Oregon (USFWS 1997). Conservation Zone 4 extends from North Bend to the southern end of Humboldt County, California (USFWS 1997). Both zones include marine waters within 1.2 miles of the ocean shoreline and lands up to 35 miles from the coast plus any designated critical habitat units beyond that distance.

Lynch et al. (2017) estimated approximately 24,100 murrelets within the entire Northwest Forest Plan (NWFP) area in 2015, with approximately 10,975 of those in Oregon. McIver et al. (2019) provides an all conservation zone estimate for 2017 of approximately 23,000 murrelets. Spies et al. (2018) estimated approximately 20,000 murrelets in the NWFP area, including those on Federal and nonfederal lands, and notes that population estimates are highly variable from year to year and have a broad confidence interval.

The all conservation zone trend for years 2001–2017 indicates no evidence of a trend (0.34% increase per year), and Conservation Zone 3 also shows no trend for years 2001 through 2018 (1.4% increase per year; 95% CI: -0.4% to 3.3%) (McIver 2019). At the state scale, in years 2000–2017, Oregon and California showed significant positive trends, while Washington exhibited a significant declining trend (McIver 2019).

Based on analyses summarized over the three states, murrelet populations appear to be stable or nondeclining in Oregon and northern California but are continuing to decline substantially in Washington (Spies et al. 2018).

Threats

Loss and degradation of late-seral forest in Oregon continue to threaten the marbled murrelet. In the Oregon Coast Range, Wimberly and Ohmann (2004) estimate that large-conifer forests declined by 58% between 1936 and 1996. Since the 1990s, further habitat loss has occurred, mainly due to timber harvest on nonfederal lands and wildfires on federal lands (Raphael et al. 2016). Raphael et al. (2016) found a net loss of approximately 2% of potential nesting habitat from 1993 to 2012 on federal lands, compared to a net loss of about 27% on nonfederal lands. For federal and nonfederal lands combined, the net loss of higher suitability habitat declined over all lands (both federal and nonfederal) from 2.53 to 2.23 million acres (a 12.1% decline). Loss of higher suitability habitat on nonfederal lands, mainly resulted from harvest and on federal lands most of the loss of higher suitability habitat was due to fire (62%) and the remaining due to harvest (23%) (Raphael et al. 2016).

Based on the NWFP estimates, higher-suitability nesting habitat declined in Oregon from approximately 853,400 acres in 1993 to 774,800 acres in 2012, a net loss of 78,600 acres (-9.2% change). Losses were greatest on nonfederal lands with 59,200 acres (21.1%) of higher-suitability habitat lost on nonfederal lands compared to 19,400 acres (3.4%) on federal lands. At the conservation-zone scale, which is the primary scale for marbled murrelet population estimate, the proportionate loss of higher suitability habitat was greatest in Conservation Zone 2 (-16.1% of baseline) and Conservation Zone 4 (-17.0% of baseline). The loss in Conservation Zones 3 and 4 were 10.9% and 7.90%, respectively.

Marbled murrelets are vulnerable to habitat fragmentation, with concern for hard edges created by clear-cuts located adjacent to nesting areas; habitat fragmentation has been linked to greater nest predation risk for the species (ODFW 2018). Malt and Lank (2007) found that disturbances by avian predators were significantly more frequent at hard edges relative to interiors, but less frequent at

soft edges. The authors found no edge effects at natural-edged sites and inferred that edge-related predation may decline with time due to forest successional processes.

Disease has not been identified as a major threat to the marbled murrelet (McShane et al. 2004); however, Highly Pathogenic Avian Influenza (HPAI) and West Nile Virus have been detected in wild birds in Oregon and represent emerging concerns (ODFW 2018).

Emerging natural and anthropogenic threats to marbled murrelet include energy development projects, large oil spills, gill-net related mortalities, derelict fish gear, harmful algal blooms that produce biotoxins, surfactants that foul feathers, low oxygen “dead zones,” and contaminants in prey that could biomagnify up the food chain (USFWS 2009). Golightly et al. (2009) documented murrelet nesting and nesting success as it relates to road disturbances and found that murrelets were more likely to nest farther away from paved roads than random sites.

Climate change is expected to increase potential for habitat loss from catastrophic wildfires, insect infestations, disease outbreaks, and severe storms, which may exacerbate unfavorable terrestrial nesting habitat (Spies et al. 2018). Climate change may influence the quality and availability of terrestrial nesting habitat (e.g., extent of fog zone and abundance of epiphytic plants that help create nesting platforms) and affect murrelet foraging habitat (e.g., prey abundance and distribution in the marine environment). In the 2009 Status Review of Marbled Murrelet, the U.S. Fish and Wildlife Service concluded that, based on climate model projections, the future conditions of forests where murrelets nest will largely be unfavorable for maintaining current forest structure and composition. Climate change may also result in changes to marine conditions for marbled murrelet, with the most likely effects on food resources. The U.S. Fish and Wildlife Service (2009) noted that the murrelet prey base will be adversely affected to some extent by climate change through changes in sea surface temperature, timing, intensity, and duration of cold-water upwelling. Acidification of marine waters may also impact marine food webs (Spies et al. 2018), resulting in cascading effects on murrelet foraging strategy. Lorenz et al. (2017) reported low breeding propensity, large marine ranges, and long nest-sea commutes in northwestern Washington, as compared to studies elsewhere in the murrelet’s range, and hypothesized that the marine habitat in the study area had lower quality compared to elsewhere in the species’ range. Changes to historical murrelet diet and annual variation in murrelet reproductive success suggest that warmer coastal waters tend to adversely affect prey quality and result in lowered reproduction (Becker et al. 2007; Becker and Beissinger 2006).

Literature Cited

- Barbaree, B. A., S. K. Nelson, B. D. Dugger, D. D. Roby, H. R. Carter, D. L. Whitworth, and S. H. Newman. 2014. Nesting Ecology of Marbled Murrelets at a Remote Mainland Fjord in Southeast Alaska. *The Condor* 116:173–184.
- Beauchamp, W. D., F. Cooke, C. Loughheed, L. W. Loughheed, C. J. Ralph, and S. Courtney. 1999. Seasonal Movements of Marbled Murrelets: Evidence from Banded Birds. *The Condor* 101:671–674.
- Becker, B. H., and S. R. Beissinger. 2006. Centennial Decline in the Trophic Level of an Endangered Seabird after Fisheries Decline. *Conservation Biology* 20:470–479.

- Becker, B., M. Zachariah Peery, and S. Beissinger. 2007. Ocean Climate and Prey Availability Affect the Trophic Level and Reproductive Success of the Marbled Murrelet, An Endangered Seabird. *Marine Ecology Progress Series* 329:267–279.
- Bertram, D.F.; C.A. MacDonald, P.D. O'Hara, J.L. Cragg, M.H. Janssen, M. McAdie, W.S. Boyd. 2015. Marbled Murrelet (*Brachyramphus marmoratus*) Movements and Marine Habitat Use Near Proposed Tanker Routes to Kitimat, BC, Canada. *Marine Ornithology* 44: 3–9.
- Bertram, D.F., MacDonald, C.A., O'Hara, P.D., Cragg, J.L., Janssen, M.H., McAdie, and M., Boyd, S. 2016. Marbled Murrelet *Brachyramphus marmoratus* Movements and Marine Habitat Use Near Proposed Tanker Routes to Kitimat, BC, Canada. *Marine Ornithology* 44: 3–9.
- Burger, A. E., Canadian Wildlife Service, and Pacific and Yukon Region. 2002. *Conservation Assessment of Marbled Murrelets in British Columbia: A Review of the Biology, Populations, Habitat Associations, and Conservation*. Canadian Wildlife Service, Pacific and Yukon Region, Delta, BC.
- Burger, A. E., I. A. Manley, M. P. Silvergieter, D. B. Lank, K. M. Jordan, T. D. Bloxton, and M. G. Raphael. 2009. Re-Use of Nest Sites by Marbled Murrelets (*Brachyramphus marmoratus*) in British Columbia. *Northwestern Naturalist* 90:217–226.
- Burkett, E. E. 1995. Marbled Murrelet Food Habits and Prey Ecology. Pages 223–246 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (eds.) *Ecology and Conservation of the Marbled Murrelet, General Technical Report PSW-GTR-152*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- Committee on the Status of Endangered Wildlife in Canada. 2012. *COSEWIC Assessment and Status Report on the Marbled Murrelet, Brachyramphus marmoratus, in Canada*. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.
- Divoky G. J. and M. Horton. 1995. Breeding and Natal Dispersal, Nest Habitat Loss, and Implications for Marbled Murrelet Populations. Pages 83–87 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (eds.) *Ecology and Conservation of the Marbled Murrelet, General Technical Report PSW-GTR-152*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- Environment Canada. 2014. *Recovery Strategy for the Marbled Murrelet (Brachyramphus marmoratus) in Canada*.
- Falxa, G. A., M. G. Raphael, and T. Coordinators. 2016. *Status and Trend of Marbled Murrelet Populations and Nesting Habitat*. Page 148. Gen. Tech. Rep., U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Friesen, V.L., Burg, T.M. & McCoy, K. 2007. Mechanisms of Population Differentiation in Seabirds. *Molecular Ecology* 16:1765–1785.
- Golightly, R. T., C. D. Hamilton, and P. N. Hébert. 2009. *Characteristics of Marbled Murrelet (Brachyramphus marmoratus) Habitat in Northern California*: 49.
- Halbert, P. and S. W. Singer. 2017. *Marbled Murrelet Landscape Management Plan for Zone 6*. California Department of Parks and Recreation, Felton, California.
- Hamer, T. E. and S. K. Nelson. 1995. Nesting Chronology of the Marbled Murrelet. Pages 49–56 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (eds.) *Ecology and Conservation of the Marbled*

- Murrelet, General Technical Report PSW-GTR-152*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- Huff, M. H., M. G. Raphael, S. L. Miller, S. K. Nelson, and J. Balwin. 2006. *Northwest Forest Plan - The First 10 years (1994-2003): Status and Trends of Populations and Nesting Habitat for the Marbled Murrelet*. Page 160. Gen. Tech. Rep., U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Lorenz, T. J., M. G. Raphael, T. D. Bloxton, and P. G. Cunningham. 2017. Low Breeding Propensity and Wide-Ranging Movements by Marbled Murrelets in Washington: Marbled Murrelet Space Use. *The Journal of Wildlife Management* 81:306–321.
- Lynch, D., J. Baldwin, M. M. Lance, S. F. Pearson, M. G. Raphael, C. Strong, and R. Young. 2017. *Marbled Murrelet Effectiveness Monitoring, Northwest Forest Plan: 2016 Summary Report*.
- Mack, E. D., W. P. Ritchie, S. K. Nelson, E. Kuo-Harrison, P. Harrison, and T. E. Hamer. 2003. *Methods for Surveying Marbled Murrelets in Forests: A Revised Protocol for Land Management and Research*. Page 82. Technical Publication, Pacific Seabird Group.
- Malt, J. and D. Lank. 2007. Temporal Dynamics of Edge Effects on Nest Predation Risk for the Marbled Murrelet. *Biological Conservation* 140: 160–173.
- Mathews, N. J. C. and A. E. Burger. 1998. Diving Depth of a Marbled Murrelet. *Northwestern Naturalist* 79:70–71.
- McIver, W., J. Baldwin, M.M. Lance, S.F. Pearson, C. Strong, N. Johnson, D. Lynch, M.G. Raphael, R. Young, T. Lorenz and K. Nelson. 2019. *Marbled Murrelet Effectiveness Monitoring, Northwest Forest Plan: 2018 Summary Report*. 22 p.
- McShane, C., T. Hamer, H. Carter, V. L. Friesen, D. Ainley, R. Tressler, S. K. Nelson, A. E. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. *Evaluation Report for the 5-Year Status Review of the Marbled Murrelet in Washington, Oregon, and California*. Page 370.
- Nelson, S. K., M. H. Huff, S. L. Miller, and M. G. Raphael. 2006. Marbled Murrelet Biology: Habitat Relations and Populations. Pages 9-30 in M. H. Huff, M. G. Raphael, S. L. Miller, S. K. Nelson, and J. Baldwin (eds.), *Northwest Forest Plan – The First 10 years (1994-2003): Status and Trends of Populations and Nesting Habitat for the Marbled Murrelet, General Technical Report PNW-GTR-650*. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.
- Nelson, S. K. 1997. Marbled Murrelet (*Brachyramphus marmoratus*). *The Birds of North America Online*.
- Nelson, S. K., and T. E. Hamer. 1995. Nesting Biology and Behavior of the Marbled Murrelet. Pages 57–67 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (Eds.), *Ecology and Conservation of the Marbled Murrelet*. General Technical Report PSW-GTR-152. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- Nelson, S. K. and R. W. Peck. 1995. Behavior of Marbled Murrelets at Nine Nest Sites in Oregon. *Northwestern Naturalist* 76:43–53.

- Nelson, S. Kim and A. K. Wilson. 2002. *Marbled Murrelet Habitat Characteristics on State Lands in Western Oregon*. Unpublished Report, submitted to Oregon Department of Forestry, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Council for Air and Stream Improvement. As cited in Weikel, J. 2018. *Marbled Murrelet Technical Report Draft*. Page 37. Technical Report, Oregon Department of Forestry. Pg. 9.
- Northrup, J.M., J.W. Rivers, S.K. Nelson, D.D. Roby, M.G. Betts. (2018) Assessing the Utility of Satellite Transmitters for Identifying Nest Locations and Foraging Behavior of the Marbled Murrelet *Brachyramphus marmoratus*. *Marine Ornithology* 46:47–55.
- Oregon Department of Fish and Wildlife (ODFW). 2018. *Status Review of the Marbled Murrelet (Brachyramphus marmoratus) in Oregon and Evaluation of Criteria to Reclassify the Species from Threatened to Endangered under the Oregon Endangered Species Act*. Page 134.
- Pearson, S. F. 2018. Marbled Murrelet Effectiveness Monitoring Team. Page 19. *Summary Report of 2017, Northwest Forest Plan Interagency Regional Monitoring Program*.
- Piatt, J. F., A. E. Burger, K. J. Kuletz, S. A. Hatch, V. L. Friesen, T. P. Birt, M. L. Arimitsu, G. S. Drew, A. M. A. Harding, and K. S. Bixler. 2007. *Status Review of the Marbled Murrelet (Brachyramphus marmoratus) in Alaska and British Columbia*. Open-File Report, U.S. Department of the Interior.
- Pilssner, J., H., B. A. Cooper, R. H. Day, P. M. Sanzenbacher, A. E. Burger, and M. G. Raphael. 2015. *A Review of Marbled Murrelet Research Related to Nesting Habitat Use and Nest Success*. Page 425. Final, Oregon Department of Forestry.
- Ralph, J., C., G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt. 1995. *Ecology and Conservation of the Marbled Murrelet*. Page 13. General Technical Report PSW-GTR-152, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- Raphael, M. G., G. A. Falxa, D. Lynch, S. K. Nelson, S. F. Pearson, A. J. Shirk, and R. D. Young. 2016. Status and Trend of Nesting Habitat for the Marbled Murrelet Under the Northwest Forest Plan. Pages 37–94 in G. A. Falxa and M. G. Raphael (Tech. Coords.), *Northwest Forest Plan – The First 20 years (1994–2013): Status and Trend of Marbled Murrelet Populations and Nesting Habitat*. General Technical Report PNW-GTR-933. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.
- Raphael, M. G., G. A. Falxa, and A. E. Burger. 2018. Chapter 5: Marbled Murrelet. Page 72 in T. A. Spies, P. A. Stine, R. Gravenmier, J. W. Long, and J. W. Reilly (eds.), *Synthesis of Science to Inform Land Management within the Northwest Forest Plan Area*. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 301–370, Portland, OR.
- Rodway, M. S., H. R. Carter, S. G. Sealy, and R. W. Campbell. 1992. Status of the Marbled Murrelet in British Columbia. Pages 17–41 in H. R. Carter and M. L. Morrison (eds.), *Status and Conservation of the Marbled Murrelet in North America*. Proceedings of the Western Foundation of Vertebrate Zoology, Camarillo, California.
- Speich, S. M. and T. R. Wahl. 1995. Marbled Murrelet Populations of Washington – Marine Habitat Preferences and Variability of Occurrence. Pages 313–326 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (eds.), *Ecology and Conservation of the Marbled Murrelet, General Technical Report PSW-GTR-152*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.

- Spies, T. A., P. A. Stine, R. Gravenmier, J. W. Long, M. J. Reilly, and R. Mazza. 2018. *Synthesis of science to Inform Land Management Within the Northwest Forest Plan Area: Executive Summary*. Gen. Tech. Rep. PNW-GTR-970. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 186 p. 970.
- Strachan, G., M. McAllister, and C. J. Ralph. 1995. Marbled Murrelet At-Sea and Foraging Behavior. Pages 247–254 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (eds.), *Ecology and Conservation of the Marbled Murrelet, General Technical Report PSW-GTR-152*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- Strong, C. S., B. S. Keitt, W. R. McIver, C. J. Palmer, and I. Gaffney. 1995. Distribution and Population Estimates of Marbled Murrelets at Sea in Oregon During the Summers of 1992 and 1993. Pages 339–352 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt (eds.), *Ecology and Conservation of the Marbled Murrelet, General Technical Report PSW-GTR-152*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.
- U.S. Fish and Wildlife Service (USFWS). 1997. *Recovery Plan for the Threatened Marbled Murrelet (Brachyramphus marmoratus) in Washington, Oregon, and California*. Page 286. U. S. Fish and Wildlife Service, Region 1.
- U.S. Fish and Wildlife Service (USFWS). 2009. *Marbled Murrelet (Brachyramphus marmoratus) 5-Year Review*. U. S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, WA.
- U.S. Fish and Wildlife Service (USFWS). 2012. *Report on Marbled Murrelet Recovery Implementation Team Meeting and Stakeholder Workshop*. Page 66. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, Washington.
- Weikel, J. 2018. *Marbled Murrelet Technical Report Draft*. Page 37. Technical Report, Oregon Department of Forestry.
- Wimberly M.C. and J.L. Ohmann. 2004. A multi-scale Assessment of Human and Environmental Constraints on Forest Land Cover Change on the Oregon (USA) Range. *Landsc Ecol* 19:631–646.

C17 Red Tree Vole, North Oregon Coast DPS (*Arborimus longicaudus*)

Legal Status

State: Sensitive

Federal: Not Listed. 2024. 12-Month Finding on a 2011 Petition to List a Distinct Population Segment of the Red Tree Vole as Endangered or Threatened. 76 FR 63720-63762. Determined Not Warranted for Listing as Endangered or Threatened in 2019 (84 FR 69707- 69712) and finding subsequently withdrawn (87 FR 63472). Again Determined Not Warranted for Listing as Endangered or Threatened in 2024 (89 FR 8137).

Critical Habitat: N/A

Recovery Planning: N/A.

Species Status Assessment: Completed (USFWS 2023)

The taxonomy, biology, ecology, and status of the red tree vole, North Oregon Coast distinct population segment (DPS), are provided by the U.S. Fish and Wildlife Service (USFWS 2011, 2019, and 2023). Swingle and Forsman (2016) provide an annotated bibliography of the species.



Photo: USFWS

Taxonomy

The animals now included in the North Oregon Coast DPS were originally classified in the species *Phenacomys longicaudus*, native to California and Oregon (USFWS 2008). When these animals were proposed for listing in 2007, they were recognized as subspecies *Arborimus longicaudus silvicola* by Wilson and Reeder (2005). Based on the listing proposal, the U.S. Fish and Wildlife Service (USFWS) determined that subspecies *silvicola* did not warrant recognition as a subspecies under the federal Endangered Species Act (ESA) (USFWS 2011). USFWS determined, however, that individuals from the North Oregon Coast population were genetically distinct enough from the rest of the red tree vole species to constitute a DPS, and described it as the red tree vole (*Arborimus longicaudus*), North Oregon Coast DPS, and classified it as a candidate species (USFWS 2011). Subsequent listing decisions determined the species was not warranted for listing as endangered or threatened (USWS 2023).

Distribution

General

Red tree vole is endemic to the lower elevation (generally below 1,300 meters [4,265 feet]) coniferous forests of western Oregon, generally west of the crest of the Cascade Range and northwestern California north of the Klamath River. Red tree voles have not been found north of the Columbia River (Verts and Carraway 1998). The species is absent from the Willamette Valley, though it can persist in the foothills along the valley edge. The range of the red tree vole, North Oregon Coast DPS encompasses the Oregon Coast Range from the Columbia River south to the Siuslaw River, with the western edge of the Willamette Valley being the eastern boundary of the DPS (Figure C17-1) (USFWS 2011). Red tree vole, North Oregon Coast DPS is uncommon above 1,000 meters (Forsman et al. 2016).

The North Oregon Coast DPS is considered uncommon and sparsely distributed compared to red tree vole populations elsewhere in its range (Forsman et al. 2016), particularly the area within the DPS north of Highway 20, which accounts for nearly 75% of the DPS (Figure C17-1) (Forsman et al. 2016).

The historical northern limit of red tree voles in the North Oregon Coast DPS is unclear. The northernmost record of red tree voles in this region was near Saddle Mountain in central Clatsop County (Verts and Carraway 1998). Red tree voles have not been detected in recent survey efforts in northern Clatsop and Columbia Counties (Forsman and Swingle 2009; unpublished data, as cited in USFWS 2011; Price et al. 2015). This area historically had extensive forests with large Douglas-fir and western hemlock characteristic of red tree vole habitat. Much of this region was logged in the late 1800s, and it is likely that most suitable red tree vole habitat was removed in Clatsop, Columbia, and Washington Counties before red tree vole presence could be documented (USFWS 2016).

Occurrence in the Plan Area

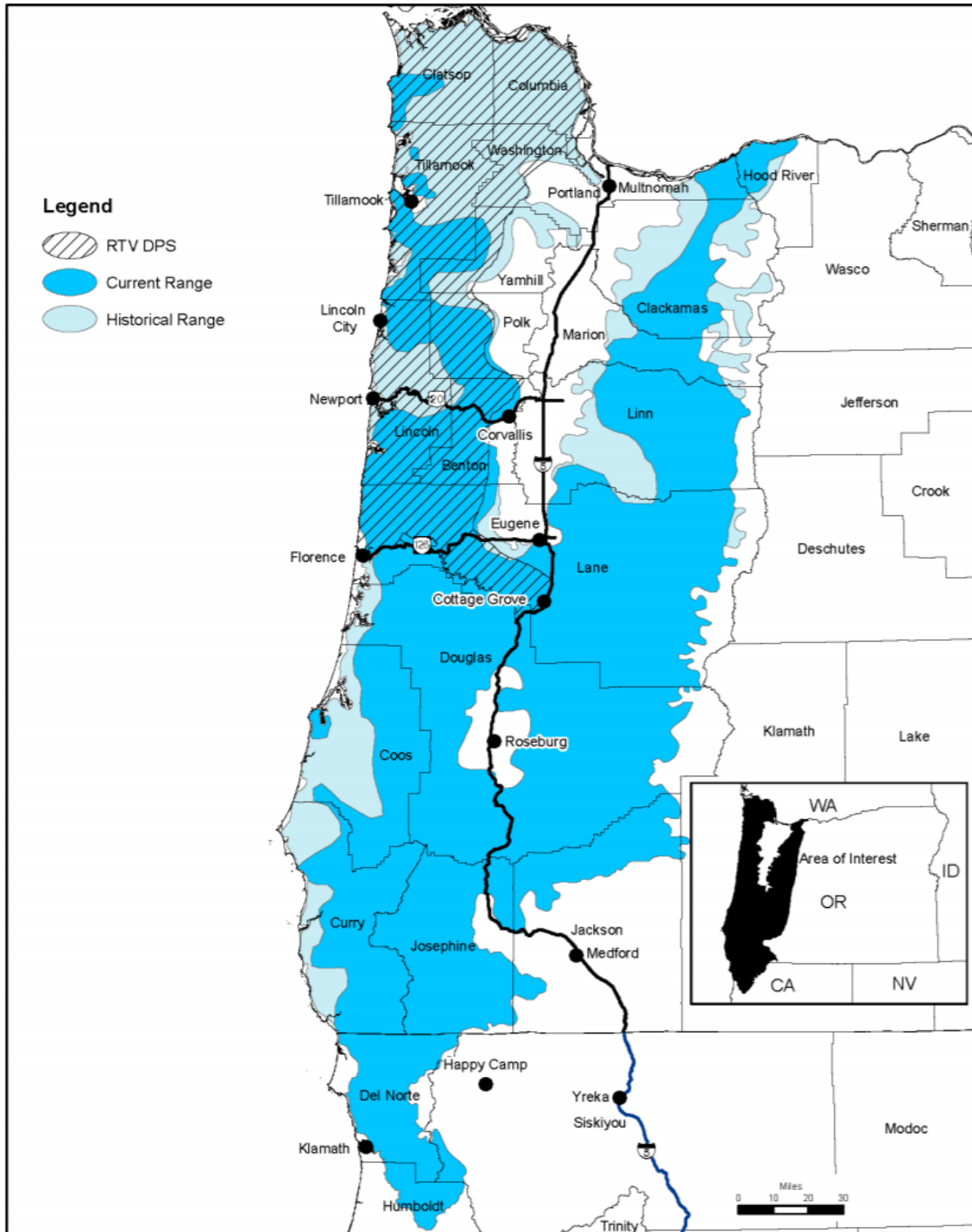
Within the DPS, the red tree vole is mostly restricted to isolated populations in old forest stands in the northern half of the DPS and larger blocks of federal land in the southern half of the DPS, with smaller numbers occurring in younger stands (Forsman et al. 2016; Price et al. 2015). The species is uncommon in the northern third of the DPS, including the Clatsop State Forest and most of the Tillamook State Forest (Figure C17-2). Price et al. (2015) surveyed 86 randomly selected plots in Tillamook and Clatsop State Forests in 2011 to 2013. Thirty-three red tree vole nests were found in four plots. Of these, 20 (61%) nests were found in stands 90 to 125 years old, and 13 (39%) were found in one plot in a 65-year-old stand (located approximately 150 meters from a 140-year-old stand). Of the 33 nests, 6 (18%) were occupied or likely occupied. The four occupied plots were located on the western edge of the Tillamook State Forest in stands that did not burn during the 1933–1951 Tillamook Burn fires. Red tree voles also occur along the southern edge of the Tillamook State Forest in Tillamook and Yamhill Counties.

From 2019-2022, Oregon State University and the National Council for Air and Stream Improvement conducted a red tree vole study to assess occurrence across stand ages and distances from old forest on private industrial and public lands in the central Oregon Coast Range (Piasecki 2023). In the ODF permit area, researchers located active red tree vole nests in 15 of 69 (22%) trees surveyed on the West Oregon District (Jason Piasecki, pers. comm). All identified nests were distributed across

multiple stands that primarily ranged from 23 to 56 years in age, with 11 (16%) of nests documented in a 97-year-old stand. Over the entire study area, Piasecki et al. (2026) found that red tree vole nest persistence was found to be highest (0.98, 95% CI = 0.81 – 0.99) in old forests (≥ 80 years old) where nests were more cryptic or associated with protective tree structures (e.g., cavities). Persistence was lower (0.9, 95% CI = 0.79 – 0.95) and more variable in young forest stands (<80 years old). Recently occupied tree vole nest density exhibited a bimodal pattern, with local peaks in 30-year stands (1.24 ± 0.35 nests/ha) within 1,425 m of old forest patches, declining to near-zero in 50 – 79 year stands, then reaching maximum densities in old forests (53.5 ± 14.9 nests/ha).

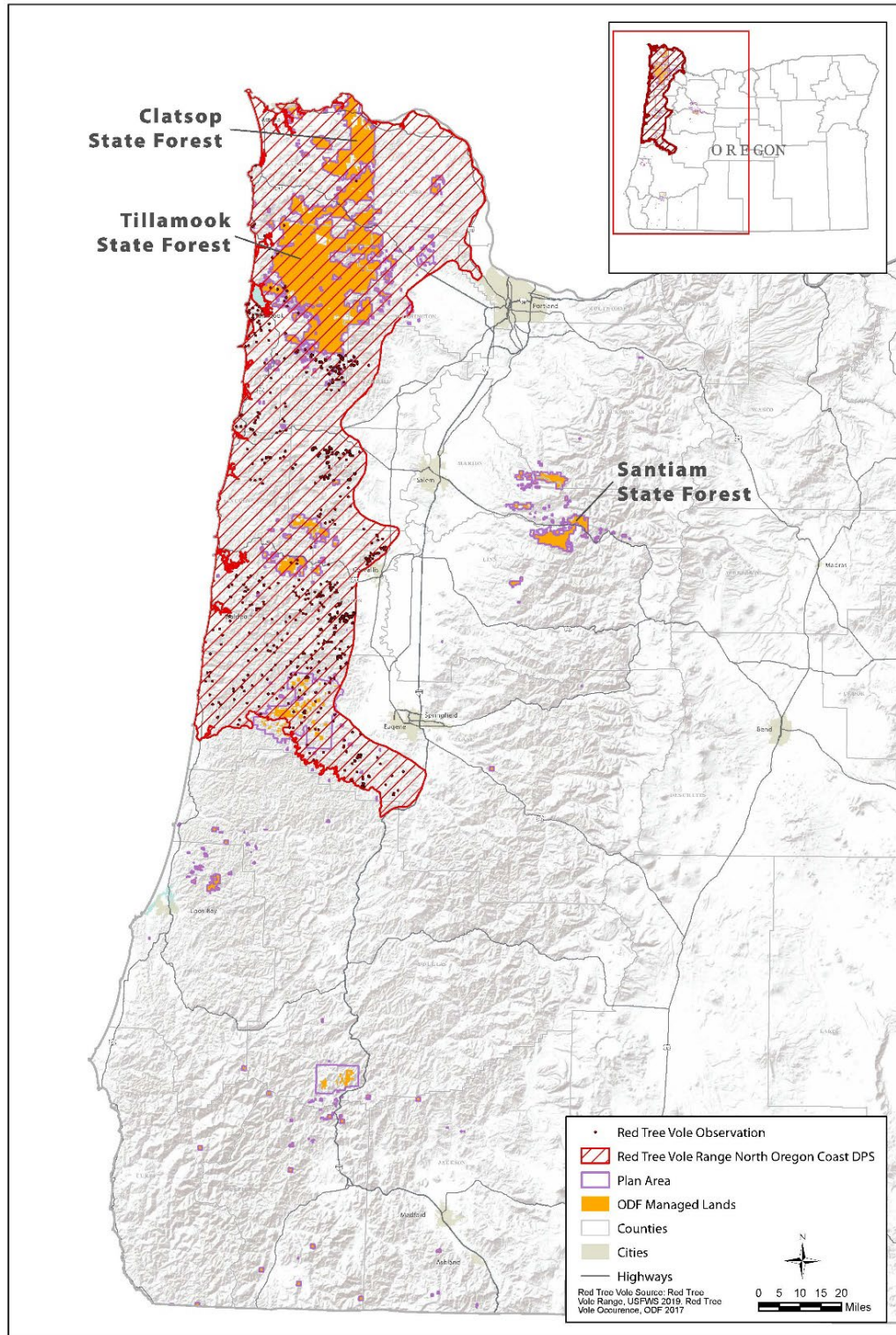
Natural History

Published information on the red tree vole, North Coast DPS includes work on the red tree vole, and on the closely related Sonoma tree vole (*Arborimus pomo*). The red tree vole and Sonoma tree vole were considered a single species until 1991 (Johnson and George 1991). Where information is lacking or limited on the red tree vole, information on the Sonoma tree vole is presented because no ecological or life history differences have been noted for the two species (Smith et al. 2003).



Source: USFWS 2019.

Figure C17-1. Historical and Current Range of the Red Tree Vole (Forsman et al. 2016) and the North Oregon Coast Distinct Population Segment (Hashed Area)



Western Oregon State Forests
Draft - Red Tree Vole North Oregon Coast DPS and Occurrence

Sources: USFWS 2019

Figure C17-2. Range of Red Tree Vole (North Oregon Coast DPS) and Known Occurrences

Habitat Requirements

Red tree vole occurs primarily in structurally complex late-seral conifer or mixed conifer-hardwood forests (Dunk and Hawley 2009; USFWS 2011; Forsman et al. 2016; Rosenberg et al. 2016; Linnell et al. 2017; Johnston and Moskal 2017). Attributes of late-successional forest positively correlated with habitat suitability include large-diameter trees (Dunk and Hawley 2009; Rosenberg et al. 2016; Johnston and Moskal 2017); density of large conifers; percent of conifer cover; percent of food-source trees such as Douglas-fir, Sitka spruce, and western hemlock (Forsman et al. 2016); structural diversity (Dunk and Hawley 2009; Forsman et al. 2016; Johnston and Moskal 2017); and extent of old forest cover (Linnell et al. 2017).

Within the westernmost portions of the North Oregon Coast DPS, red tree vole habitat is characterized by the Sitka spruce (*Picea sitchensis*) plant series. Sitka spruce is dominant in the tree canopy with grand fir (*Abies grandis*), red alder (*Alnus rubra*), coast redwood (*Sequoia sempervirens*), and western hemlock (*Tsuga heterophylla*); trees are less than 75 meters, the canopy is intermittent to continuous, shrub layer is sparse to continuous, and the herbaceous layer is usually abundant, especially with ferns (California Native Plant Society 2019). The series is highly productive, producing large trees relatively quickly, and contains plant associations that develop and maintain older forest characteristics (USFWS 2011). Two plant associations are identified for the series in southwestern Oregon: Sitka Spruce/Salal-Evergreen Huckleberry and Sitka Spruce-White Fir/Salmonberry (Hemstrom and Longan 1986). Although the Sitka spruce plant series occurs along most of the Oregon coast, it extends farthest inland in northwestern Oregon. Most of the Sitka spruce series can be found within 1 mile of the Pacific Ocean, in the wet and mild climate of coastal plains and headlands (U.S. Forest Service 1992). The Sitka spruce plant series setting is somewhat unique to the North Oregon Coast DPS, as most of the plant series in Oregon occurs in the North Oregon Coast DPS (USFWS 2016). It is within this portion of the DPS—in western Lincoln, Tillamook, and Clatsop Counties—where the red tree vole diet is dominated by Sitka spruce and western hemlock needles. East of the Sitka spruce plant series in the North Oregon Coast DPS, as well as throughout the rest of its range, the red tree vole consumes primarily Douglas-fir (see *Diet*, below) (USFWS 2016).

Red tree vole nest trees are located in the forest canopy and are constructed from twigs and resin ducts, fecal pellets, lichens, and conifer needles (Gillesberg and Carey 1991; Forsman et al. 2009). Red tree vole nest trees tend to be larger than trees without nests, even in stands of large trees (Johnston and Moskal 2017). Old-growth trees may be ideal for tree voles because primary production is high and needles are concentrated, providing maximum food availability (Carey 1991). Range-wide, the red tree vole is primarily associated with Douglas-fir. Within the North Coast DPS, however, red tree voles tend to favor western hemlock and Sitka spruce for diet and nest placement (Forsman et al. 2008; Price et al. 2015).

Though abundance is considerably higher in late seral forest structure, the red tree vole is sometimes found in early-to-mid seral stands (0 to 79 years old) (Price et al. 2015). Young forest stands may provide interim habitat for tree voles and connectivity between remnant patches of older forests (Linnell et al. 2017), but value in supporting viable populations is uncertain (USFWS 2011), and available evidence suggests tree vole occupation of younger forest stands is unlikely or relatively short-lived (Diller pers. comm., as cited in USFWS 2011; Hopkins pers. comm., as cited in USFWS 2011). The role of young forests in supporting viable red tree vole populations remains unclear; however, they may provide connectivity to older forests where more stable vole populations exist (Linnell et al. 2017; Piasecki et al. 2026).

Landscape context of older forest habitat patches influences habitat suitability. Red tree voles are sensitive to habitat fragmentation (Martin and McComb 2002; Linnell et al. 2017; Rosenberg 2019) and avoid nesting at forest edges (Johnston and Moskal 2017), and their relatively short dispersal distance limits their ability to colonize or move to isolated old forest patches. Distance to old forest patches also influences the likelihood of occurrence in young forest (Johnston and Moskal 2016; Linnell et al. 2017). For example, Linnell et al. (2017) analyzed habitat and landscape-level factors affecting habitat suitability for the North Oregon Coast DPS and found that suitable habitat is correlated with old forest (≥ 80 years old). Suitability of young forest (< 80 years old) was negatively correlated with distance from large patches of old forest and recent disturbance. Models found that if old forests contracted to only federal land (a 1.4% decrease regionally), average distance to nearest patch would increase from 3.1 kilometers to 11.1 kilometers. Alternatively, if there was an increase (1.4% in old forest of patches randomly distributed in the landscape), average distance between patches would be reduced by 1.8 kilometers. The authors conclude that even a small amount of restored or regenerated old forest would improve connectivity and increase population resiliency (Linnell et al. 2017).

Diet

Red tree voles eat conifer needles, stripping away resin ducts within the needles and eating the rest, and the tender bark of conifer twigs. In most of their range, diet comprises primarily Douglas-fir conifer needles (Forsman et al. 2016). In the North Oregon Coast DPS, however, red tree voles rarely forage on Douglas-fir, even where available, and instead eat needles from western hemlock and Sitka spruce (Forsman and Swingle 2009; unpublished data, as cited in USFWS 2011; Maser pers. comm., as cited in USFWS 2011).

Reproduction

Adult red tree voles live alone, except when females have litters; males and females only come together to breed. Females and males have nests made of vegetation and other materials. Nests can range from grapefruit-sized to that of a bushel basket (USFWS 2016).

Red tree voles can breed throughout the year, but most reproduction occurs between February and September (Swingle 2005). Red tree voles become sexually mature at 2.5 to 3.0 months of age (Clifton 1960). Litters average 2.9 young (range of 1 to 4) (Maser et al. 1981; Verts and Carraway 1998). Juveniles disperse when they are 1.6 to 2.0 months old (Swingle 2005; Forsman et al. 2009). Females can be impregnated immediately after a litter is born, so females can have two litters in their nests (Swingle 2005; Forsman et al. 2009).

Movement

Red tree voles spend most of their time in the tree canopy, coming to the ground rarely to move between trees. In a study of 45 radio-collared red tree voles in the southern Coast Range and Cascades in southwestern Oregon, Swingle and Forsman (2009) found 18 red tree voles to have small home ranges, consisting of their nest tree and a few adjacent trees. The remainder occupied up to six different nests up to 162 meters apart in different trees. Mean and median home ranges were 0.17 and 0.08 hectare, respectively. Home range sizes did not differ between sex, age, or age of forest.

Red tree voles tend to disperse short distances generally ranging from 3 to 75 meters (Swingle 2005), suggesting that relatively small distances (i.e., roughly less than 366 meters) between old forest patches may be barriers to dispersal (USFWS 2011).

Ecological Relationships

Swingle et al. (2010) found that weasels (*Mustela* spp.) are the primary predators of red tree voles. Other animals that prey on red tree voles include fisher, barred owl, and other raptors. Spotted owls are predators of red tree voles elsewhere in its range—but this interaction seems to be limited—in the DPS (Forsman et al. 2016). Western gray squirrel (*Sciurus griseus*), Douglas squirrel (*Tamiasciurus douglasii*), and raccoon (*Procyon lotor*) have been filmed chasing red tree voles or tearing into tree vole nests in apparent attempts to capture voles (Forsman pers. comm., as cited in USFWS 2011).

Population Status and Trends

Little is known about current and historical population sizes of the North Oregon Coast DPS due, in part, to the challenges of observing and capturing red tree voles. Historical surveys (e.g., late 1800s to mid-1900s) were generally conducted to inventory the presence of species, rather than to estimate abundance of a particular species (Jobanek 1988). Once red tree vole behavior was understood, searchers were typically able to find red tree voles. Once found, they were often able to find many nests in the same area (USFWS 2016).

More recent surveys for red tree voles in or near areas where they historically occurred have found relatively few tree voles. For example, Forsman and Swingle (2006, unpublished data, as cited in USFWS 2011) found 27 red tree voles over 1,143 person-hours searching potentially suitable habitat (one red tree vole per 42 person-hours search effort). Price et al. (2015) spent 50 person-hours per nest in the Clatsop and Tillamook State Forests and concluded that tree voles were likely absent because the area was either logged or burned in the early 1900s, and subsequently intensively managed on short rotations.

Although population size estimates are not available to estimate trends, data and anecdotal information such as what is provided here strongly suggest that current red tree vole abundance in the DPS is considerably lower than historical abundance (USFWS 2016).

Threats

The red tree vole, North Oregon Coast DPS is primarily threatened by habitat loss and fragmentation from timber harvest and wildfire (USFWS 2011). Logging and relatively short rotation intervals preclude the development of late-successional forest habitat, and maintain forests in early seral stages. Fragmentation by continued logging on short rotation intervals adjacent to old forest habitat further isolates and diminishes the quality of remnant patches of old forest habitat (USFWS 2016). Active management, such as thinning stands, can also reduce vole numbers or eliminate them (USFWS 2016).

Estimates of suitable habitat, derived from habitat models and historic forest maps, provide an index on the amount of potentially suitable habitat and changes in extent over time. Using this approach,

Forsman et al. (2016) found that the amount of red tree vole habitat in Oregon declined by 65% between 1914 and 2006, with an 80% decline in the northern Coast Ranges overlapping the DPS.

Remaining older forests are distributed across the DPS mostly as small, isolated fragments. Using results from a habitat suitability model created by Dunk and Hawley (2009) and other unpublished data, USFWS estimates that only 0.3% of the DPS is in a forest type that red tree vole strongly selects, whereas almost 90% of the DPS is in a forest type condition that red tree voles tend to avoid (USFWS 2016). Using habitat modeling with airborne light detection and ranging (LiDAR), Johnston and Moskal (2017) found red tree vole nests were often in the largest trees in the stand and away from forest edges. Linnell et al. (2017) found red tree vole relative habitat suitability was positively correlated with current old forest cover at the local-scale and negatively correlated with distance from large patches of old forest. At the landscape level, proximity to old forest and the absence of recent disturbance contributes to the habitat suitability of young forests (Linnell et al. 2017).

Within the plan area, much of the Tillamook State Forest was burned by the Tillamook Burn, a series of four large fires from 1933 to 1951 that burned approximately 143,000 hectare (353,360.70 acres), much of it old forest (Wells 1999). The burned areas were subsequently subject to salvage logging and harvest at short rotation intervals. This area likely supported red tree voles historically, but extensive fires and subsequent management has made this area unsuitable for red tree voles (Price et al. 2015; Forsman et al. 2016). Similarly, the Yaquina Burn of 1847 to 1853 devastated 450,000 acres of the Coast Range west of Corvallis, Oregon, from South Fork of the Siletz River to the mouth of Siuslaw River, significantly altering habitat conditions for this species in the southern half of the DPS.

Literature Cited

- California Native Plant Society (CNPS). 2019. *A Manual of California Vegetation*, Online Edition. Available: <http://vegetation.cnps.org/alliance/44>. Accessed: July 25, 2019. California Native Plant Society. Sacramento, CA.
- Carey, A. B. 1991. *The Biology of Arboreal Rodents in Douglas-Fir Forests*. Page 46. Gen. Tech. Rep., U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
- Clifton, P.L. 1960. *Biology and life History of the Dusky Tree Mouse* *Phenacomys silvicola* (Howell). Walla Walla, WA: Walla Walla College. 140 p. M.A. thesis.
- Dunk, J. R., and J. J. V. G. Hawley. 2009. Red-Tree vole Habitat Suitability Modeling: Implications for Conservation and Management. *Forest Ecology and Management* 258:626–634.
- Forsman, E. D., and J. K. Swingle. 2010. Doug Bake and red Tree Voles: A Tale of Discovery in the Pacific Northwest. *Northwestern Naturalist* 91:102–105.
- Forsman, E. D., R. G. Anthony, and C. J. Zabel. 2004. Distribution and Abundance of Red Tree Voles in Oregon Based on Occurrence in Pellets of Northern Spotted Owls. *Northwest Science* 78:294–302.
- Forsman, E. D., J. K. Swingle, and W. Price. 2008. *Red Tree Vole (Arborimus longicaudus) Surveys at Oswald West, Fort Stevens, and Ecola State Parks, 26–28 April 2008*. Page 8. Unpublished Report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis, OR.

- Forsman, E. D., J. K. Swingle, and N. R. Hatch. 2009. Behavior of Red Tree Voles (*Arborimus longicaudus*) Based on Continuous Video Monitoring of Nests. *Northwest Science* 83:262–272.
- Forsman, E. D., J. K. Swingle, R. J. Davis, B. L. Biswell, and A. S. Lawrence. 2016. *Tree Voles: An Evaluation of their Distribution and Habitat Relationships Based on Recent and Historical Studies, Habitat Models, and Vegetation Change*. Page 119. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
- Gillesberg, A.-M., and A. B. Carey. 1991. Arboreal Nests of *Phenacomys longicaudus* in Oregon. *Journal of Mammalogy* 72:784–787.
- Hemstrom, M.A., and S.E. Logan 1986. *Plant Association and Management Guide Siuslaw National Forest*. USDA Forest Service. Pacific Northwest Region. E6-Ecol 220-1968a.
- Jobanek, G. A. 1988. Searching for the Tree Vole: An Episode in the 1914 Biological Survey of Oregon. *Oregon Historical Quarterly* 89:369–399.
- Johnson, M. L., and S. B. George. 1991. Species Limits within the *Arborimus longicaudus* Species-Complex (Mammalia: Rodentia) with a Description of a New Species from California. *Contributions in Science, Natural History Museum of Los Angeles County* 429:1–16.
- Johnston, A. N., and L. M. Moskal. 2017. High-Resolution Habitat Modeling with Airborne LiDAR for Red Tree Voles: Red Tree Vole Habitat Models. *Journal of Wildlife Management* 81:58–72.
- Linnell, M. A., R. J. Davis, D. B. Lesmeister, and J. K. Swingle. 2017. Conservation and relative Habitat Suitability for an arboreal Mammal Associated with old Forest. *Forest Ecology and Management* 402:1–11.
- Martin, K. J., and W. C. McComb. 2002. Small Mammal Habitat Associations at Patch and Landscape Scales in Western Oregon. *Forest Science* 48:255–264.
- Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dyrness. 1981. *Natural History of Oregon Coast Mammals*. Page 496. Gen. Tech. Rep., USDA Forest Service, Portland, OR.
- Price, A., Jason S Mowdy, James K Swingle, and Eric D Forsman. 2015. Distribution and Abundance of Tree Voles in the Northern Coast Ranges of Oregon. *Northwestern Naturalist* 96:37–49.
- Rosenberg, D. K. 2019. A Tale of Two Voles: The Challenge of the Commonness-Rarity Continuum in Conservation Planning. *Forest Ecology and Management* 434:165–171.
- Rosenberg, D. K., R. J. Davis, K. J. Van Norman, J. R. Dunk, E. D. Forsman, and R. D. Huff. 2016. Patterns of Red Tree Vole Distribution and Habitat Suitability: Implications for Surveys and Conservation Planning. *Ecosphere* 7:e01630. 10.1002/ecs2.1630.
- Smith, W. P., R. G. Anthony, J. R. Waters, N. L. Dodd, and C. J. Zabel. 2003. Ecology and Conservation of Arboreal Rodents of Western Coniferous Forests. Pages 157-206. Chapter 6 in C. J. Zabel and R. G. Anthony (eds.), *Mammal Community Dynamics: Management and Conservation in the Coniferous Forests of Western North America*. Cambridge University Press, Cambridge, UK.
- Swingle, J. K. 2005. *Daily Activity Patterns, Survival, and Movements of Red Tree Voles (Arborimus longicaudus) in Western Oregon*. Oregon State University.
- Swingle, J. K., and E. D. Forsman. 2009. *Home Range Areas and Activity Patterns of Red Tree Voles (Arborimus longicaudus) in Western Oregon*. SPIE.

- Swingle, J. K., and E. D. Forsman. 2016. *Annotated Bibliography of the Red Tree Vole (Arborimus longicaudus), Sonoma Tree Vole (A. pomosus), and White-Footed Vole (A. albipes)*. Page 184. Gen. Tech. Rep., U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
- Swingle, J. K., E. D. Foreman, and A. G. Robert. 2010. Survival, Mortality, and Predators of Red Tree Voles (*Arborimus longicaudus*). *Northwest Science* 84:225–265.
- U.S. Fish and Wildlife Service (USFWS). 2008. Endangered and Threatened Wildlife and Plants; A 90-Day Finding on a Petition to List the Dusky Tree Vole (*Arborimus longicaudus silvicola*) as Threatened or Endangered. *Federal Register* 209:63919–63926. Google Scholar.
- U.S. Fish and Wildlife Service (USFWS). 2011. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List a Distinct Population Segment of the Red Tree Vole as Endangered or Threatened. *Federal Register* 76: 63720–63762.
- U.S. Fish and Wildlife Service (USFWS). 2016. U.S. Fish and Wildlife Service Species Assessment and Listing Priority Assignment Form, Red Tree Vole (*Arborimus longicaudus*). U.S. Fish and Wildlife Service, Region 1.
- U.S. Fish and Wildlife Service (USFWS). 2019. Species status assessment: north Oregon coast population of the Red Tree Vole (*Arborimus longicaudus*). Version 1.0. Available: <https://ecos.fws.gov/ServCat/DownloadFile/169143>.
- U.S. Fish and Wildlife Service (USFWS). 2023. Species status assessment north Oregon coast distinct population segment of the red tree vole (*Arborimus longicaudus*). Version 2.0. Available: <https://iris.fws.gov/APPS/ServCat/DownloadFile/252782>.
- U.S. Forest Service. 1992. *Sitka Spruce Series PISI*. Authored by Paula Fong R. Available: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5319843.pdf.
- Verts, B. J., and L. N. Carraway. 1998. *Land Mammals of Oregon*. University of California Press, Berkeley.
- Wells, G. 1999. *The Tillamook: A Created Forest Comes of Age*. Oregon State University Press, Corvallis, OR.
- Wilson, D.E. and D.M. Reeder (eds.). 2005. *Mammal Species of the World: A Taxonomic and Geographic Reference*. 3rd ed. Baltimore, MD: John Hopkins University Press:963 p.

Appendix D
Species Considered for Coverage

Table D-1. Species Considered for Coverage in the Western Oregon State Forests Habitat Conservation Plan

Species	Status ^a			Criteria ^b			Recommended Covered Status ^c	Notes
	State	Federal	Range	Status	Impact	Data		
Fish								
Oregon coast coho <i>Oncorhynchus kisutch</i>	SS	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Lower Columbia River coho <i>Oncorhynchus kisutch</i>	SE	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Upper Willamette River spring Chinook <i>Oncorhynchus tshawytscha</i>	--	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Upper Willamette River winter steelhead <i>Oncorhynchus mykiss</i>	--	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Columbia River chum <i>Oncorhynchus keta</i>	--	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Southern Oregon/Northern California coho <i>Oncorhynchus kisutch</i>	SS	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Lower Columbia River Chinook <i>Oncorhynchus tshawytscha</i>	SSC	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Eulachon <i>Thaleichthys pacificus</i>	--	FT	Y	Y	Y	Y	Y	Limited to the Columbia and Umpqua Rivers but does utilize confluence of streams and rivers on state forest
Oregon Coast Chinook <i>Oncorhynchus tshawytscha</i>	--	--	Y	(Y)	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area, likely to be listed during the permit term
Lower Columbia River steelhead <i>Oncorhynchus mykiss</i>	SSC	FT	N	Y	N	Y	N	Unlikely to occur in the plan and permit area. There is a single CSL parcel adjacent to Boulder Creek where LCR steelhead could occur. Conservation measures identified in the HCP would be applied throughout the permit area and chance for take is remote.
Bull trout <i>Salvelinus confluentus</i>	--	FT	N	Y	N	Y	N	Unlikely to occur in the plan and permit area. There is a single CSL parcel adjacent to the Middle Fork Willamette River where bull trout could occur. Conservation measures identified in the HCP would be applied throughout the permit area and chance for take is remote.
Green sturgeon <i>Acipenser medirostris</i>	SS/SSC	FT	N	Y	N	N	N	Could occur in the lower reaches of large coastal rivers. Downstream effects from ODF management activities would be attenuated, chance for take is remote.
Shortnosed sucker <i>Chasmistes brevirostris</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Lost River sucker <i>Deltistes luxatus</i>	--	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Pacific lamprey <i>Lampetra tridentatata</i>	SS	FSOC	Y	N	Y	Y	N	Not expected to become listed during permit term
Western river lamprey <i>Lampetra ayresii</i>	SS	--	Y	N	Y	N	N	Not expected to become listed during permit term
Great Basin redband trout <i>Oncorhynchus mykiss gibbsi</i>	SS	FSOC	Y	N	N	Y	N	Plan area is outside of range or current known distribution
Mollusks								
Western ridged mussel <i>Gonidea angulata</i>	--	UR	Y	Y	Y	N	N	Occurs in multiple locations throughout the plan and permit area; however, it is not currently listed, and available data on habitat and conservation needs are limited.
Amphibians								
Oregon slender salamander <i>Batrachoseps wrighti</i>	SS	UR	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area and expected to become listed during the permit term

Species	Status ^a			Criteria ^b			Recommended Covered Status ^c	Notes
	State	Federal	Range	Status	Impact	Data		
Columbia torrent salamander <i>Rhyacotriton kezeri</i>	SS	UR	Y	Y	Y	Y	N	Occurs in multiple locations throughout the plan and permit area; however, it is not currently listed, and available data on habitat and conservation needs are limited. It was included in the public draft, but the request for take coverage for this species was removed from this final HCP.
Cascade torrent salamander <i>Rhyacotriton cascadae</i>	SS	UR	Y	Y	Y	Y	N	Occurs in multiple locations throughout the plan and permit area; however, it is not currently listed, and available data on habitat and conservation needs are limited. It was included in the public draft, but the request for take coverage for this species was removed from this final HCP.
Southern torrent salamander <i>Rhyacotriton variegatus</i>	SS	--	Y	Y	Y	Y	N	May occur in the plan and permit area; however, it is not currently listed, and available data on habitat and conservation needs are limited.
Oregon spotted frog <i>Rana pretiosa</i>	SSC	FT	Y	Y	N	Y	N	Within the range but no overlap of covered activities with current occupied site. Unlikely to recolonize without habitat restoration and reintroduction.
Reptiles								
Western pond turtle <i>Actinemys marmorata</i>	SC	PT	Y	Y	Y	N	N	Occurs in multiple locations throughout the plan and permit area; however, it is not currently listed, and available data on habitat and conservation needs are limited.
Leatherback sea turtle <i>Dermochelys coriacea</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Loggerhead sea turtle <i>Caretta caretta</i>	ST	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Olive ridley sea turtle <i>Lepidochelys olivacea</i>	ST	FT	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Birds								
Northern spotted owl <i>Strix occidentalis</i>	ST	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Marbled murrelet <i>Brachyramphus marmoratus</i>	ST	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area
Short-tailed albatross <i>Phoebastria albatrus</i>	--	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Streaked horned lark <i>Eremophila alpestris strigata</i>	--	FT	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Western snowy plover <i>Charadrius nivosus nivosus</i>	--	FT	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Yellow-billed cuckoo <i>Coccyzus americanus</i>	--	FT	Y	Y	N	Y	N	Range is highly restricted in Oregon and habitat is limited to large cottonwood galley type riparian areas not found on ODF-managed lands.
Northern goshawk <i>Accipiter gentilis atricapillus</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. Can manage around nest sites if they become apparent.
Olive-sided flycatcher <i>Contopus cooperi</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term
American peregrine falcon <i>Falco peregrinus anatum</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term
Mammals								
Coastal marten <i>Martes caurina</i>	ST	FT	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area and expected to become listed during permit term
Red tree vole (North Oregon Coast DPS) <i>Arborimus longicaudus</i>	SS	--	Y	Y	Y	Y	Y	Occurs in multiple locations throughout the plan and permit area and expected to become listed during permit term.
Red tree vole (Southern DPS) <i>Arborimus longicaudus</i>	--	--	Y	N	Y	(Y)	N	Review with Scoping Team

Species	Status ^a			Criteria ^b			Recommended Covered Status ^c	Notes
	State	Federal	Range	Status	Impact	Data		
Pacific fisher <i>Martes pennanti</i>	SSC	--	Y	Y	Y	Y	N	Potential for overlap in dispersed SW OR parcels. ODF is using a CCAA for this species.
Gray wolf (Western DPS) <i>Canis lupus</i>	SE	PE	Y	Y	N	N	N	Potential impacts are too hypothetical at this point in time. Focus would be on den sites, which are currently limited.
Columbia white-tailed deer <i>Odocoileus virginianus leucurus</i>	--	FT	Y	Y	N	Y	N	Assumes riparian strategies would avoid impacts
North American wolverine <i>Gulo gulo luscus</i>	ST	FT	N	N	N	Y	N	Plan area is outside of range or current known distribution
Killer whale (Southern resident DPS) <i>Orcinus orca</i>	--	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Blue Whale <i>Balaenoptera musclus</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Fin Whale <i>Balaenoptera physalus</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Gray Whale <i>Eschrichtius robustus</i>	SE	--	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Humpback Whale <i>Megaptera novaeangliae</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
North Pacific Right Whale <i>Eubalaena japonica</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Sei Whale <i>Balaenoptera borealis</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Sperm Whale <i>Physeter macrocephalus</i>	SE	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Fringed myotis <i>Myotis thysanodes</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
Long-legged myotis <i>Myotis Volans</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
Silver-haired bat <i>Lasionycteris noctivagans</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
Hoary bat <i>Lasiurus cinereus</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
Townsend’s big-eared bat <i>Corynorhinus townsendii</i>	SSC	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
Pallid Bat <i>Antrozous pallidus</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
California myotis <i>Myotis californicus</i>	SS	--	Y	N	Y	Y	N	Not expected to become listed during permit term. HCP and FMP policies will minimize disturbance
American pika <i>Ochotona princeps</i>	SS	--	Y	N	N	Y	N	Not expected to become listed during permit term. Talus slopes are generally avoided during covered activities.
Insects								
Monarch butterfly <i>Danaus plexippus</i>	--	PT	Y	Y	N	Y	N	May occur in Oregon, primarily in the Willamette Valley, in grasslands, old fields, savannahs, suburban yards and gardens, orchards, roadsides, utility rights-of way, and open forests. The monarch breeds and migrates through Oregon relying on native milkweed and nectar from flowering plants. The western monarch migrates south to California to overwinter. A proposed rule was published in the Federal Register on December 12, 2024 (89 FR 100662; 50 CFR 17) to list the monarch butterfly as threatened with a 4(d) rule and designate critical habitat at the overwintering grounds in California. The 4(d) rule includes an exception for activities that may maintain, enhance, remove, or establish milkweed and nectar plants within the breeding and migratory range that do not result in

Species	Status ^a			Criteria ^b			Recommended Covered Status ^c	Notes
	State	Federal	Range	Status	Impact	Data		
								conversion of native or naturalized grassland, shrubland, or forested habitats. This exception specifies that such activities include fire-management actions (e.g., prescribed burns, maintenance of fuel breaks and minimum clearance requirements, and other fuel- reduction activities) and silviculture practices and forest-management activities that use state-approved best management practices. The 4(d) rule provides exceptions for HCP covered activities.
Fender’s blue butterfly <i>Icaricia icarioides fenderi</i>	--	FE	Y	Y	N	Y	N	Not likely to occur in the plan area due to lack of suitable habitat
Oregon silverspot butterfly <i>Speyeria zerene hipolyta</i>	--	FT	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Taylor’s checkerspot <i>Euphydryas editha taylori</i>	--	FE	N	Y	N	Y	N	Plan area is outside of range or current known distribution
Vernal pool fairy shrimp <i>Branchinecta lynchi</i>	--	FT	N	Y	N	Y	N	Plan area is outside of range or current known distribution

Notes:

^a **Status**
State Status
SE = State listed as endangered
ST = State listed as threatened
SS = State sensitive
SSC = State sensitive-critical
– = Not state listed
Federal Status
FE = Federally endangered
FT = Federally threatened
UR = Under review
PT = Federally proposed threatened
PE = Federally proposed endangered
– = Not federally listed.

^b **Criteria**
Range: The species is known to occur or is likely to occur within the plan area, based on credible evidence, or the species is not currently known in the study area but is expected in the study area during the permit term (e.g., through range expansion or reintroduction to historic range).
Status: The species meets one or more of the following criteria.
▪ Listed under the federal Endangered Species Act (ESA) as threatened or endangered, or proposed for listing.
▪ Listed under the Oregon ESA as threatened or endangered or a candidate for such listing.
▪ Expected to be listed under Federal or State ESA within the permit term (50 years). Potential for listing during the permit term is based on the current listing status, consultation with Wildlife Agency staff and other experts, evaluation of species population trends and threats, and best professional judgment.
Impact: The species or its habitat would be adversely affected by covered activities or projects that may result in take of the species.
Data: Sufficient data exist on the species’ life history, habitat requirements, and occurrence in the study area to adequately evaluate impacts on the species and to develop conservation measures to mitigate these impacts to levels specified by regulatory standards.
Species proposed for coverage in the Western Oregon State Forests Habitat Conservation Plan were limited to those species for which impacts from covered activities were likely, in order to provide take authorization for the highest priority species.

^c **Recommended Covered Status**
Y = Recommended as covered species in the Western Oregon State Forests Habitat Conservation Plan.
N = Not recommended for coverage in the Western Oregon State Forests Habitat Conservation Plan.

Appendix E

Effects Analysis Approach

Fish Limiting Factors

Lower Columbia River Coho

Population Group	Populations	Key Limiting Factors2	Adult Abundance1		Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area					Contributing Streams in Permit Area (outside species distribution)2		
			Recent 5 yr Average & Range (2014 – 2018)3	Percent of Total ESU Abundance		Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
Coastal	Youngs Bay	Population Diversity (A) Habitat Quantity (A)	93 (26/161)	1%	141	7	5%	6.7	88.3	81.4	96.9	4.8	4.8	0.0	3.4%	4.6	73.4	68.5	91.2
	Big Creek	Population Diversity (A) Habitat Quantity (A)	400 (160/792)	4	83	17	20%	16.9	169.2	152.2	135.1	15.1	15.1	0.0	18.2%	15.0	148.8	133.7	126.7
	Clatskanie River	Population Diversity (A) Riparian Condition (J)	908 (25/3,246)	10%	104	3	3%	6.9	143.2	140.6	94.8	2.7	2.7	0.0	2.6%	4.9	106.6	103.9	88.0
	Scappoose Creek	Riparian Condition (J) Peripheral and Transitional Habitats (J)	767 (178/1,587)	8%	139	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Coastal Total		2,169 (389/5,786)	23%	326	20	6%	30.5	400.7	374.2	326.7				0.0%	24.5	328.8	306.2	305.8
Cascade	Clackamas River	Population Diversity (A) Water Quality (A & J)	4,968 (1,628/10,672)	56%	390	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Sandy River	Riparian Condition (J) Peripheral and Transitional Habitats (J)	2,049 (443/5,942)	22%	181	0.1	0.06%	0.1	1.0	0.9	0.0	0.1	0.0	0.1	0.1%	0.1	1.0	0.9	0.0
	Cascade total		7,017 (2,071/16,614)	74%	572	0.1	0.02%	0.1	1.0	0.9	0.0				0.0%	0.1	1.0	0.9	0.0

Population Group	Populations	Key Limiting Factors2	Adult Abundance1		Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area					Contributing Streams in Permit Area (outside species distribution)2		
			Recent 5 yr Average & Range (2014 – 2018)3	Percent of Total ESU Abundance		Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Pemit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
Gorge	Lower Gorge Tributaries	Population Diversity (A) Habitat Quantity (A)	201 (0/395)	2%	125	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Upper Gorge Tributaries and Big White Salmon River	Habitat Quantity (A) Riparian Condition (J)	-	-	108	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Upper Gorge Tributaries and Hood River	Population Diversity (A) Habitat Quantity (A&J)	53 (0/107)	1%	134	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Gorge total		253 (0/502)	3%	367	0	0	0.0	0.0	0.0	0.0					0.0	0.0	0.0	0.0

some occurrence in plan/permit area

1 - ODFW Salmon and Steelhead Recovery Tracker

2 - A = Adult; J = Juvenile

3 - Youngs Bay and Big Creek abundance is reported for 2008-2012. Data is not avaiable for these populations from 2014-2018

Oregon Coast Coho

Population Group	Populations	Key Limiting Factor(s)	Adult Abundance1		Total Stream Miles	Stream Miles in Plan Area			Total Fish Bearing in Plan Area	Contributing Streams in Plan Area (outside species distribution)2		Stream Miles in Permit Area					Total Fish Bearing in Permit Area	Contributing Streams in Permit Area (outside species distribution)2	
			Recent 5 yr. Average & Range (2013– 2017)	Percent of Total ESU Abundance		Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area		Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area		Fish Bearing	Non-fish Bearing
North Coast	Necanicum	Stream Complexity	1,767 (529/5,727)	1%	99.5	1.1	1%	1.1	2.85	1.7	7.8	0.8	0.0	0.8	0.8%	0.8	12.2	11.4	14.4
	Nehalem	Steam Complexity Water Quality	10,246 (3,079/30,577)	8%	769.1	241.5	31%	215.0	544.61	303.1	1,420.5	214.6	212.3	2.3	27.9%	192.2	2,870.6	2,656.0	3,145.3
	Tillamook Bay	Steam Complexity Water Quality	7,173 (1,345/20,090)	5%	461.5	233.3	51%	196.9	414.63	181.3	1,627.8	225.3	223.6	1.7	48.8%	189.9	3,409.0	3,183.8	3,528.5
	Nestucca	Steam Complexity	3,050 (946/6,369)	2%	255.7	4.2	2%	2.4	10.64	6.4	20.5	4.2	4.2	0.0	1.7%	2.4	137.4	133.1	137.4
	Sand Lake (North Coast Dependents)	Steam Complexity Water Quality	1,245 (206/4,607)	<1%	57.0	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	North Coast Total		23,481 (6,740/67,370)	17%	1642.7	480.2	29%	415.4	972.74	492.5	3,076.6				0.0%	385.3	6,429.2	5,984.2	6,825.6
Mid-Coast	Salmon	Hatchery Impacts Steam Complexity	1,336 (332/3,680)	1%	57.8	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Siletz	Stream Complexity	7,518 (2,216/19,496)	6%	283.5	7.3	3%	7.0	27.68	20.4	49.9	5.7	3.3	2.4	2.0%	5.5	77.0	71.3	106.9
	Yaquina	Stream Complexity Water Quality	7,551 (2,400/25,582)	6%	280.5	19.1	7%	17.2	65.93	46.8	76.9	13.1	9.2	3.9	4.7%	11.1	180.6	167.5	230.0
	Beaver	Spawning Gravel Stream Complexity	2,435 (332/6,564)	2%	55.9	0.6	1%	0.5	1.01	0.4	1.6	0.6	0.6	0.0	1.0%	0.5	2.6	2.1	2.6
	Alsea (harvest occurs in this HUC, no fish streams though)	Steam Complexity Water Quality	10,566 (4,288/25,733)	8%	423.5	0.0	0%	0.0	0.37	0.4	0.0	0.0	0.0	0.0	0.0%	0.0	1.9	1.9	2.5
	Siuslaw	Steam Complexity Water Quality	15,927 (7,129/38,896)	12%	840.9	33.5	4%	29.7	64.07	30.5	44.1	16.3	16.3	0.0	1.9%	15.1	206.6	190.3	356.5
	Rock Creek (Mid-Coast Dependents)	Stream Complexity Spawning Gravel	1,406 (473/2,012)	1%	43.9	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Tenmile (Mid-Coast Dependents)	Stream Complexity Spawning Gravel			62.8	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Yachats (Mid-Coast Dependents)	Stream Complexity Spawning Gravel			51.9	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Mid Coast total		46,739 (22,673/121,963)	34%	1423.0	33.5	2%	54.4	159.06	98.6	172.5				0.0%	32.2	468.8	433.2	698.6

Population Group	Populations	Key Limiting Factor(s)	Adult Abundance1		Total Stream Miles	Stream Miles in Plan Area			Total Fish Bearing in Plan Area	Contributing Streams in Plan Area (outside species distribution)2		Stream Miles in Permit Area					Total Fish Bearing in Permit Area	Contributing Streams in Permit Area (outside species distribution)2	
			Recent 5 yr. Average & Range (2013– 2017)	Percent of Total ESU Abundance		Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area		Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area		Fish Bearing	Non-fish Bearing
Lakes	Siltcoos	Non-Native Fish Species Stream Complexity/Water Quality	3,134 (715/7,178)	2%	96.7	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Tahkenitch	Non-Native Fish Species Stream Complexity/Water Quality	1,941 (269/3,691)	1%	52.6	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Tenmile	Non-Native Fish Species Stream Complexity/Water Quality	4,874 (318/11,141)	4%	89.5	0.8	1%	0.5	1.66	0.8	4.8	0.8	0.8	0.0	0.9%	0.5	7.0	6.1	7.1
	Mercer (Lakes Dependent)	Non-Native Fish Species Stream Complexity/Water Quality			23.7	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Lakes Total		9,949 (1,302/22,010)	7%	23.7	0.8	3.4%	0.5	1.66	0.8	4.8				0.0%	0.5	7.0	6.1	7.1
Umpqua	Lower Umpqua	Stream Complexity Water Quality	12,746 (3,725/36,942)	9%	610.2	2.4	0.4%	2.7	4.19	1.7	5.5	1.9	1.9	0.0	0.3%	2.1	12.8	10.9	17.0
	Middle Umpqua	Water Quality Stream Coplexity	4,681 (1,159/13,939)	3%	559.4	0.3	0.1%	0.3	0.33	0.0	0.9	0.3	0.0	0.3	0.1%	0.3	1.2	0.9	1.2
	North Umpqua	Hatchery Impacts Stream Complexity	2,537 (1,148/3,979)	2%	215.8	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	South Umpqua	Water Quality Stream Coplexity	6,263 (765/12,178)	5%	816.1	8.8	1%	6.5	15.34	6.5	92.3	8.3	7.3	1.0	1.0%	6.0	92.1	83.9	121.8
	Umpqua total		26,227 (7,494/66,272)	19%	1591.4	9.2	1%	9.5	19.86	8.2	98.7				0.0%	8.4	106.2	95.7	140.1
Mid-South Coast	Coos	Stream Complexity Water Quality	11,221 (2,689/38,880)	8%	483.2	13.7	3%	14.0	19.42	5.7	47.3	11.0	11.0	0.0	2.3%	11.0	69.3	58.3	92.0
	Coquille	Stream Complexity Water Quality	16,558 (3,357/41,660)	12%	597.8	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Flores	Stream Complexity Water Quality	1,236 (693/1,936)	1%	120.0	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Sixes	Stream Complexity Water Quality	267 (69/567)	0%	71.7	0.0	0%	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Mid-South Coast Dependents	Stream Complexity Water Quality	27 (0/105)	<1%	NA	0.0	NA	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0%	0.0	0.0	0.0	0.0
	Mid-South Coast total		29,309 (8,092/82,077)	22%	1272.7	13.7	1%	14.0	19.42	5.7	47.3					11.0	69.3	58.3	92.0

some occurrence in plan/permit area

1 - ODFW Salmon and Steelhead Recovery Tracker

2 - StreamNet and the Statewide hydo layer do not always align. These values are a general estimate, not an accurate total.

Columbia River Chum

Population Group	Populations	Key Limiting Factors	Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area					Contributing Streams in Permit Area (outside species distribution)2		
				Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
Gorge	Lower Gorge Tributaries	Riparian Conditions (A&J) Peripheral and Transitional Habitats (A&J)	75	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Upper Gorge Tributaries	Habitat Quantity (A&J) Riparian Condition (A&J)	55	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hood River	Not Listed	0	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gorge total		130	0	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0.0	0.0	0.0	0.0
Coastal	Big Creek	Habitat Quantity (A) Sediment Conditions (J)	45	8	18%	0.0	169.2	161.1	135.1	8.1	8.1	0.0	17.8%	0.0	148.8	140.7	126.7
	Clatskanie River	Sediment Conditions (J) Water Quality (A)	25	0	0%	0.0	143.2	143.2	94.8	0.0	0.0	0.0	0.0%	0.0	106.6	106.6	88.0
	Youngs Bay	Habitat Quantity (A) Sediment Conditions (J)	57	1	2%	0.0	88.3	87.2	96.9	0.3	0.3	0.0	0.5%	0.0	73.4	73.1	91.2
	Coastal total		127	9	7%	0.0	400.7	391.5	326.7	8.4	8.4	0.0	7%	0.0	328.8	320.4	305.8

some occurrence in plan/permit area

note: no ODFW abundance data

2 - StreamNet and the Statewide hydo layer do not always align. These values are a general estimate, not an accurate total.

Upper Willamette River Steelhead

Population Group	Populations	Key Limiting Factors	Adult Abundance1		Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area					Contributing Streams in Permit Area (outside species distribution)2		
			Recent 5 yr Average & Range (2014 – 2018)	Percent of Total ESU Abundance		Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
	Molalla River	Habitat Quality Water Quality	1,484 (1,273/1,987)	22%	296	2	1%	0.61	31.7	29.9	75.6	0.6	0.6	0.0	0.2%	0.15	24.6	24.0	60.2
	North Santiam River	Habitat Access Water Quality	2,826 (1,650/3,863)	43%	174	9	5%	7.50	90.8	82.1	252.9	6.3	6.3	0.0	3.6%	5.11	68.1	61.8	173.2
	South Santiam River	Habitat Access Water Quality	1,988 (1,519/3,546)	30%	326	2	1%	2.40	6.0	3.6	25.6	2.4	2.4	0.0	0.7%	2.40	6.0	3.5	21.9
	Calapooia River	Water Quantity Habitat Access	312 (140/684)	5%	88	0	0%	0	0.0	0.0	0.4	0.0	0.0	0.0	0.0%	0.00		0.0	0.4
	West Side Tributaries	Habitat Access Water Quality	NA	NA	857	16	2%	7.95	243.8	227.9	214.0	14.4	14.4	0.0	1.7%	6.50	221.5	207.2	156.8
	Willamette total				1741	29	2%	18.5	372.3	343.3	568.5					14.16	320.2	296.5	412.6

some occurrence in plan/permit area

1 - ODFW Salmon and Steelhead Recovery Tracker

2 - StreamNet and the Statewide hydo layer do not always align.

These values are a general estimate, not an accurate total.

Upper Willamette River Chinook

Population Group	Populations	Key Limiting Factors	Adult Abundance1		Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area					Contributing Streams in Permit Area (outside species distribution)2		
			Recent 5 yr Average & Range (2014 – 2018)	Percent of Total ESU Abundance		Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/ CSL)	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
Willamette	Calapooia River	Water Quality Water Quantity			77	0	0	0.0	0.0	0.0	0.4	0	0	0	0.0%	0.0	0.0	0.0	0.4
	Clackamas River	Habitat Access Population Diversity			140	0	0	0.0	0.0	0.0	0.0	0	0	0	0.0%	0.0	0.0	0.0	0.0
	McKenzie River	Habitat Access Water Quantity			301	0	0	0.0	0.0	0.0	0.0	0	0	0	0.0%	0.0	0.0	0.0	0.0
	Middle Fork Willamette River	Water Quality Water Quantity			284	0	0	0.0	2.6	2.6	4.6	0	0	0	0.0%	0.0	2.2	2.2	2.2
	Molalla River	Habitat Quality Water Quality			189	0	0	0.0	31.7	31.7	75.6	0	0	0	0.0%	0.0	24.6	24.6	60.2
	North Santiam River	Water Quality Water Quantity			182	5	3%	0.0	90.8	85.5	252.9	4.1	4.1	0	2.3%	0.0	68.1	64.0	173.2
	South Santiam River	Water Quality Water Quantity			207	0	0	0.0	6.0	6.0	25.6	0	0	0	0.0%	0.0	6.0	6.0	21.9
	Willamette total				1380	5	0.4%	0.0	131.1	125.8	359.1					0.0	100.9	96.8	257.9
Z-Outside (area outside independent population)	Z-Outside				498	0	0		1.0	1.0	1.0	0	0	0	0		1.0	1.0	1.0

some occurrence in plan/permit area

1 - ODFW Salmon and Steelhead Recovery Tracker

2 - StreamNet and the Statewide hydo layer do not always align. These values are a general estimate, not an accurate total.

Population Group	Populations	Key Limiting Factors	Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area					Contributing Streams in Permit Area (outside species distribution)2		
				Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Percent (%) in Permit Area (BOF/CSL)	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
Rogue	Chetco	Urban/Residential/Industrial Development Channelization/Diking	281	0	0%	0.0	0.0	0.0		0	0	0	0.0%	0.0	0.0	0.0	0.0
	Elk	Channelization/Diking Urban/Residential/Industrial Development	69	0	0%	0.0	0.0	0.0		0	0	0	0.0%	0.0	0.0	0.0	0.0
	Illinois	Roads Dams/Diversions	451	0.2	0%	0.0	1.3	1.1	13.8	0.18	0	0.18	0.0%	0.0	1.3	1.1	13.8
	Lower Rogue	Roads Urban/Residential/Industrial Development	101	0	0%	0.0	0.0	0.0		0	0	0	0.0%	0.0	0.0	0.0	0.0
	Middle Rogue and Applegate	Urban/Residential/Industrial Development Dams/Diversions	826	1	0.1%	0.0	8.6	7.5	43.6	1.16	0.67	0.49	0.1%	0.0	8.6	7.5	43.0
	Smith	Channelization/Diking Agriculture	56	1	2%	0.0	1.5	0.4	2.1	1.18	0	1.18	2.1%	0.0	1.5	0.4	2.1
	Upper Klamath	Dam/Diversions Roads	0	0	0%	0.0	0.0	0.0	0.5	0	0	0	0.0%	0.0	0.0	0.0	0.5
	Upper Rogue	Agricultural Practices Urban/Residential/Industrial Development	253	0	0%	0.0	0.0	0.0	1.2	0	0	0	0.0%	0.0	0.0	0.0	1.2
	Winchuck	Channelization/Diking Urban/Residential/Industrial Development	63	0	0%	0.0	0.2	0.2	0.8	0	0	0	0.0%	0.0	0.2	0.2	0.8
	Rogue Total		2099	3	0.1%	0.0	11.7	9.2	62.0	2.5	0.7	1.9	0%	0.0	11.7	9.2	61.4

some occurrence in plan/permit area

2 - StreamNet and the Statewide hydo layer do not always align. These values are a general estimate, not an accurate total.

Lower Columbia River Chinook

Population Group	Populations	Key Limiting Factors1	Total Stream Miles	Stream Miles in Plan Area			Contributing Streams in Plan Area (outside species distribution)2			Stream Miles in Permit Area				Contributing Streams in Permit Area (outside species distribution)2		
				Miles in Plan Area	Percent (%) in Plan Area	Miles of Critical Habitat in Plan Area	Total Fish Bearing in Plan Area	Fish Bearing	Non-Fish Bearing	Total Miles	BOF Miles	CSL Miles	Miles of Critical Habitat in Permit Area	Total Fish Bearing in Permit Area	Fish Bearing	Non-fish Bearing
Cascade	Clackamas River	Sediment Conditions (A) Population Diversity (A)	173	0	0	0.0	0.0	0.0	0.0	0	0	0	0.0	0	0.0	0.0
	Sandy River	Sediment Conditions (A) Population Diversity (A)	110	0	0	0.0	1.0	1.0	0.0	0	0	0	0.0	1.0	1.0	0.0
Gorge	Lower Gorge Tributaries	Population Diversity (A) Water Quantity (A)	68	0	0	0.0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	0.0
	Upper Gorge Tributaries	Population Diversity (A) Mortality (A)	61	0	0	0.0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	0.0
	Hood River	Population Diversity (A) Habitat Quantity (A)	107	0	0	0.0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0	0.0
Coastal	Scappoose Creek	Population Diversity (A) Sediment Conditions (A)	26	0	0	0.0	0.0	0.0	0.3	0	0	0	0.0	0.0	0.0	0.3
	Big Creek	Habitat Quantity Population Diversty				0.0	169.2	169.2	135.1					148.8	148.8	126.7
	Clatskanie River	Population Diversity Sediment Conditions				0.0	143.2	#VALUE!	94.8					106.6	106.6	88.0
	Young's Bay	Habitat Quantity (A) Sediment Conditions (A)				0.0	88.3	#VALUE!	96.9					73.4	73.4	91.2
						0.0	401.7	#VALUE!	327.1				0.0	1.0	1.0	0.3

1 - A= Adult

Eulachon

Species	Key Limitng Factors	Notes	Stream Miles in Plan Area
Southern DPS Eulachon	Climate Change Bycatch	Eulachon are not expected to occur in streams on ODF land. There is ODF land adjacent to the Columbia, which is used by the species.	Limited - assume BGO's for salmonids would also benefit eulachon.

Temperature Protection Memo

Western Oregon State Forest HCP**Riparian Conservation Area and Temperature Protection****Introduction**

The Oregon Department of Forestry (ODF) is preparing a multi-species Western Oregon State Forests Habitat Conservation Plan (HCP) to support the issuance of incidental take permits (ITPs) under the federal Endangered Species Act (ESA) for Western Oregon State Forests that are managed by ODF. The HCP is a long-term plan that will support the conservation of threatened and endangered species, or those species that are likely to become listed, while allowing management of the forest including ongoing timber harvest activities.

Covered species are those species for which US Fish and Wildlife Service (USFWS) and National Marine Fisheries Services (NMFS) will provide take authorization to ODF to conduct the covered activities. The permit area provides habitat for a variety of species, including species listed under state and federal endangered species protection laws, and others that are not yet listed, but may become listed during the permit term. ODF selected the covered species for the HCP based on review of all species of conservation concern known or suspected to occur in the plan area during the permit term.

As part of HCP development agencies coordinated on the development of riparian buffers that would protect watershed processes, and specific to this memo, stream temperatures to benefit the covered species that utilize streams and adjacent riparian forests. These include nine fish and two amphibians: Oregon Coast coho, Oregon Coast spring chinook, Lower Columbia River coho, Lower Columbia River chinook, Columbia River chum, Upper Willamette River spring chinook, Upper Willamette River steelhead, Southern Oregon/Northern California coast coho, eulachon, Columbia torrent salamander, and Cascade torrent salamander.

Riparian Conservation Area Designation

Degraded water quality, especially elevated stream temperature, is one of the primary threats to many of the covered fish species (NMFS 2013, 2014; ODFW and NMFS 2011). The restoration of riparian function, through the implementation of riparian conservation areas (RCAs) in the permit area, will help reduce stream temperature increases by maintaining or increasing shading, the primary driver of stream temperature (Beechie et al. 2012). This will benefit the covered species and provide longer-term climate change resilience.

ODF will establish Riparian Conservation Areas (RCAs) adjacent to streams. The functions of streams within the permit area will be maintained by retaining vegetation in riparian areas during adjacent harvest activities. No harvest will occur within the RCAs.

The buffer widths provided for RCAs represent a minimum buffer and are reported in horizontal distance unless otherwise noted, meaning that the width is applied and measured in the field horizontally, regardless of slope. It is measured beginning at the aquatic zone, which can be one of the following: the average high-water level of the water body, the edge of the stream-associated wetland or side channel, or the channel migration zone,¹ whichever is farthest from the waterway, and extends perpendicular from the stream toward the uplands. Since the buffers are reported using horizontal distance, as slope increases, the effective width (i.e. distance along slope) of the conservation area in the field also increases.

¹ The area where the active channel of a stream or river is prone to move, and the movement results in a potential near-term loss of riparian function and associated habitat adjacent to the stream.

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Scientific Basis for the Temperature Protection Zone

Harvest activities adjacent to fish bearing streams can increase summer stream temperatures through reduction of shade that results in increased solar radiation reaching the water's surface. This can also occur on small, non-fish bearing streams that flow into fish bearing streams, particularly in stream reaches immediately above fish bearing streams. Temperature increases, if not managed, can extend downstream into fish bearing waters and affect the covered fish species. To address potential effects to the covered species from harvest activities in the permit area, the width of RCAs have been designated based on fish presence, stream size and flow duration (perennial versus seasonal), and potential to deliver wood.

RCAs adjacent to small non-fish bearing perennial and seasonal streams will be narrower than RCAs adjacent to fish bearing and medium and large non-fish streams (see Chapter 4 *Conservation Actions* for full RCA description). Small perennial non-fish bearing streams will have RCAs that extend 120 feet (horizontal distance) from the aquatic zone for the first 500 feet upstream of the end of fish use to protect stream temperatures in water within that 500 feet, as well as allowing for some temperature recovery from upstream, as it flows from a small non-fish perennial stream into a fish bearing stream. Upstream of the 500-foot process protection zone, the buffer will be 35 feet (horizontal distance) from the aquatic zone (Table ; Figure).

Table 1. Minimum Riparian Conservation Area Widths (Horizontal Distance) for Small Perennial and Seasonal Type N Streams

Stream Type	Within Process Protection Zone		Upstream of 500-foot Process Protection Zone
	Temperature	Wood	
Perennial Small Type N	120	--	35
Potential debris flow track (Seasonal Type N) ^a	--	50	35
High energy (Seasonal Type N) ^b	--	50	35
Seasonal other (Type N) ^c	0 ^d	0 ^d	0 ^d

Notes:

^a Potential debris flow tracks: Reaches on seasonal Type N streams that have a high potential of delivering wood to a Type F stream by debris flow.

^b High Energy: Reaches on seasonal Type N streams that have a high potential of delivering wood and sediment to a Type F stream during a high-flow event.

^c Seasonal: A stream that does not have surface flow after July 15.

^d Seasonal other (Type N) streams will have a 35' equipment restriction zone.

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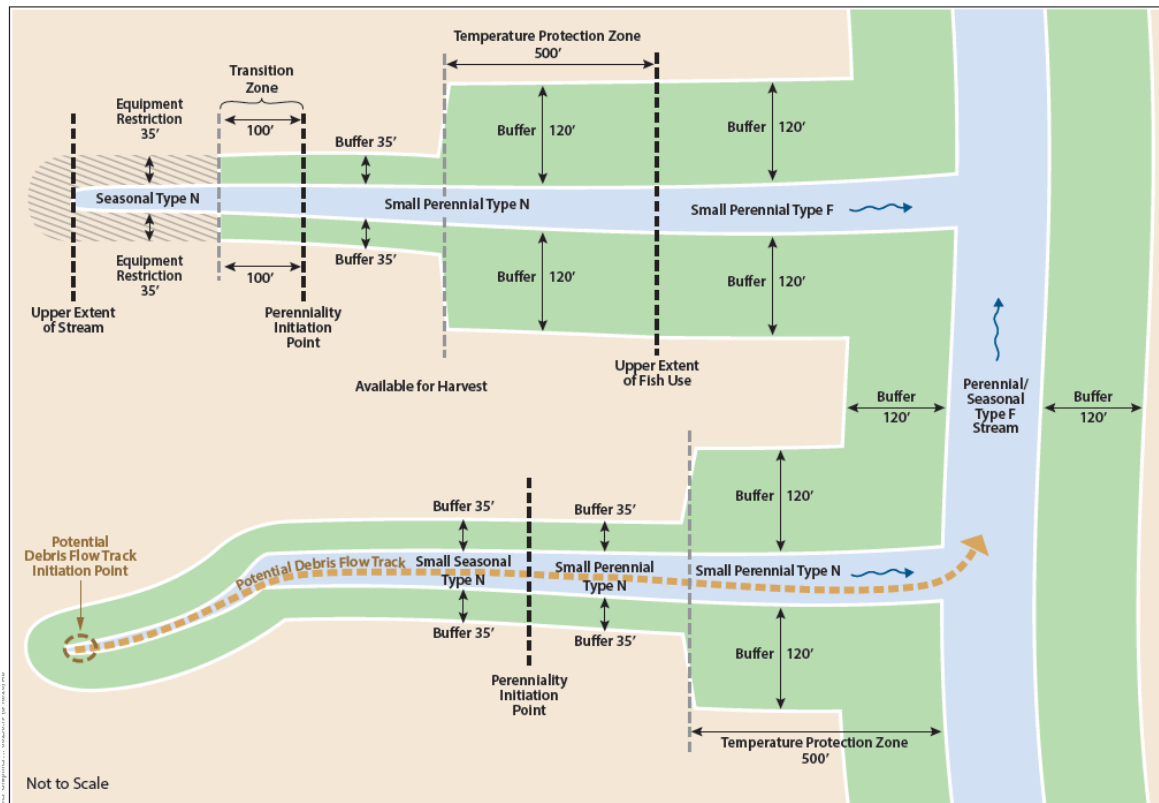


Figure 1. Riparian Conservation Areas Scenarios with Temperature Protection Zones

The 120-foot RCA (horizontal distance) within the 500-foot temperature zone at the intersection of fish and small perennial non-fish streams will help ameliorate stream temperature increases. The temperature protection zone was identified based on a literature review process with the Western Oregon State Forest HCP Scoping Team². A list of sources reviewed by the Scoping Team to assess how forestry activities and riparian management strategies affect downstream temperatures and identify the proposed temperature protection zone is provided in Attachment 1 and summarized below.

Julie Firman (ODFW) performed a literature review (Figure 2) and assessment (Figure 3) of heating related to buffer width, and Blandon et al. (2018) performed a similar analysis for buffer length (Figure 4). In addition, Leinenbach (2016) Bayesian model of stream temperature response to buffering was reviewed (Figure 5). The results of these analysis and the studies discussed below indicate that while a 120-foot wide by 500-foot long temperature protection zone buffer will not entirely dissipate accumulated heat from the harvested area, it will allow stream temperatures to return to near the pre-harvest temperature regime prior to reaching a fish bearing stream.

Effects of rising temperature on the listed species could include physiological stress and reduced growth, disruption of life cycle timing, and increased predation and disease that would potentially reduce survival and

² The Scoping Team is comprised of representatives from: Oregon Department of Forestry, Oregon Department of State Lands, Oregon Department of Environmental Quality, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service.

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reproductive success (NMFS 2016). During the summer months, many of the streams coho salmon juveniles inhabit are already close to lethal temperatures, and with the expectation of rising stream temperatures due to global climate change, increases in infection rates of juvenile coho salmon by parasites may become an increasingly important stressor both for freshwater and marine survival (NMFS 2016).

Lestelle (2007) summarized several studies on effects of water temperature on juvenile coho salmon. For example, a study in the Mattole River (Northern California) reported coho were not found in streams that exceeded a maximum weekly temperature³ of 18°C (Welsh et al. 2001 in Lestelle 2007). Another study in the Sixes River (Southern Oregon) reported juvenile coho salmon to be absent or rare in stream segments where temperatures exceeded 21°C (Frissell 1992 in Lestelle 2007). Overall, it is recommended that water temperatures not exceed 20-21°C to avoid lethality to coho salmon (Richter and Kolmes 2005).

While the 500-foot by 120-foot temperature protection zone is not expected to totally offset the effects of harvest on stream temperature, it would result in substantial reduction of water temperature changes prior to entering fish bearing streams. Bladon et al. (2018) found that while maximum daily stream temperatures were elevated in small, non-fish bearing headwaters after harvest there was not measurable downstream warming related to upstream harvest activities.

Numerous upstream-downstream longitudinal studies examined temperature recovery downstream of single harvest units. Davis et al. (2015), in an analysis of sites from ODF's RipStream study, found that the temperature change 300m (984ft) downstream of harvest units on small and medium fish bearing streams was approximately 56% of the change at the harvest unit, on average (range of 1-82% of harvest unit change). However, this behavior was highly site-dependent (streams with lower gradients and/or greater surface area showed lower temperature change magnitudes at 300m). Arismendi and Groom (2018), in another RipStream analysis, also showed a tendency for downstream sites to converge towards the pre-harvest equilibrium, that the tendency generally strengthened with time, and post-harvest temperature regimes with wide buffers returned to behavior that was statistically similar to their pre-harvest characteristics while sites with narrow buffers often did not. Several other studies examining the extent of stream temperature recovery towards pre-harvest conditions downstream of harvest units show incomplete downstream mitigation of single harvest unit temperature increases that were due to narrow streams buffers (Keith et al. 1998: 0.5° of 5.0°C of the temperature increase remaining after 73m (240ft) and 0.5° of 6.0°C temperature increase remaining after 46m (151ft); MacDonald et al. 1998: 2° of 3.0°C increase remaining after 500m (1640ft); Rutherford et al. 2004: 0.77 to 7.18°C increase reduced by 0.35 to 2.51°C, over distances of 153 to 892m (502 to 2,926ft); Wilkerson et al. 2006 (unbuffered streams): 1.8° of 2.8°C of increase remaining and 1.3° of 2.5°C increase remaining after 100m (328ft); and Zwieniecki and Newton 1999: study mean across sites was 0.4° of 1.09°C increase remaining after 150m (492ft).

Unlike the small non-fish bearing streams observed by Bladon et al. 2018, some of the above studies were primarily on fish bearing streams. Non-fish bearing headwater streams often have very high groundwater inputs, low flow volumes relative to fish bearing streams, and substantial post-harvest flow increases so heat loss and dilution may be a greater factor in return to equilibrium than in fish bearing streams (e.g. Moore et al. 2003, Story et al. 2003, Kibler et al. 2013). Heated water from harvested sites around non-fish bearing headwaters can rapidly decrease in temperature and move towards pre-harvest equilibrium upon flowing through fully forested stream reaches in the absence of subsequent harvest units, depending on site conditions such as gradient and cold water inputs. With other harvest units present, measureable cumulative

³ Seven-day maximum temperature

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heating is probable unless harvest site BMPs prevent substantial riparian shade loss. Cole and Newton (2013) showed cumulative temperature increases through multiple harvest units with private forest-type buffers (0 to 50 feet), even when separated by uncut reaches, on 3 of 4 study streams. The 120ft wide buffers in the temperature protection zone will likely prevent additional harvest related heating through this reach.

While temperature recovery may not be total through the 500ft temperature protection zone, the relative total flow contribution of non-fish streams in a harvest unit to the receiving fish bearing stream is critical. For example, a temperature increase of 0.5°C in a non-fish stream will be undetectable ($\leq 0.2^\circ\text{C}$) if it provides 40% or less of the total fish-bearing stream's flow, while an increase of 1.5°C must comprise no more than 13% of the total combined flow. Figure 3 shows an average increase of 1°C for a 35ft buffer, which falls within the range of responses in the longitudinal studies described above. With attenuation to 0.75°C at 500ft (see figure 3 in Davis et al. 2015), temperature increases may be undetectable if the non-fish streams' contributions in a particular harvest area are no more than 27% of the combined total flow of the receiving fish bearing stream. Using Figure 4 derived from Bladon et al (2018), that non-fish stream contribution could be as high as 67%. Considering the range of temperature recovery responses in the literature, the semi-conservative nature of heat pollution, and the dependence on site-specific characteristics, the 500 foot temperature protection zone provides a reasonable degree of certainty that measureable temperature impacts to fish bearing reaches will be avoided.

Buffer width (m)	Buffer width (ft)	Heating C	Location	Reference
0	0	6.1	HJ Andrews	Johnson and Jones 2000
0	0	5.5	Alsea	Harris 1977
0	0	5	BC coastal mtns	Moore et al. 2005
0	0	4	Newfoundland	Curry et al. 2002
0	0	3.9	BC coastal mtns	Feller 1981
0	0	3.6	Maine	Wilkerson et al. 2006
0	0	3	Bull Run	Harr and Fredriksen 1988
0	0	2.9	Maine	Wilkerson et al. 2006
0	0	2.5	Vancouver Island	Holtby and Newcombe 1982
0	0	2.5	SW BC	Kiffney et al. 2003
0	0	2	Alsea	Harris 1977 (patches)
0	0	1.5	W. WA	Janisch et al. 2012
8	26	0.3	Trask	Bladon et al. 2018
8	26	0.5	Trask	Bladon et al. 2018
10	33	0.6	W. WA	Janisch et al. 2012
10	33	1.1	W. WA	Janisch et al. 2012
10	33	3	WA coast range	Jackson et al. 2001
10	33	2.4	WA coast range	Jackson et al. 2001
10	33	2.4	WA coast range	Jackson et al. 2001
10	33	1	BC coastal mtns	Gomi et al. 2006
11	36	1.2	Maine	Wilkerson et al. 2006
11	36	0.4	Trask	Bladon et al. 2018
12	39	0.6	Trask	Bladon et al. 2018
15	49	0	Alsea	Bladon et al. 2016
15	49	0.3	Alsea	Bladon et al. 2018
15	49	0.7	W. OR	Groom et al 2011
17	56	0.4	Trask	Bladon et al. 2018
18	60	0.6	N. Umpqua	ODEQ for science team review 2008
20	66	1	Newfoundland	Curry et al. 2002
23	75	0	Maine	Wilkerson et al. 2006
30	98	0	Deschutes	Reiter
30	98	0.5	N. Umpqua	ODEQ for science team review 2008
30	98	0.1	BC coastal mtns	Gomi et al. 2006
46	150	0.03	N. Umpqua	ODEQ for science team review 2008
50	164	0	W. OR	Groom et al 2011

Figure 2. Sources Reviewed for Heating Related to Buffer

Western Oregon State Forest HCP

Figure 2. Sources Reviewed for Heating Related to Buffer

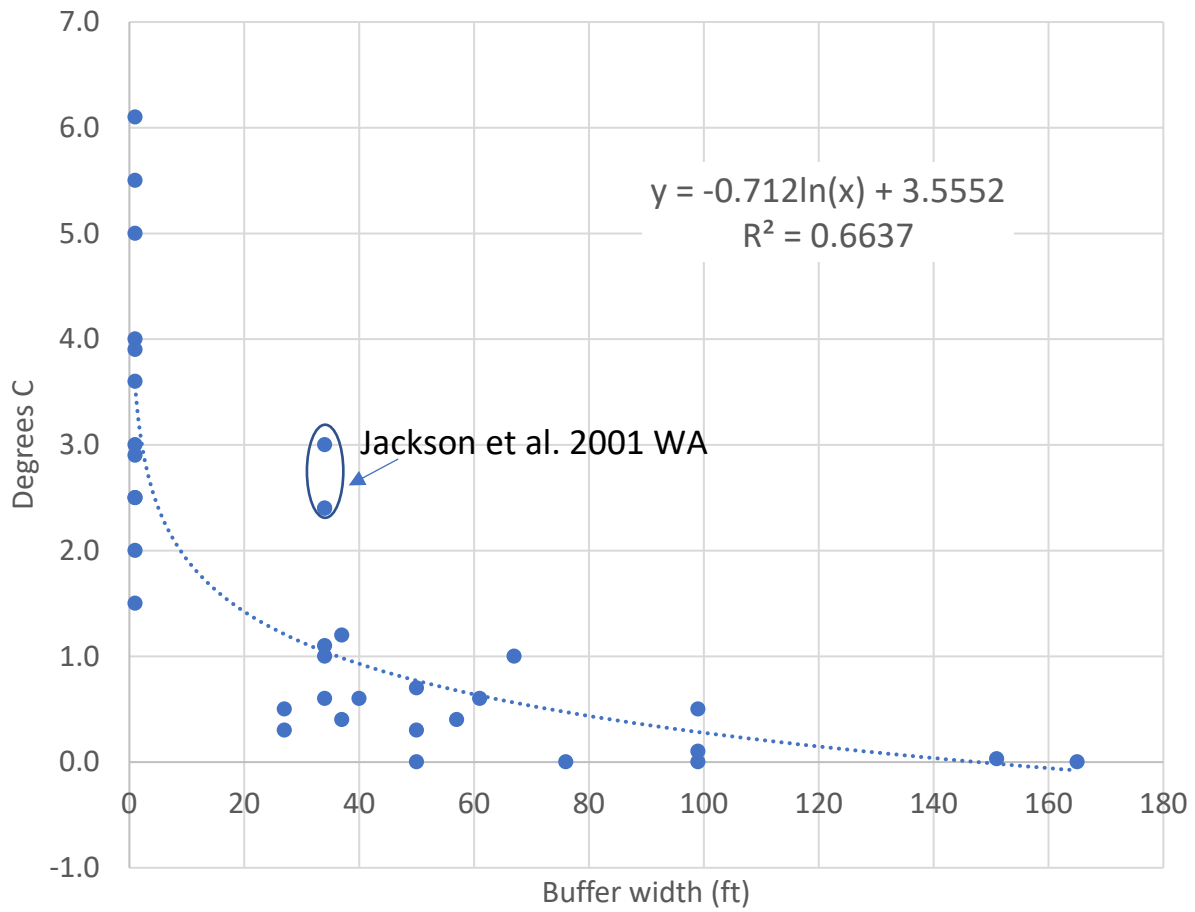


Figure 3. Heating Related to Buffer Width

Western Oregon State Forest HCP

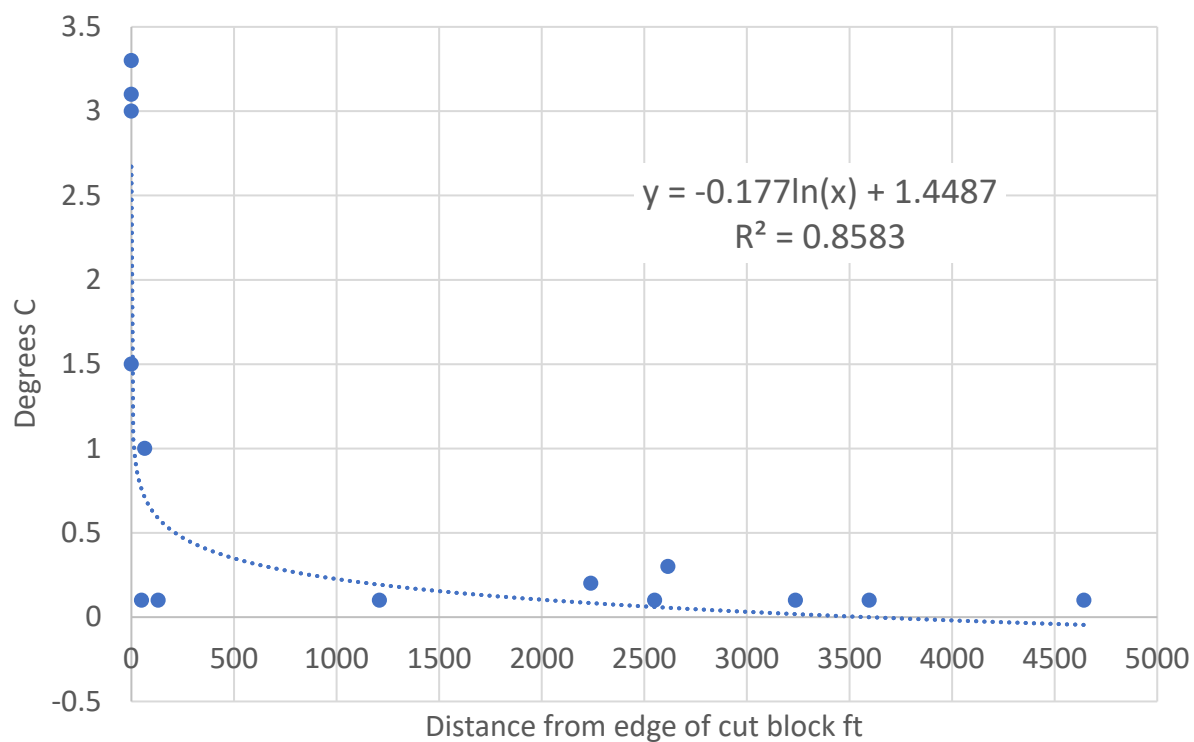


Figure 4. Temperature Exceedance or Elevation Changes as Water Moves Downstream from a Harvested Area (Bladon et al. 2018)

Western Oregon State Forest HCP

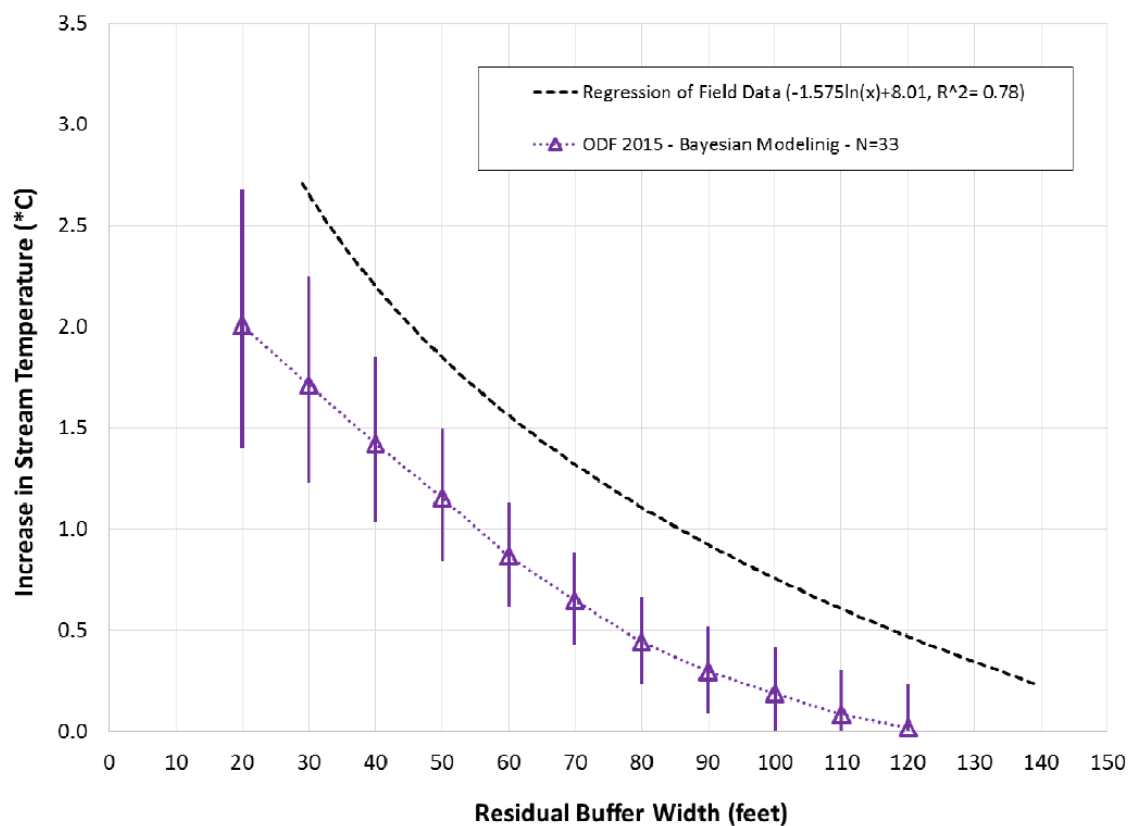


Figure 5. Modeled mean stream temperature response associated with “no-cut” riparian buffers with adjacent clearcut harvest (Leinenbach 2016)

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Attachment 1 – References

Arismendi, I., & J.D. Groom. 2019. A novel approach for examining downstream thermal responses of streams to contemporary forestry. *Science of the Total Environment* 651: 736-748.

Beschta, R. L., & Taylor, R. L. 1988. Stream temperature increases and land-use in a forested Oregon watershed. *Water Resources Bulletin*, 24, 19-25.

Bladon, K. D., N.A. Cook., J.T. Light., and C. Segura. 2016. A catchment-scale assessment of stream temperature response to contemporary forest harvesting in the Oregon Coast Range. *Forest Ecology & Management*, 379, 153-164.

Bladon, K.D., C. Segura, N. Cook, S. Bywater-Reyes, and M. Reiter. 2018. A multicatchment analysis of headwater and downstream temperature effects from contemporary forest harvesting. *Hydrological Processes* 32(2): 293-304.

Cole, E, and M Newton. 2013. Influence of streamside buffers on stream temperature response following clear-cut harvesting in western Oregon. *Canadian Journal of Forest Research* **43**: 993-1005.

Curry, R.A., D. A. Scruton, and K. SD. Clarke. 2002. The thermal regimes of brook trout incubation habitats and evidence of changes during forestry operations. *Canadian Journal of Forest Research* 32: 1200–1207.

Davis, L.J., Reiter, M., and J. D. Groom. 2015. Modelling temperature change downstream of forest harvest using Newton’s law of cooling. *Hydrological Processes* 30: 959-971.

Drake, D., J. Hagar, C. Jordan, G. Lettman, C. Sheridan, T. Spies, and F. Swanson. 2008. Western Oregon Plan Revision Draft Environmental Impact Statement: Science Team Review. March 3. 98 pp. Access at: https://www.blm.gov/or/plans/wopr/files/Science_Team_Review_DEIS.pdf

EPA (United States Environmental Protection Agency). 2013. Potential Modeling Approach to Evaluate the Effects of Thinning Activities on Stream Shade. EPA Comment to BLM 11/19/2013. Portland, OR.

Gomi, T., R.D. Moore, and A.S. Dhakal. 2006. Headwater stream temperature response to clear-cut harvesting with different riparian treatments, coastal British Columbia, Canada. *Water Resources Research*, 42, W08437.

Groom, J. D., L. Dent, L.J. Madsen., and J. Fleuret. 2011. Response of western Oregon (USA) stream temperatures to contemporary forest management. *Forest Ecology and Management*, 262, 1618-1629.

Groom, J.D., S.L. Johnson, J.D. Seeds, G.G. Ice. 2017. Evaluating links between forest harvest and stream temperature threshold exceedances: The value of spatial and temporal data. *Journal of the American Water Resources Association*. August 761-773.

Jackson, C.R., C.A. Sturm, and J.M. Ward. 2001. Timber harvest impacts on small headwater stream channels in the Coast Ranges of Washington. *Journal of the American Water Resources Association* 37(6):1533–1549.

Western Oregon State Forest HCP

- Janisch, J. E., S. M. Wondzell, and W. J. Ehinger. 2012. Headwater stream temperature: Interpreting response after logging, with and without riparian buffers, Washington, USA. *Forest Ecology and Management*, 270, 302-313.
- Johnson, S. L., and J. A. Jones. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences* 57:30-39.
- Keith, R.M., T.C. Bjornn, W.R. Meehan, N.J. Hetrick, and M.A. Brusven. 1998. Response of juvenile salmonids to riparian and instream cover modifications in small streams flowing through second-growth forest of southeast Alaska. *Transactions of the American Fisheries Society* **127**: 889-907.
- Kibler, K.M., A. Skaugset, L.M. Ganio, and M.M. Huso. Effect of contemporary forest harvesting practices on headwater stream temperatures: Initial response of the Hinkle Creek catchment, Pacific Northwest, USA. *Forest Ecology and Management* 310: 680-691.
- Kiffney, P.M., J.S. Richardson, and J.P. Bull. 2003. Responses of Periphyton and Insects to Experimental Manipulation of Riparian Buffer Width Along Forest Streams. *Journal of Applied Ecology* 40 (6): 1060–76.
- Leinebach, P., G. McFadden, and C. Torgersen. 2013. Effects of Riparian Management Strategies on Stream Temperature. Science Review Team Temperature Subgroup. January 17.
- Leinenbach, Peter. 2016. Review of literature describing the relationship between stream shade loss and the subsequent stream temperature increase. Memorandum to Terasa Kubo, USEPA. January 12, 2016. 6 p.
- Macdonald, J.S., J.C. Scrivener, D.A. Patterson, and A. Dixon-Warren. 1998. Temperatures in aquatic habitats: the impacts of forest harvesting and the biological consequences to sockeye salmon incubation habitats in the interior of B.C. *In* M.K. Brewing and D.M.A. Monita (eds.) *Forest-Fish Conference: Land Management Practices Affecting Aquatic Ecosystems*. Natural Resources Canada, Canadian Forest Service Information Report NOR-X-356: 313-324.
- Moore, R.D., J.S. Macdonald, H. Herunter. 2003. Downstream thermal recovery of headwater streams below cutblocks and logging roads. *In* E.A. MacIsaac (ed.) *Forestry Impacts on Fish Habitat in the Northern Interior of British Columbia: A Compendium of Research from the Stuart-Takla Fish-Forestry Interaction Study*. *Canadian Technical Report of Fisheries and Aquatic Sciences* **2509**: 179-189.
- Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian Microclimate and Stream Temperature Response to Forest Harvesting: A Review. *Journal of the American Water Resources Association*. 41(4):813-834.
- Poole, G. C., J. Risley, and M. Hicks. 2001. Spatial and temporal patterns of stream temperature. Issue Paper 3, EPA Region 10 Temperature Water Quality Criteria Guidance Development Project, U.S. Environmental Protection Agency, Portland, Oregon.
- Reiter, M., R.E. Bilby, and J. Heffner. 2015. Stream temperature patterns over 35 years in a managed forest of western Washington. *Journal of the American Water Resources Association*, 51, 1418-1435.
- Rutherford, J.C., N.A. Marsh, P.M. Davies, and S.E. Bunn. 2004. Effects of patchy shade on stream water temperature: how quickly do small streams heat and cool? *Marine and Freshwater Research* **55**: 737-748.

Western Oregon State Forest HCP

Story, A., R.D. Moore, and J.S. Macdonald. 2003. Stream temperatures in two shaded reaches below cutblocks and logging roads: Downstream cooling linked to subsurface hydrology. *Canadian Journal of Forest Research*, 33, 1383-1396.

Wilkerson, E., J.M. Hagan, D. Siegel, and A.A. Whitman. 2006. The effectiveness of different buffer widths for protecting headwater stream temperature in Maine. *Forest Science* **52**: 221-231.

Zwieniecki, M.A. and M. Newton. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of Western Oregon. *Western Journal of Applied Forestry* **14**: 106-113.

Frequency Tables

Aquatic Frequency Table

Activity			Frequency											Notes	
			Frequently ¹			Infrequently ²			Rarely ³			Not Expected to Occur			
			All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial		35 ' ERZ Seasonal
Timber Harvest Methods	Cable Corridors		X	X	X										
	Skid Roads					X		X					X		Skid roads in RCAs would likely be in outer edges of RCAs where alternate methods were not available due to terrain restrictions
	Climb/Top Trees for a Tailhold					X		X					X		
	Guylines					X	X	X							
	Using Equipment as Mobile Anchors								X		X		X		Won't apply in most circumstances, but could happen.
	Yarding Slash				X							X	X		
	Burn Slash										X	X	X		
Timber Harvest Types	Regeneration Harvest	Clear Cut			X							X	X		
	Partial Cut Harvest	Heavy Thinning			X							X	X		
		Moderate Thinning			X							X	X		
		Light Thinning			X							X	X		
	Salvage							X				X	X		Salvage harvest will not occur in RCAs unless to specifically provide for the safety of the public, etc. Trees will not be removed in RCAs
	Hazard Tree Removal								X	X	X				
Reforestation and Young Stand Management	Site Preparation	Mechanical			X							X	X		
	Tree Planting	Initial Planting			X							X	X		
		Interplanting							X	X	X				For Seasonal ERZs this would occur when stocking levels fall below Forest Practice Act minimums. For RCAs and perennial ERZs this would only occur when adding a new tree component into an RCA (such as during a restoration activity).
	Manual Release Treatments				X							X	X		
	Mountain Beaver Control		X	X	X										
	Precommercial Thinning and Pruning				X							X	X		
Road System Management Activities	New Road Construction	With Type F stream crossings				X	X	X							Includes Bridge Installation and landings; Build spur roads and install culvert crossings on small type N streams both seasonal and perennial
		Non-Type F stream crossings				X	X	X							
	Road Use	During Timber Harvest	X	X	X										
		Post Harvest	X	X	X										
	Road Maintenance and Improvement	With stream crossings	X	X	X										Bridge Replacement, Culvert Replacement, Road Widening
		No stream crossings	X		X		X								Haul Routes/Existing Roads (grading and rocking)

Activity			Frequency											Notes	
			Frequently ¹			Infrequently ²			Rarely ³			Not Expected to Occur			
			All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial		35 ' ERZ Seasonal
Road System Management Activities cont.	Road Vacating					X	X	X							Some roads, including legacy roads, may need to be vacated due to their proximity to a fish-bearing stream, high erosion potential, or landslide hazards that could affect the covered species, and because these issues cannot be addressed with road improvement activities.
	Drainage Structure Construction and Maintenance	Temporary Perennial Stream Crossing				X	X							X	Short-term crossings that are used for harvest activities and removed after
		Temporary Seasonal Stream Crossing			X							X	X		
		Permanent Type N Stream Crossing	X	X										X	Long-term crossings, using bridges and culverts, that will remain on the landscape post-harvest and be utilized by other forest users.
		Permanent Type F Stream Crossing				X	X							X	
	Water Drafting and Storage		X	X	X										Mostly ponds and non-fish streams, but also at bridge crossings of some large/med fish streams that provide access to draft
	Landing Construction and Maintenance											X	X	X	
Quarries, Borrow Sites, and Stockpile Sites	Existing Rock Quarries								X				X	X	
	Rock Quarry Development											X	X	X	
	Existing Borrow Sites								X	X	X				
	Borrow Site Development											X	X	X	
	Existing Stockpile Sites								X	X	X				
	Stockpile Site Development											X	X	X	
Fire Management	Broadcast Burning								X		X		X		Broadcast burning as a whole would be rare. When it does occur it would be across the unit and would include the seasonal stream ERZs. Some potential for minor creeping into edges of RCAs
	Pile Burning										X	X	X		Limitations of equipment reach for piling will make burning less frequent in the seasonal ERZ, compared to the rest of the harvest unit
	Underburning								X		X		X		
Recreation Infrastructure, Maintenance, and Use	New Trail Construction					X	X	X							
	Trail Maintenance and Improvement		X	X	X										ERZ activity would be primarily associated with stream crossings.
	Trail Vacating		X	X	X										Trail vacating will likely be Frequent in the first 20 years and decrease to rarely over time as trails are relocated to sustainable locations
	Permanent Stream Crossings					X	X	X							Activity would be associated with new trail construction and replacement of existing trail bridges.
	Recreation Facility Construction								X	X	X				The only new facility development that would be allowed within an RCA would be a boat launch/boat ramp.
	Recreation Facility Improvement of Campgrounds, Trailheads, Interpretive Sites								X	X	X				Improving a component within the footprint of an existing recreation facility.
	Recreation Facility Maintenance and Use of Campgrounds, Trailheads, Interpretive Sites		X				X	X							Maintenance of existing infrastructure

Activity		Frequency											Notes	
		Frequently ¹			Infrequently ²			Rarely ³			Not Expected to Occur			
		All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial	35 ' ERZ Seasonal	All RCAs	35' ERZ Perennial		35 ' ERZ Seasonal
Conservation Strategy Implementation Activities	Stream Complexity and Enhancement Projects				X	X	X							
	Research Activities				X	X	X							

¹ Frequently = Activity intersects RCAs multiple times annually, on every State Forests district. Amount of activity varies by district, dependent on habitat and forest health goals.

² Infrequently = Activity intersects RCAs a few times annually but is generally not be present on every State Forests district, every year.

³ Rarely = Activity intersects RCAs no more than once annually, for any given State Forests district.

Terrestrial Frequency table

Activity			Frequency in HCAs			Notes
			Frequently ¹	Infrequently ²	Rarely ³	
Timber Harvest Methods	Cable Corridors		X			
	Skid Roads		X			
	Climb/Top Trees for a Tailhold		X			
	Guylines		X			
	Using Equipment as Mobile Anchors		X			
	Yarding and Burn Slash		X			
Timber Harvest Types	Regeneration Harvest	Clear Cut	X			Would only occur in Swiss Needle Cast and Hardwood Dominated Stands. This would only occur the first 30 years of the permit term and any further activity would need to be negotiated with the services.
	Partial Cut Harvest	Heavy Thinning	X			
		Moderate Thinning	X			
		Light Thinning	X			
	Salvage				X	Salvage harvest will not occur in HCAs unless it is specifically to reduce a risk to safety or to promote a specific habitat need
	Hazard Tree Removal		X			
Reforestation and Young Stand Management	Site Preparation	Mechanical	X			
	Tree Planting	Initial Planting	X			Would only occur in stands where a regeneration harvest had occurred
		Interplanting			X	Would only occur in stands where a regeneration harvest had occurred and occurs when stocking levels fall below Forest Practice Act minimums
	Manual Release Treatments		X			
	Mountain Beaver Control		X			
	Precommercial Thinning and Pruning		X			
Road System Management Activities	Road Use		X			
	Road Construction		X			
	Road Maintenance and Improvement		X			
	Road Vacating			X		Some roads, including legacy roads, may need to be vacated due to their proximity to a fish-bearing stream, high erosion potential, or landslide hazards that could affect the covered species, and because these issues cannot be addressed with road improvement activities.
	Landing Construction and Maintenance		X			
Quarries, Borrow Sites, and Stockpile Sites	Existing Rock Quarries			X		
	Rock Quarry Development				X	
	Existing Borrow Sites			X		
	Borrow Site Development				X	
	Existing Stockpile Sites		X	X		Use of existing stockpiles inside of HCAs will vary depending on location of operations. Individual stockpiles may go many years without activity.
	Stockpile Site Development				X	
Fire Management	Broadcast Burning				X	Would only occur in stands where a regeneration harvest had occurred
	Pile Burning		X			Would only occur in stands where a regeneration harvest had occurred
	Underburning				X	

Activity		Frequency in HCAs			Notes
		Frequently ¹	Infrequently ²	Rarely ³	
Recreation Infrastructure, Maintenance, and Use	New Trail Construction	X			
	Trail Maintenance and Improvement	X			
	Trail Vacating	X		X	Trail vacating will likely be Frequent in the first 20 years and decrease to rarely over time as trails are relocated to sustainable locations
	Recreation Facility Construction			X	
	Recreation Facility Improvement of Campgrounds, trailheads, interpretive sites		X		
	Recreation Facility Maintenance and Use of Campgrounds, Trailheads, Interpretive Sites	X			
Conservation Strategy Implementation Activities	Barred Owl Management	X			

¹ Frequently = Activity intersects HCAs multiple times annually, on every State Forests district. Amount of activity varies by district, dependent on habitat and forest health goals.

² Infrequently = Activity intersects HCAs a few times annually, but is generally not be present on every State Forests district, every year.

³ Rarely = Activity intersects HCAs no more than once annually, for any given State Forests district.

Terrestrial Modeling Information

Terrestrial Modeling Methods

The following approach was used to develop the habitat models for Northern spotted owl, marbled murrelet, and red tree voles. Additional details on model parameters unique to each species are found in Appendix C.

- **Step 1. Identify Parameters.** Based on the scientific literature, identify key habitat features to include as parameters in each species' model. Important sources of information include studies on habitat relationships, particularly existing habitat suitability models. Parameters were selected for the model that are reliable and consistent indicators of stand characteristics known to be suitable habitat for that species and therefore may be, or is likely to be, occupied by the species in the permit area and for parameters that can be reported at the scale of an individual forest stand by ODF. Parameters could not be used that are based on small-scale habitat features that cannot be feasibly represented at a stand level scale, such as tree limbs that provide nest platforms for marbled murrelet. Models include 3–4 parameters each.

Spatial and landscape-level parameters such as patch size and distance to other patches were not included in the models. The intent of the models is to characterize habitat suitability at the stand-level using SLI data. Rather, the conservation strategy seeks to improve important spatial and landscape-level habitat conditions by conserving, expanding, and connecting habitat patches. Important spatial and landscape-level features were assessed in combination with the habitat suitability models, occurrence data, and other sources of information when identifying habitat patches to conserve for the focal species.

- **Step 2. Select Data.** Select the SLI stand structure parameter that best characterizes each species' habitat parameter. For example, northern spotted owl needs multilayered, multispecies canopies with large (at least 20- to 30-inch diameter at breast height [DBH]) overstory trees for nesting and roosting (USFWS 2012). The number of trees per acre with a DBH of 30 inches or greater was selected as the stand structure parameter to characterize stands with large overstory trees. Other stand structure parameters, such as Diameter Diversity Index (DDI) (Spies et al. 2007), were used to characterize multilayered canopies. For covered species that occur in only a portion of the permit area, habitat data were clipped to the published range of the species, as described in each species account.
- **Step 3. Develop Logistic Models.** Model the relationship between each stand structure parameter and habitat quality. Logistic models were used to estimate suitability across a range of values for each stand structure parameter, with a probability between 0 and 1 (with an increasing probability corresponding with increasing habitat suitability for that stand structure parameter). Logistic models were built by first assigning habitat suitability probabilities to a stand structure parameter value where there is support in the literature for these assignments. For marbled murrelet and red tree vole habitat suitability probabilities were assigned to stand structure parameter values to correspond with thresholds for the following habitat suitability categories: highly suitable, suitable, marginally suitable, and not habitat. For northern spotted owl, habitat suitability probabilities were assigned to stand structure parameter values to correspond with thresholds to distinguish nesting and roosting habitat, foraging habitat, dispersal habitat, and non habitat. This was done to convert the continuous habitat suitability values to biologically meaningful categories that could be used in the HCP.

A logistic equation was then created to connect those established data points and provide habitat suitability values for the range of possible stand structure parameter values. The shape of the logistic curve for each stand structure parameter illustrates the relationship between a range of habitat structure parameter values and habitat suitability probabilities.

The logistic function was fit to the assigned habitat suitability probability to selected stand structure parameter values by minimizing error. Assigned habitat suitability probabilities served as targets for the solver. The actual habitat suitability value computed by the solver function generally differed from the assigned target by less than ± 0.1 .

Habitat suitability probabilities for stand structure parameter values were assigned depending on data from the scientific literature from ecological field studies, habitat models, and the expert opinion of ODF biologists and species experts external to ODF. For example, red tree voles are most abundant in structurally diverse, multi-canopy conifer forests with large trees (Forsman et al. 2016, Rosenberg et al. 2016). DDI provides a quantitative index of canopy layering. DDI describes the relative similarity of a given stand to an old growth stand in terms of the number of trees per acre in each of 4 diameter classes. Stands can range from a DDI of almost 0 up to a maximum of 10, with 0 representing the least layering and 10 representing the most layering. Forsman et al. (2016) found that red tree vole habitat suitability increased along a sigmoidal curve with increasing DDI. Habitat suitability probabilities were assigned to correspond to mean DDI values for four modeled suitability classes from the Forsman et al. (2016) model: highly suitable, suitable, marginal, unsuitable (Table 3-4 in Forsman et al. 2016). Habitat conditions where red tree voles may use young forests (<80 years old) were not considered suitable or marginal because it remains unclear if these stands contribute to a reasonable assurance of species use and persistence (USFWS 2011; Piasecki 2023). Mean DDI for highly suitable habitat in the Forsman et al. model is 6.6 (± 0.1 standard error [SE]), 6.0 (± 0.1 SE) for suitable habitat, 4.9 (± 0.1 SE) for marginal, and 3.7 (± 0.1 SE) for unsuitable. For this Plan's model, a DDI of 7.0 was assigned a habitat suitability probability of 0.8; a DDI of 6.0 was assigned a habitat suitability probability of 0.6; a DDI of 5.0 was assigned a habitat suitability probability of 0.4; and a DDI of 4.0 was assigned a habitat suitability probability of 0.2.

Rationales for assigning habitat suitability probabilities to parameter values are provided in Appendix E.

- **Step 4. Weight parameters.** For some species, certain habitat characteristics are more important than others in determining habitat suitability and probability of occurrence. In cases where the scientific literature supports weighting of an available habitat parameter, that parameter was given more weight in the model than other parameters. Weight of one parameter is relative to the other parameters in each model. Parameters were weighted equally if scientific literature did not strongly suggest weighting. Professional judgement by ODF biologists and species experts was used to weight one or more values more than others when supported by the scientific literature.
- **Step 5. Calculate habitat suitability.** Habitat suitability index is the weighted product of all of the model parameter suitability probabilities for a given stand (see Terrestrial Modeling Information in Appendix E). The total habitat suitability index is on a continuous scale of 0 (lowest suitability) to 1.0 (highest suitability). The habitat suitability index is interpreted as the probability that the forest stand provides suitable habitat for that species.

The same suitability category threshold probability targets used for each parameter in each model were used to categorize total habitat suitability index scores for each stand. While the

indices themselves are continuous, thresholds within the continuum were established to quantify acres of habitat in discrete categories, from highly suitable types to unsuitable (i.e., non-habitat).

- **Step 6. Test and refine models.** Each model was refined and tested by comparing model results to a variety of other data, including known occurrence records, existing habitat models based on other datasets such as USFS Forest Inventory and Analysis plot data, and ODF's mapping of forest structure in the permit area. Habitat suitability scores and parameter weights in this Plan's model were adjusted to improve overlap between the Plan's model and comparative data and models. The habitat models were also reviewed by wildlife agency staff and external species experts and refined in response to their feedback. Index thresholds that define habitat categories for each species were also adjusted to better capture the full range of habitat conditions that currently exist on the permit area.

Model Uses and Limitations

The habitat suitability models are intended to be used only for planning purposes at the scale of the permit area. For example, the modeled suitability of habitat in an area does not necessarily mean that the species will be present or absent or that the habitat is fully developed or suitable today. Rather, modeled suitability means that a stand has characteristics similar to habitat known to be suitable for that species and therefore may be or is likely to be occupied by the species. Habitat suitability models were used by ODF to estimate the potential amount and location of take and identify areas with high conservation value for each covered species across the entire permit area. The habitat models were also used to project habitat development over time, through growth and implementation of habitat enhancement actions. The monitoring program, described in Chapter 6, *Monitoring and Adaptive Management*, includes the process to determine whether the important habitat parameters are present in areas identified as habitat for covered species (by the habitat models). The monitoring program will also assess how those habitat parameters may change over time.

Model Variables and Parameters

NSO HSI Model Variables and Parameters

Let x_{ddi} , x_{age} , x_{tpa30} , and x_{ht} represent the variables for diameter diversity index, stand age, trees per acre (TPA30), and top height, respectively.

Let $Q_i(x_i)$ represent the quality score function for variable i , where $i \in \{ddi, age, tpa30, ht\}$.

Let a_i and b_i represent the logistic curve coefficients unique to each quality function.

Let w_i represent the component weight assigned to each variable.

Mathematical Formulation

The Habitat Suitability Index (HSI) is modeled as a weighted geometric mean:

$$HSI = [Q_ddi(x_ddi)^{w_ddi} \cdot Q_age(x_age)^{w_age} \cdot Q_tpa30(x_tpa30)^{w_tpa30} \cdot Q_ht(x_ht)^{w_ht}]^{1 / (w_ddi + w_age + w_tpa30 + w_ht)}$$

Where the individual quality scores are defined by the following logistic functions:

$$Q_ddi(x_ddi) = 1 / (1 + e^{(a_ddi - b_ddi \cdot x_ddi)})$$

$$Q_age(x_age) = 1 / (1 + e^{(a_age - b_age \cdot x_age)})$$

$$Q_tpa30(x_tpa30) = 1 / (1 + e^{(a_tpa30 - b_tpa30 \cdot x_tpa30)})$$

$$Q_ht(x_ht) = 1 / (1 + e^{(a_ht - b_ht \cdot x_ht)})$$

MAMU HSI Model Variables and Parameters

Let x_age , x_tpa30 , and x_ht represent the variables for stand age, trees per acre (TPA30), and top height, respectively.

Let $Q_i(x_i)$ represent the quality score function for variable i , where $i \in \{age, tpa30, ht\}$.

Let a_i and b_i represent the logistic curve coefficients unique to each quality function.

Let w_i represent the component weight assigned to each variable.

Mathematical Formulation

The Habitat Suitability Index (HSI) is modeled as a weighted geometric mean:

$$HSI = [Q_age(x_age)^{w_age} \cdot Q_tpa30(x_tpa30)^{w_tpa30} \cdot Q_ht(x_ht)^{w_ht}]^{1 / (w_age + w_tpa30 + w_ht)}$$

Where the individual quality scores are defined by logistic functions:

$$Q_age(x_age) = 1 / (1 + e^{(a_age - b_age \cdot x_age)})$$

$$Q_tpa30(x_tpa30) = 1 / (1 + e^{(a_tpa30 - b_tpa30 \cdot x_tpa30)})$$

$$Q_ht(x_ht) = 1 / (1 + e^{(a_ht - b_ht \cdot x_ht)})$$

RTV HSI Model Variables and Parameters

Let x_age , x_ddi , and x_tpa30 , and represent the variables for stand age, diameter diversity index, and trees per acre (TPA30), respectively.

Let $Q_i(x_i)$ represent the quality score function for variable i , where $i \in \{age, ddi, tpa30\}$.

Let a_i and b_i represent the logistic curve coefficients unique to each quality function.

Let w_i represent the component weight assigned to each variable.

Mathematical Formulation

The Habitat Suitability Index (HSI) is modeled as a weighted geometric mean:

$$HSI = [Q_{age}(x_{age})^{w_{age}} \cdot Q_{ddi}(x_{ddi})^{w_{ddi}} \cdot Q_{tpa30}(x_{tpa30})^{w_{tpa30}}]^{1 / (w_{age} + w_{ddi} + w_{tpa30})}$$

Where the individual quality scores are defined by the following logistic functions:

$$Q_{age}(x_{age}) = 1 / (1 + e^{(a_{age} - b_{age} \cdot x_{age})})$$

$$Q_{ddi}(x_{ddi}) = 1 / (1 + e^{(a_{ddi} - b_{ddi} \cdot x_{ddi})})$$

$$Q_{tpa30}(x_{tpa30}) = 1 / (1 + e^{(a_{tpa30} - b_{tpa30} \cdot x_{tpa30})})$$

Model Outputs and Species Habitat Types

NSO

$$NSO \text{ HSI} = (Q_{ddi}(x_{ddi})^{0.15} \cdot Q_{age}(x_{age})^{0.15} \cdot Q_{tpa30}(x_{tpa30})^{0.40} \cdot Q_{ht}(x_{ht})^{0.15})^{1 / 0.85}$$

Where:

$$Q_{ddi}(x_{ddi}) = 1 / (1 + e^{(2.986922889 - 0.573027166 \cdot x_{ddi})})$$

$$Q_{age}(x_{age}) = 1 / (1 + e^{(3.271161213 - 0.030466593 \cdot x_{age})})$$

$$Q_{tpa30}(x_{tpa30}) = 1 / (1 + e^{(0.984039687 - 0.137158252 \cdot x_{tpa30})})$$

$$Q_{ht}(x_{ht}) = 1 / (1 + e^{(2.684469796 - 0.027736197 \cdot x_{ht})})$$

MAMU

$$MAMU \text{ HSI} = (Q_{age}(x_{age})^{0.30} \cdot Q_{tpa30}(x_{tpa30})^{0.30} \cdot Q_{ht}(x_{ht})^{0.30})^{1 / 0.90}$$

Where:

$$Q_{age}(x_{age}) = 1 / (1 + e^{(4.209152029 - 0.036570834 \cdot x_{age})})$$

$$Q_{tpa30}(x_{tpa30}) = 1 / (1 + e^{(2.076610931 - 0.307154154 \cdot x_{tpa30})})$$

$$Q_{ht}(x_{ht}) = 1 / (1 + e^{(6.704257509 - 0.047734555 \cdot x_{ht})})$$

RTV

$$RTV \text{ HSI} = (Q_{age}(x_{age})^{0.25} \cdot (Q_{ddi}(x_{ddi})^{0.25} \cdot (Q_{tpa30}(x_{tpa30})^{0.50}))$$

Where:

$$Q_{age}(x_{age}) = 1 / (1 + e^{(5.539843 - 0.068369 \cdot x_{age})})$$

$$Q_{ddi}(x_{ddi}) = 1 / (1 + e^{(4.962488 - 0.902274 \cdot x_{ddi})})$$

$$Q_{tpa30}(x_{tpa30}) = 1 / (1 + e^{(1.78134 - 0.225761 \cdot x_{tpa30})})$$

Resulting HSI score intervals were then applied to habitat types for each modeled terrestrial species (Table E-1).

Table E-1. Summary of Habitat Types and Habitat Suitability Index (HSI) Ranges for the Modeled Terrestrial Species

Species	Habitat Type	HSI
Northern Spotted Owl	Core area 250 acres around active activity center centered in permit area	Best available
	Within 0.7 mile of active activity centers centered in permit area	0.60–1.0
	Nesting/roosting	0.60–1.0
	Foraging	0.40–0.59
	Dispersal or not habitat	0.00–0.39
	Designated occupied habitat	Delineated based on occupied and highly suitable habitat with known or expected occupancy
Marbled murrelet	100-meter non-habitat buffer around designated occupied habitat	0.00–0.29
	Highly suitable	0.80–1.0
	Suitable	0.30–0.79
	Not habitat	0.00–0.29
Red tree vole	>10 acres around known nest trees with connectivity among buffered areas, larger skips incorporated in larger thinning projects	>0/40
	Highly suitable	0.80–0.1.0
	Suitable	0.40–0.79
	Not habitat	<0.39

Table 1. Model parameters and rationales for Marbled murrelet habitat suitability and distribution model. Habitat distribution and suitability was mapped 50 miles inland.

Habitat Parameter	Stand Level Inventory Variable	Weight	Habitat Suitability Probability Assignments	Rationale
Large Trees	Trees per acre 30" + DBH	0.3	12 large trees per acre = 0.8 8 large trees per acre = 0.6 5 large trees per acre = 0.4 1 large trees per acre = 0.2	Marbled murrelet use tall, late-seral structured forest for nesting. Presence of nest platforms is considered the most important marbled murrelet nest characteristic (Raphael et al. 2018). ODF does not have data that captures presence of nest platforms. Stand Level Inventory data for number of large trees per acre (30" + DBH) is used as an indicator of trees that may have suitable nest platforms, as large limbs with forked branches, deformities, and other platform characteristics are expected to develop on larger trees. Not all large trees will have suitable nest platforms, however (Evans Mack et al. 2003), though tree diameter and height can be positively correlated with the size and abundance of nest platforms (Raphael et al. 2018). Nest platforms are usually found on trees at least 19 inches in diameter at breast height and greater than 98 ft tall (Raphael et al. 2018) with nest trees in Oregon having a mean DBH of 56 inches (SD = 19) (Oregon Department of Forestry 2018). The mean of the covariate trees of DBH 100 cm (39.4 in) per hectare in the marbled murrelet 2012 habitat model was 12.7 (SD = 10.8) which is 5 large trees per acre. Five large trees per acre was assigned a 0.4 suitability probability based on this mean value (Falxa and Raphael 2016).
Forest Height	Top Height	0.3	276 feet = 0.95 170 feet = 0.8 150 feet = 0.6 130 feet = 0.4 110 feet = 0.2 92 feet = 0.05	Maximum canopy height and stand height was found to be an important predictor of marbled murrelet occupancy in the Coos Bay BLM district and the Siuslaw National Forest (Hagar et al. 2018) and Oregon-wide (Falxa and Raphael 2016), respectively. Top height was used as an index for maximum stand height in the model. Top height represents the average height of the 40 largest trees per acre.

				Little data are available about the relationship between stand height and habitat suitability. In Oregon, mean nest tree height for 70 nests was 184 ft (SD = 46; range 108 – 279) (Oregon Department of Forestry 2018). The HCP uses expert opinion to extrapolate habitat suitability probability assignments based on data for mean nest tree height and mean stand height from Oregon Department of Forestry (2018). Stands with a top height of 92 feet or shorter and 276 feet are assumed to be unsuitable and very highly suitable, respectively. These values were selected because they are ± 2 SD from the mean nest tree height (Oregon Department of Forestry 2018).
Seral Stage	Stand Age	0.3	206 years old = 0.95 150 years old = 0.8 130 years old = 0.6 100 years old = 0.4 60 years old = 0.2	Marbled murrelet is typically associated with late-seral forests but may nest in young stands with suitable nesting substrates. Most nest in old-growth forests (>200 years old), but marbled murrelet also nest in mature to residual mature to old-growth forest (66 – 150 years old) (Nelson 1997, Oregon Department of Forestry 2018). Stands less than 60 years old are unsuitable for marbled murrelet nesting. Stands 206 years old are assumed to be very highly suitable in this HCP's model.

Table 1. Model parameters and rationales for the northern spotted owl habitat suitability and distribution model for nesting and roosting habitat.

Habitat Parameter	Stand Level		Habitat Suitability Probability Assignments	Rationale
	Inventory Variable	Weight		
Seral stage	Stand Age	0.15	170 years old = 0.8	Northern spotted owl relies on older forested habitats for nesting, foraging, and roosting (e.g., U.S. Fish and Wildlife Service 2012, Davis et al. 2016). In the Oregon Coast Range, average (and standard deviation [SD]) stand age for the nesting and roosting habitat classes in the Davis et al. (2016) model is: • Highly suitable: 159 years old (56) • Suitable: 118 years old (61) • Marginal: 60 years old (22) • Unsuitable: 29 years old (20) This HCP model assumes that habitat suitability increases with stand age, with approximately 159 year old stands having highly suitable late seral structural features. (The suitability threshold for 0.8 was set at 170 years old to result in an Excel Solver value of approximately 0.8 for 159 year old stands.) The model also assumes that stands as young as 60 years old can support nesting and roosting northern spotted owls, assuming suitable remnant nest trees are present, but that younger forests provide only marginally suitable habitat for nesting and roosting. Stands between 29 and 60 years old are unsuitable for nesting and roosting but may provide foraging habitat and stands less than 29 years old may provide dispersal habitat.
			118 years old = 0.6	
Structural Diversity	Diameter Diversity Index (DDI)	0.15	80 years old = 0.4	A structurally diverse, multicanopy forest with large trees is an important component of late seral conifer forests used by northern spotted owl for nesting and roosting (U.S. Fish and Wildlife Service 2012). DDI provides a quantitative index of canopy layering. DDI describes the relative similarity of a given stand to an old growth stand in terms of the number of trees per acre in each of 4 diameter classes. Stands can range from a DDI of almost 0 up to a maximum of 10, with 0 represent the least layering and 10 representing the most laying. Stands with older forest structure have DDI ranging from 6.5 to 10. In the Oregon Coast Range, average (and standard deviation [SD]) DDI for the nesting and roosting habitat classes in the Davis et al. (2016) model is: • Highly suitable: 7 (1)
			60 years old = 0.2	

				• Suitable: 6 (1) • Marginal: 5 (1) • Unsuitable: 1 (2)
Large Trees	Trees per acre 30"+ DBH	0.4	18 large trees per acre = 0.8 10 large trees per acre = 0.6 2 large trees per acre = 0.4 0 large trees per acre = 0.2	Large trees are important components of structurally complex late seral conifer forests for nesting and roosting northern spotted owl (U.S. Fish and Wildlife Service 2012). In the Oregon Coast Range, average (and standard deviation [SD]) large conifer ($\geq 30''$ DBH) for the nesting and roosting habitat classes in the Davis et al. (2016) model is: • Highly suitable: 18 (8) • Suitable: 10 (7) • Marginal: 2 (3) • Unsuitable: 0 (1)
Forest Height	Top Height	0.15	200 feet = 1.0 141 feet = 0.8 118 feet = 0.6 84 feet = 0.4 37 feet = 0.2	Northern spotted owl uses multilayered, multispecies canopies with large overstory trees (U.S. Fish and Wildlife Service 2012). In the Oregon Coast Range, average (and standard deviation [SD]) average stand height for the nesting and roosting habitat classes in the Davis et al. (2016) model is: • Highly suitable: 141 (26) • Suitable: 118 (27) • Marginal: 84 (20) • Unsuitable: 37 (25) Top height was used to characterize stands average stand height. Top height of 200 feet was assigned a habitat suitability probability of 1.0 because ODF forests with top height 200 feet or greater provides highly suitable habitat for northern spotted owl.

Table 1. Model parameters and rationales for the Oregon slender salamander habitat suitability and distribution model.

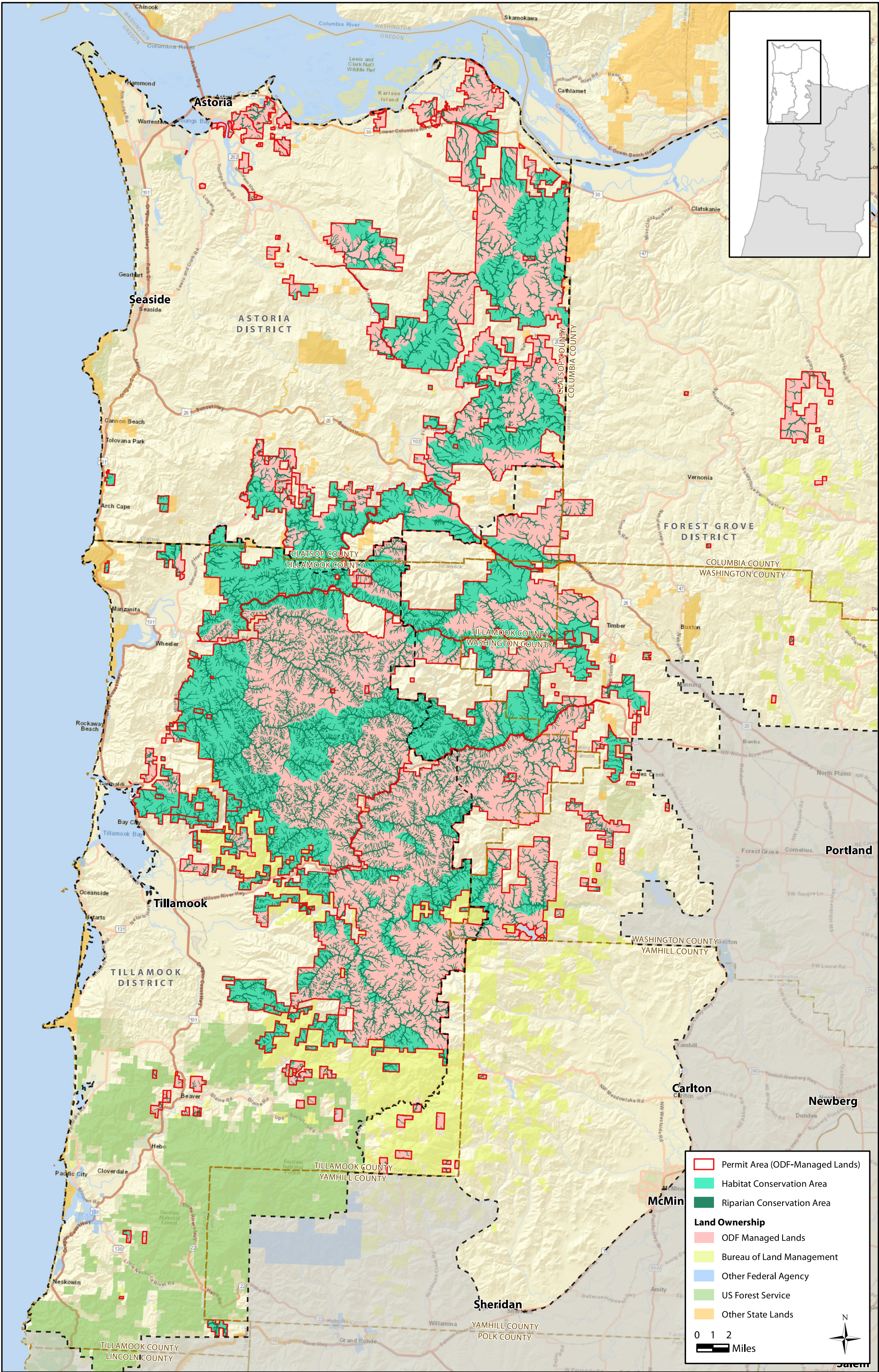
Habitat Parameter	Stand Level Inventory Variable	Weight	Habitat Suitability Probability Assignments	Rationale
Downed Wood	Large Downed Wood	0.4	2500 ft ³ per acre = 0.8 2000 ft ³ per acre = 0.6 400 ft ³ per acre = 0.4 200 ft ³ per acre = 0.2	Large downed wood is included in the Oregon slender salamander habitat suitability model to identify stands with greater amounts of large downed wood. Large downed wood quantifies the volume of downed logs per acre >24" diameter at the large end in all decay classes (1-4). ODF considers stands with more than 600 – 900 ft³ downed wood cubic feet per acre to be characteristics of late seral forests, so this range of values or more is considered to be highly suitable for Oregon slender salamander.
Forest height	Top Height	0.3	141 feet = 0.8 118 feet = 0.6 84 feet = 0.4 37 feet = 0.2	Oregon slender salamander occur in late seral forests with tall trees, generally > 20-25 meters (66-82 feet) in height (Suzuki 2009). Tall trees provide a source of future large, downed wood. Top height was used to identify stands with tall trees. The same habitat suitability probabilities for top height in the northern spotted owl model are used for Oregon slender salamander, as both species occur in late-seral forests. Forest top height ≥ 140 feet was considered to be highly suitable, as forests with top height greater than 140 feet in the Santiam State Forest tend to exhibit late seral stage structural characteristics. Stands with top height lower than 85 feet tend to exhibit mid-seral stage structural characteristics, and likely have lower amounts of large, decayed downed wood than stands with considerably taller top height.
Seral Stage	Stand Density Index (SDI)	0.3	300 = 0.67 150 = 0.33	SDI was used to identify stands with late-seral stage structural characteristics such as natural mortality of larger trees and loss of understory. SDI measures the degree of crowding or stocking in a stand and is a function of the number of trees per acre and DBH. ODF considers stands with an SDI > 300 to be characteristic of late seral forest.

Table 1. Model parameters and rationales for red tree vole habitat suitability and distribution model.

Habitat Parameter	Stand Level Inventory Variable	Weight	Habitat Suitability Probability Assignments	Rationale
Seral Stage	Stand Age	0.25	95 years old = 0.8 92 years old = 0.6 75 years old = 0.4 60 years old = 0.2	Red tree vole is associated with structurally complex late seral conifer or mixed conifer-hardwood forests (Dunk and Hawley 2009, U.S. Fish and Wildlife Service 2011, Forsman et al. 2016, Rosenberg et al. 2016, Linnell et al. 2017, Johnston and Moskal 2017). Abundance is higher in forests > 80 years old (Price et al. 2015) and models have found that old forest (i.e., > 80 years old) is an important predictor of red tree vole presence (Rosenberg et al. 2016, Linnell et al. 2017). Suitability categories are based on mean forest stand characteristics based on forest inventory plot data (Table 3-4 in Forsman et al. 2016).
Structural Diversity	Diameter Diversity Index (DDI)	0.25	7.0 DDI = 0.8 6.0 DDI = 0.6 5.0 DDI = 0.4 4.0 DDI = 0.2	Red tree vole generally requires a structurally diverse, multicanopy conifer forest with large trees (Forsman et al. 2016, Rosenberg et al. 2016). DDI provides a quantitative index of canopy layering. DDI describes the relative similarity of a given stand to an old growth stand in terms of the number of trees per acre in each of 4 diameter categories. Stands can range from a DDI of almost 0 up to a maximum of 10, with 0 represent the least layering and 10 representing the most layering. Stands with older forest structure have DDI's ranging from 6.5 to 10. Forsman et al. (2016) found that red tree vole habitat suitability increased sigmoidally with increasing DDI. Suitability categories are based on mean forest stand characteristics for modeled red tree vole habitat categories based on forest inventory plot data (Table 3-4 in Forsman et al. 2016).
Large Trees	Trees per acre 30"+ DBH	0.5	14.0 large trees per acre = 0.8 10.0 large trees per acre = 0.6 5.0 large trees per acre = 0.4 3.0 large trees per acre = 0.2	Large trees are important components of structurally complex late seral conifer forests for red tree vole (Forsman et al. 2016, Rosenberg et al. 2016). Rosenberg et al. found density of large conifers (≥ 75 cm DBH [29.5 inches]) to be strongly associated with red tree vole habitat, with suitability increasing logarithmically with increasing density of large conifers. Suitability categories are based on mean forest stand characteristics based on forest inventory plot data (Table 3-4 in Forsman et al. 2016).

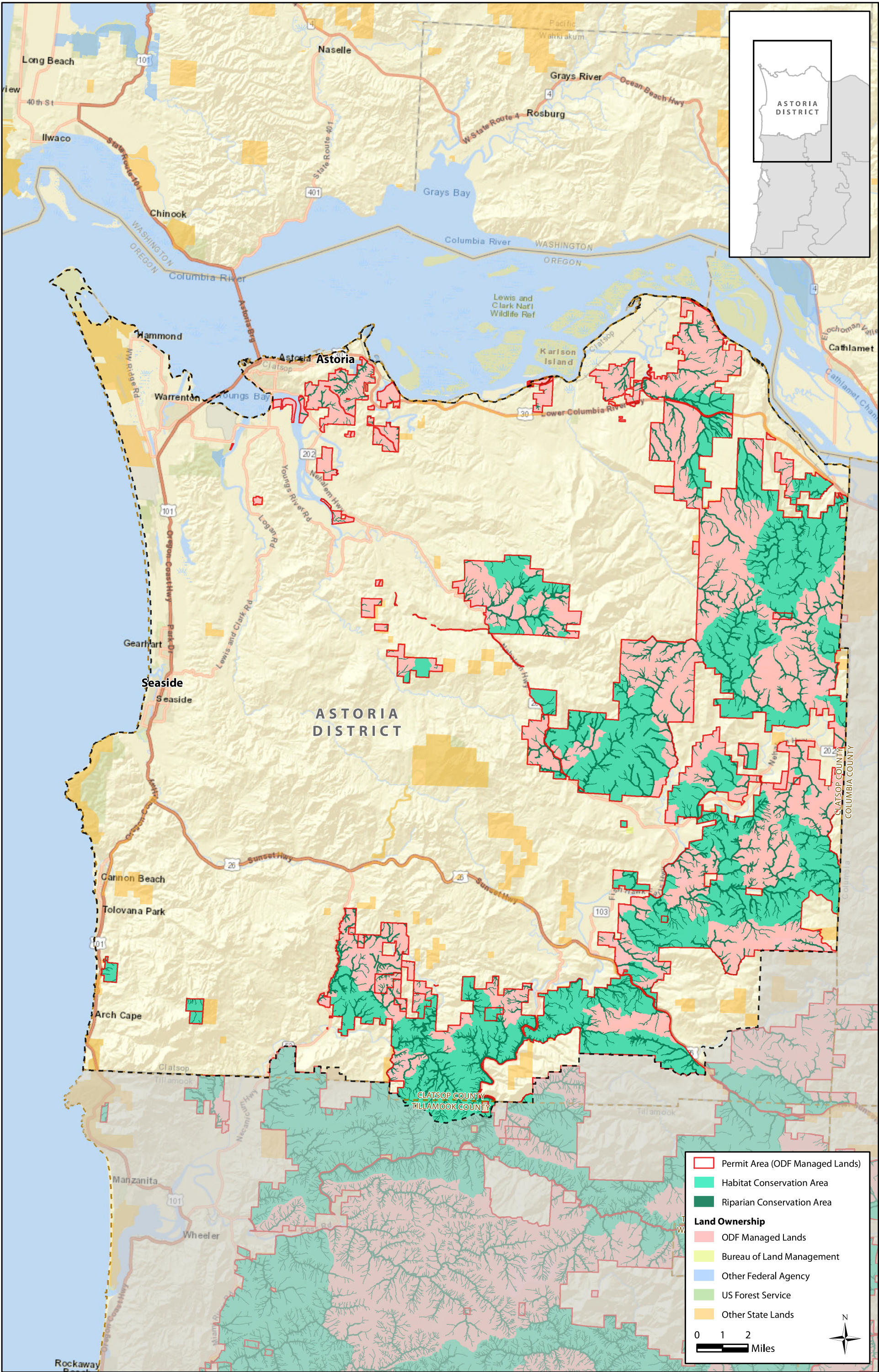
Appendix F

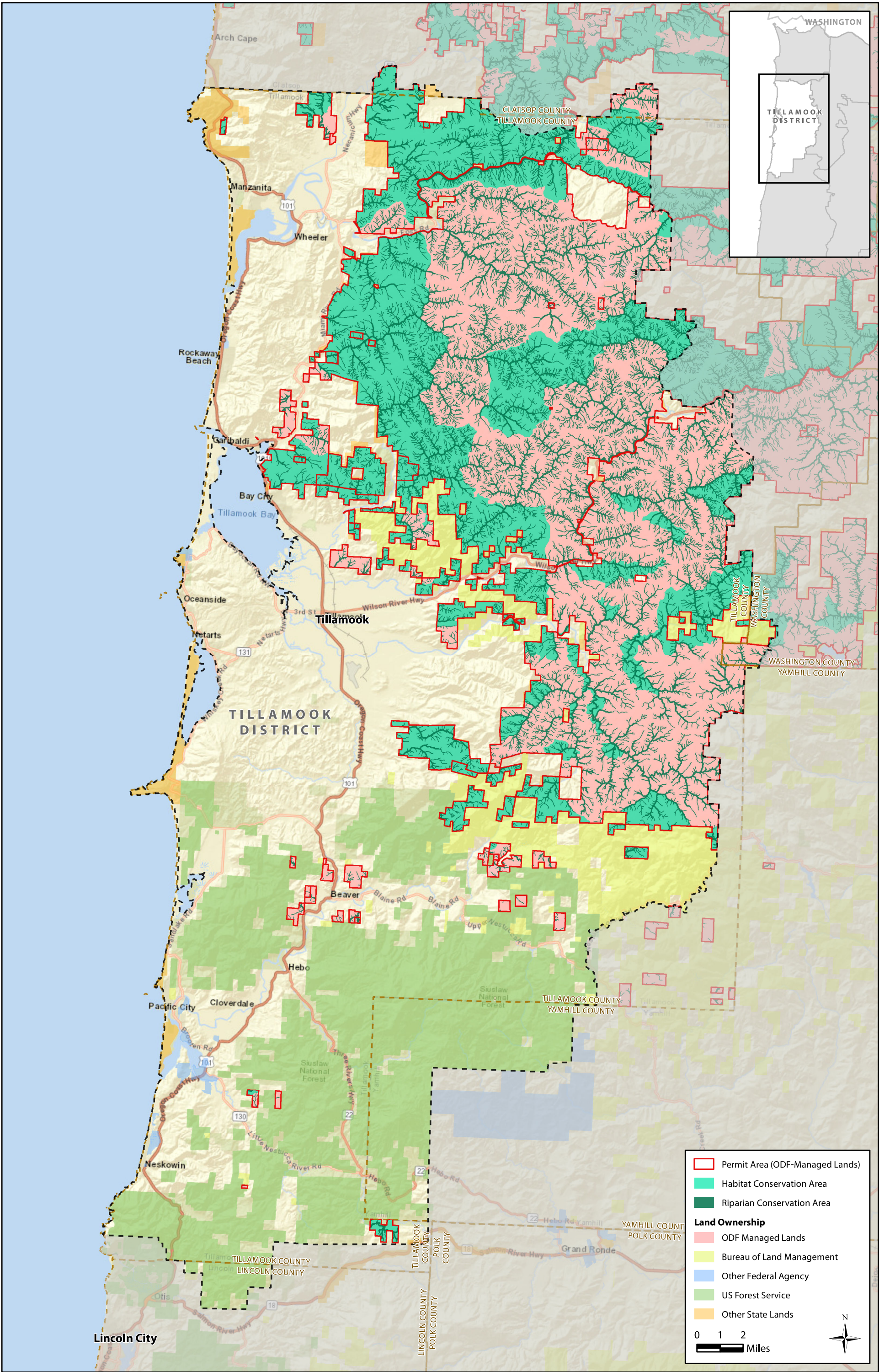
Habitat Conservation Area Maps

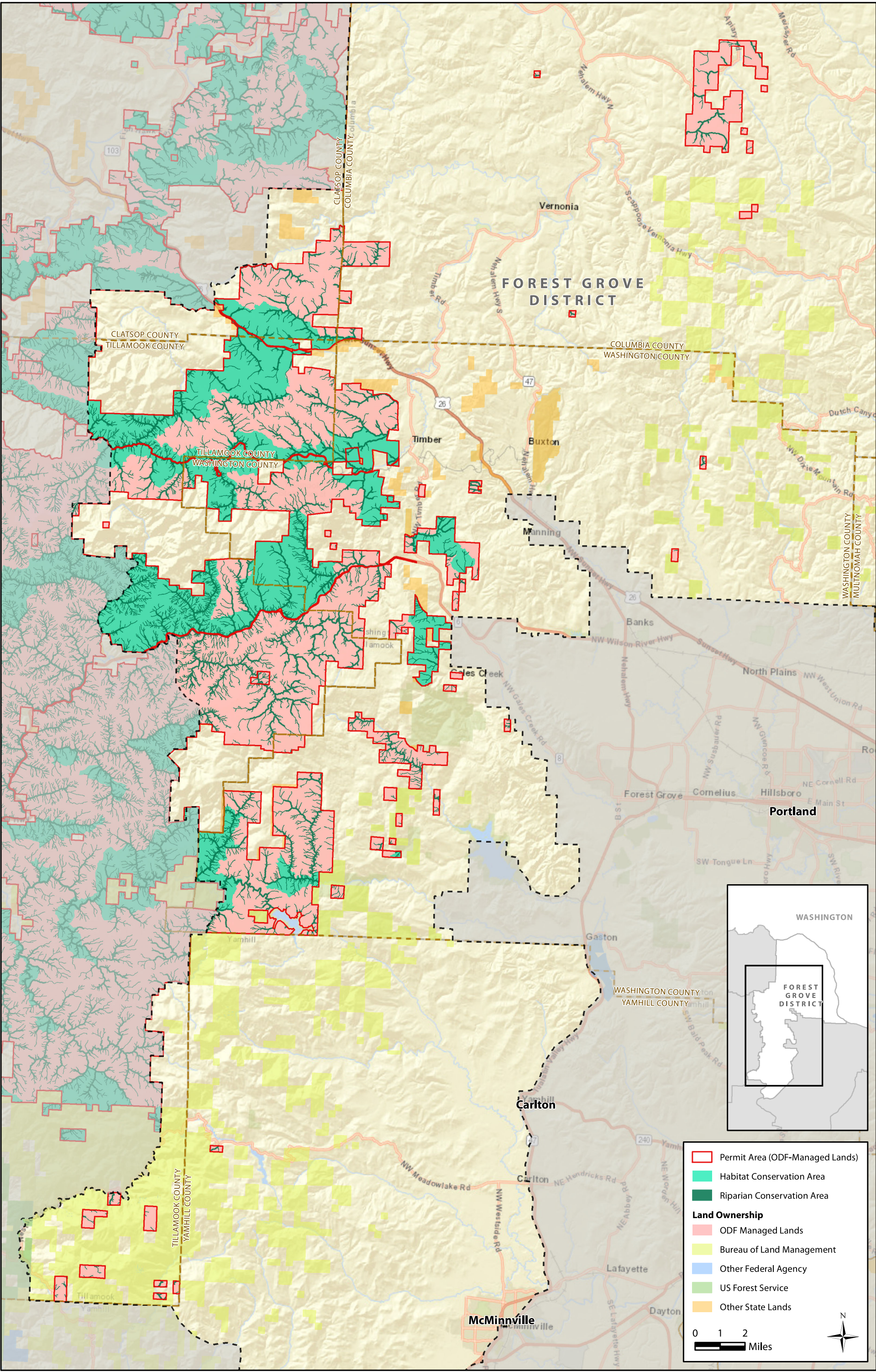


Western Oregon State Forest HCP – Habitat Conservation Areas, Astoria, Forest Grove, and Tillamook Districts

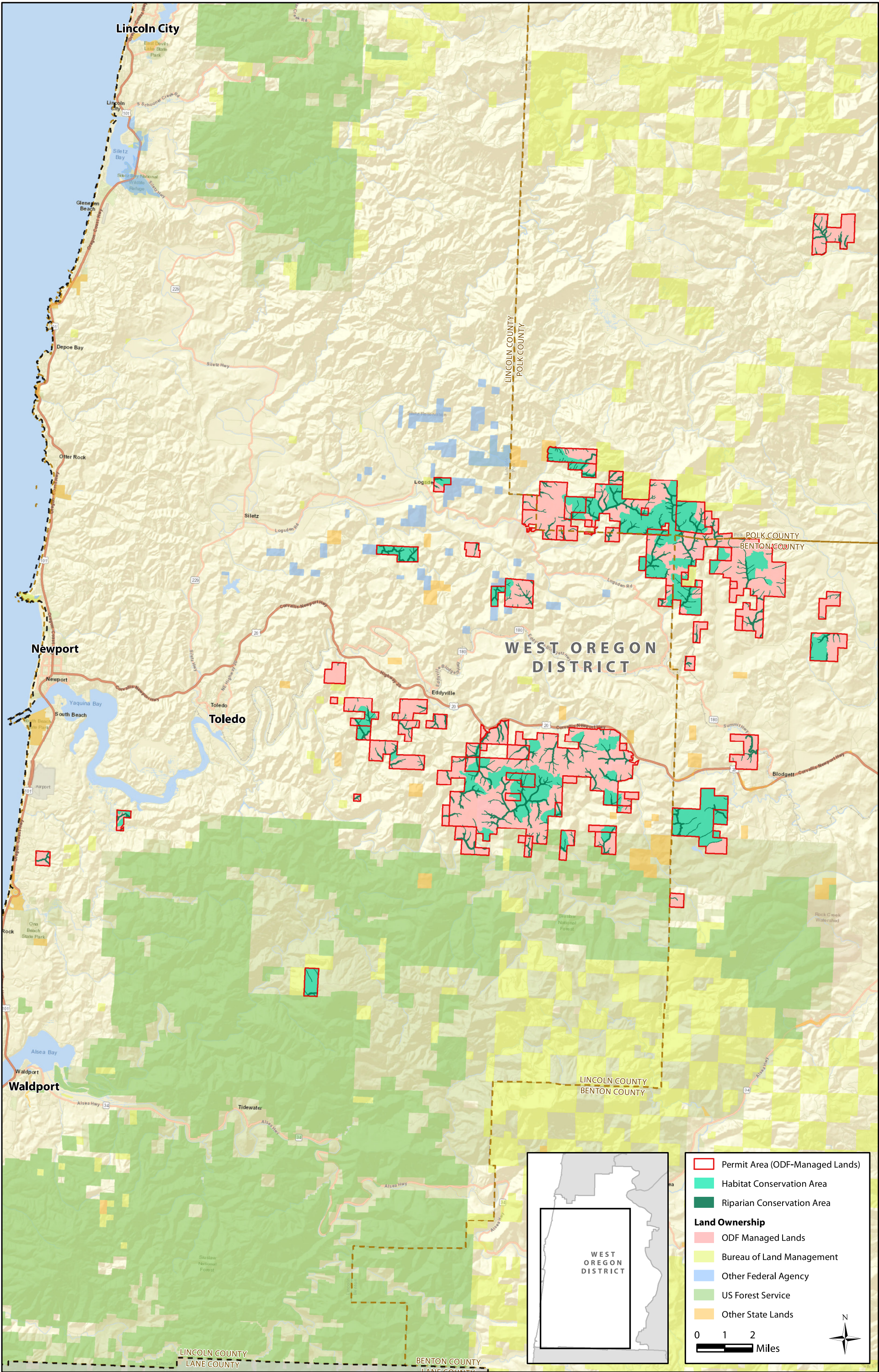




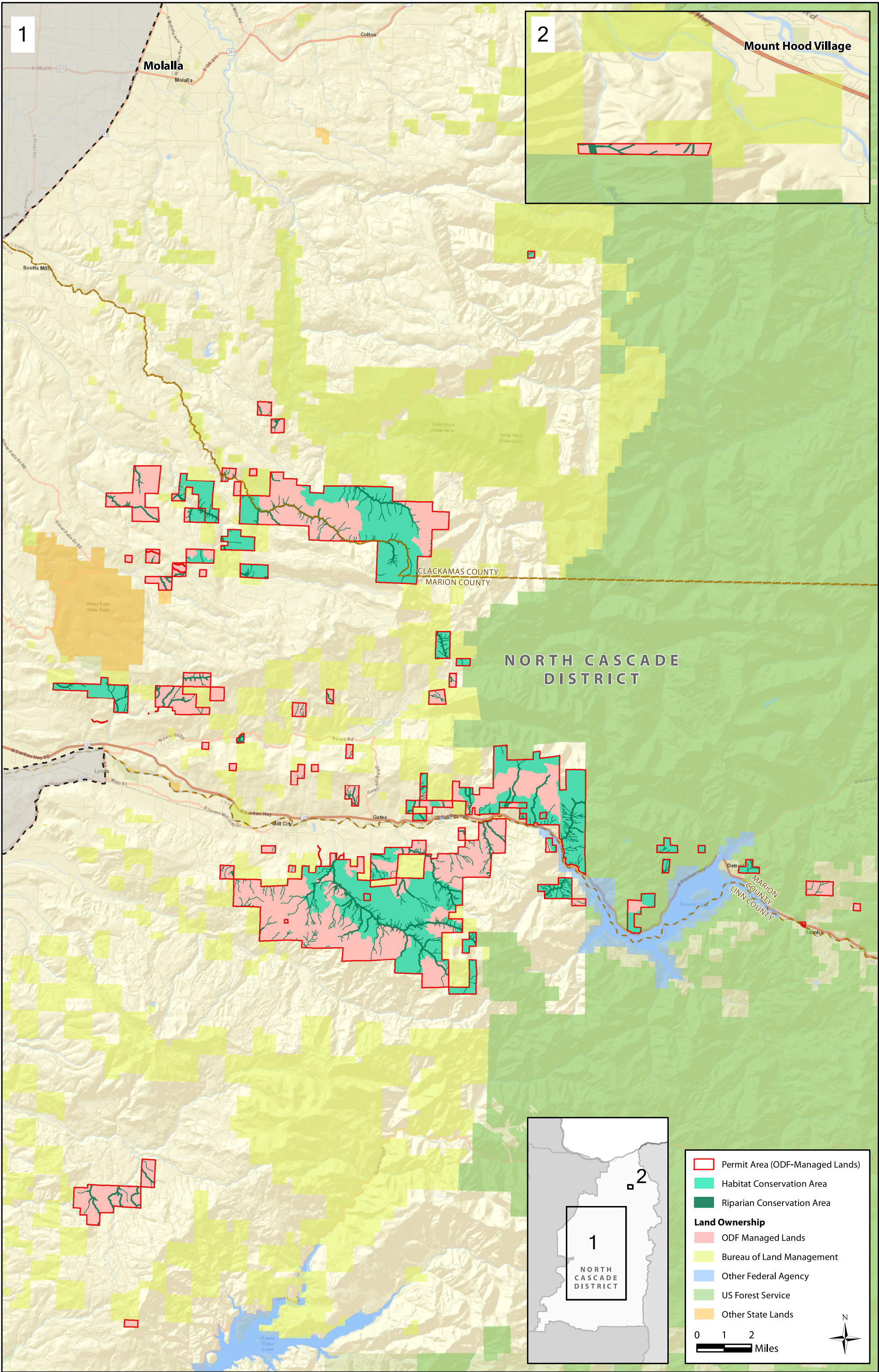


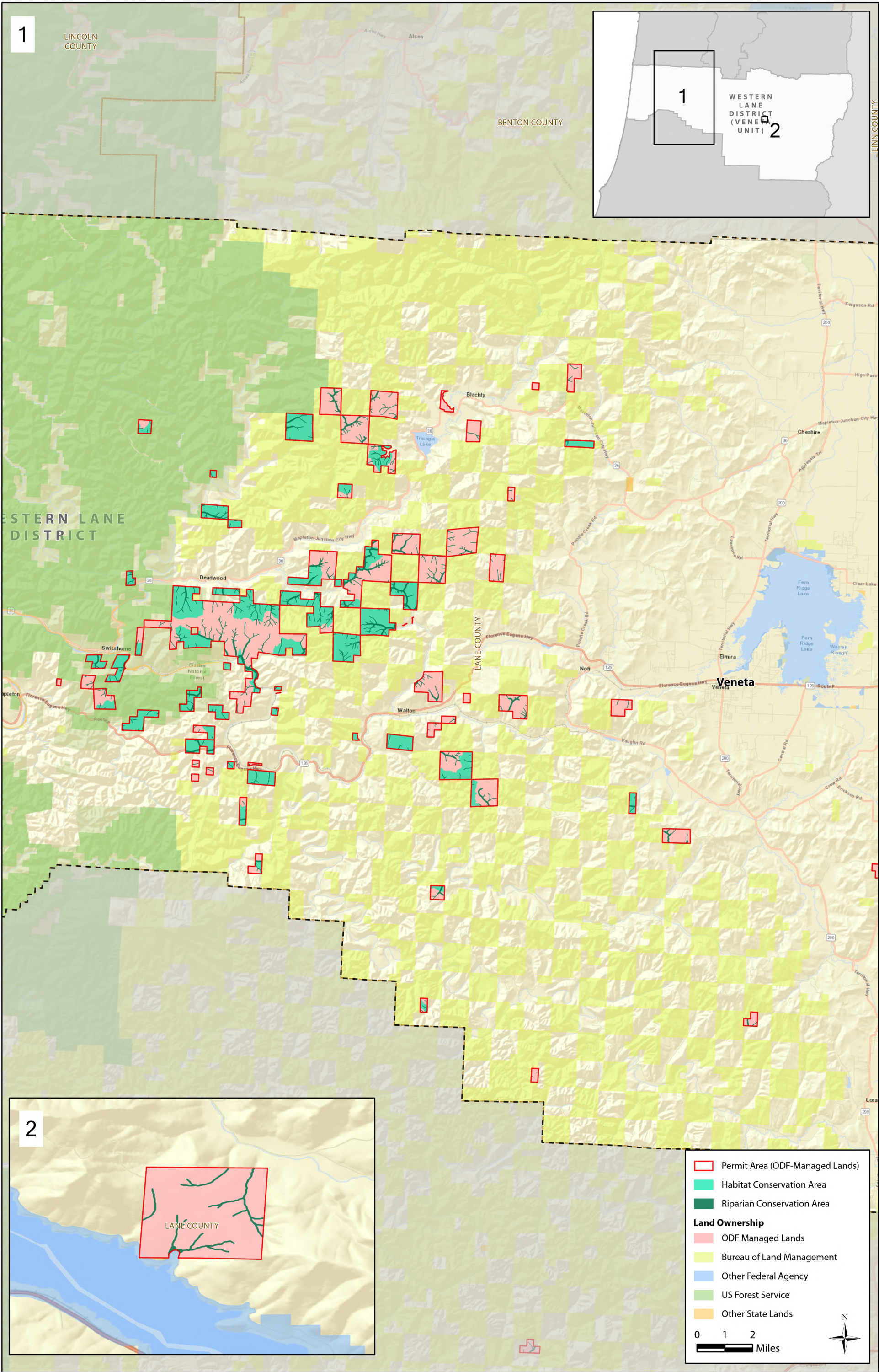


Western Oregon State Forest HCP – Habitat Conservation Areas, Forest Grove District

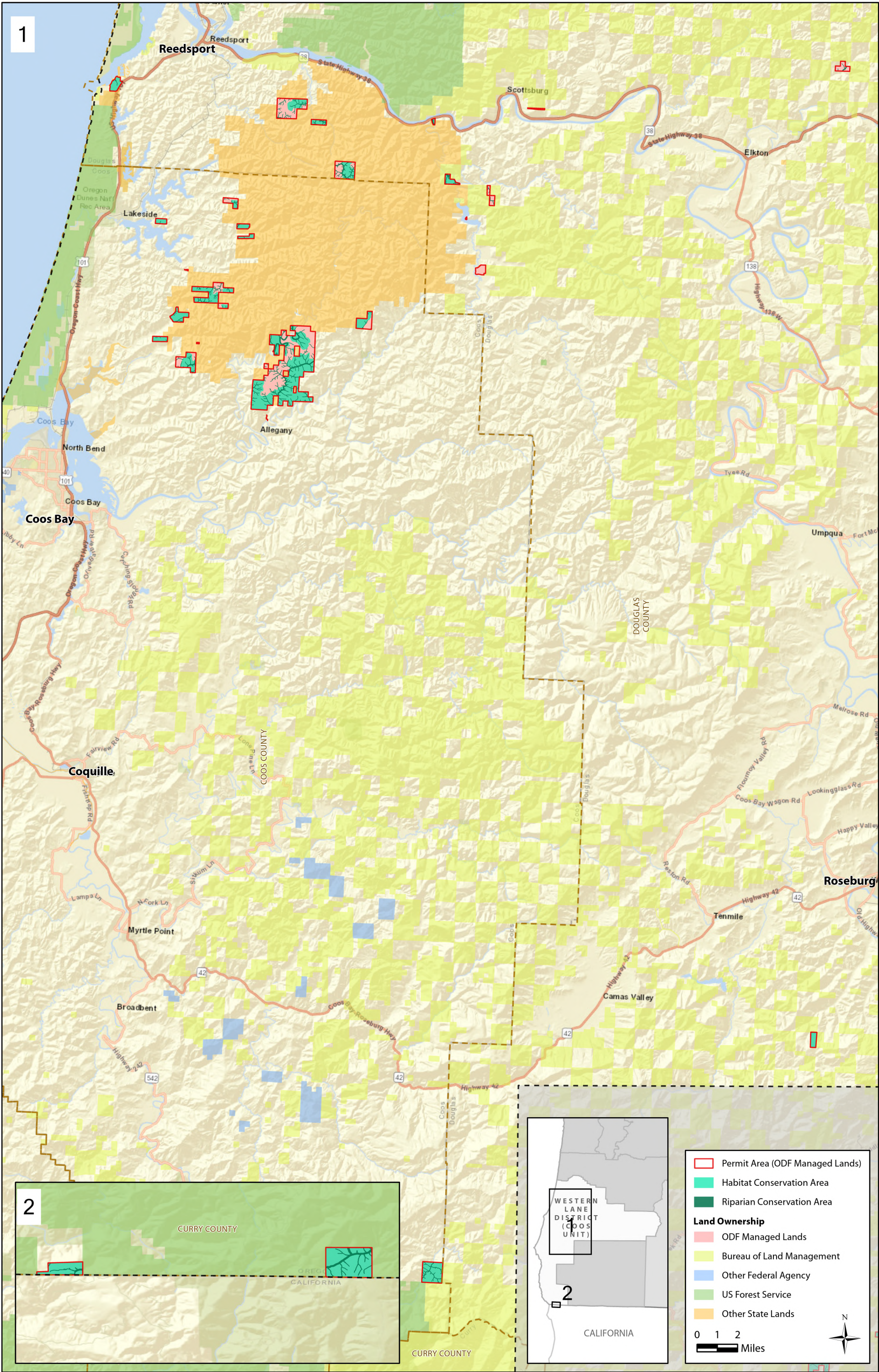


Western Oregon State Forest HCP – Habitat Conservation Areas, West Oregon District

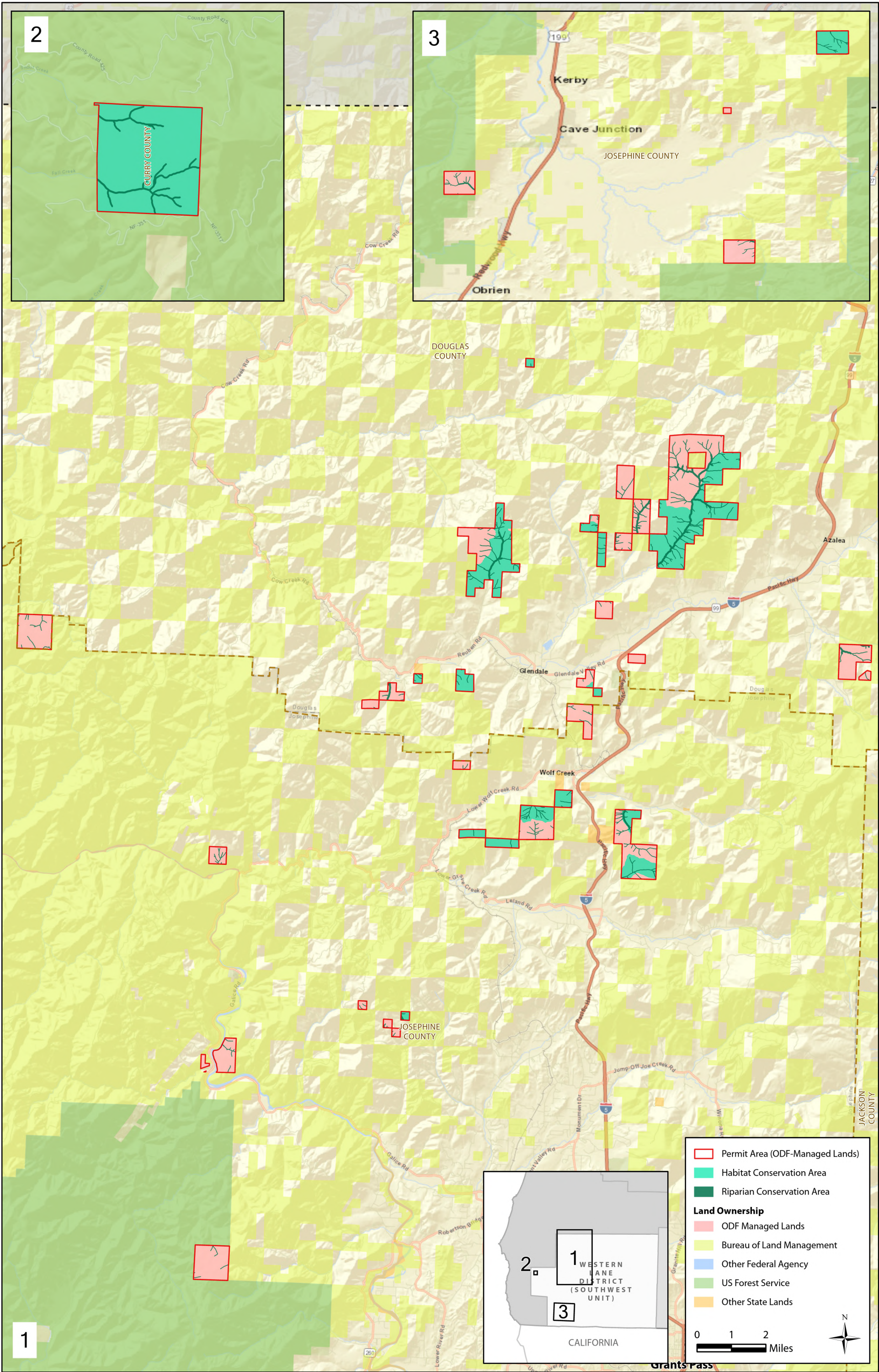


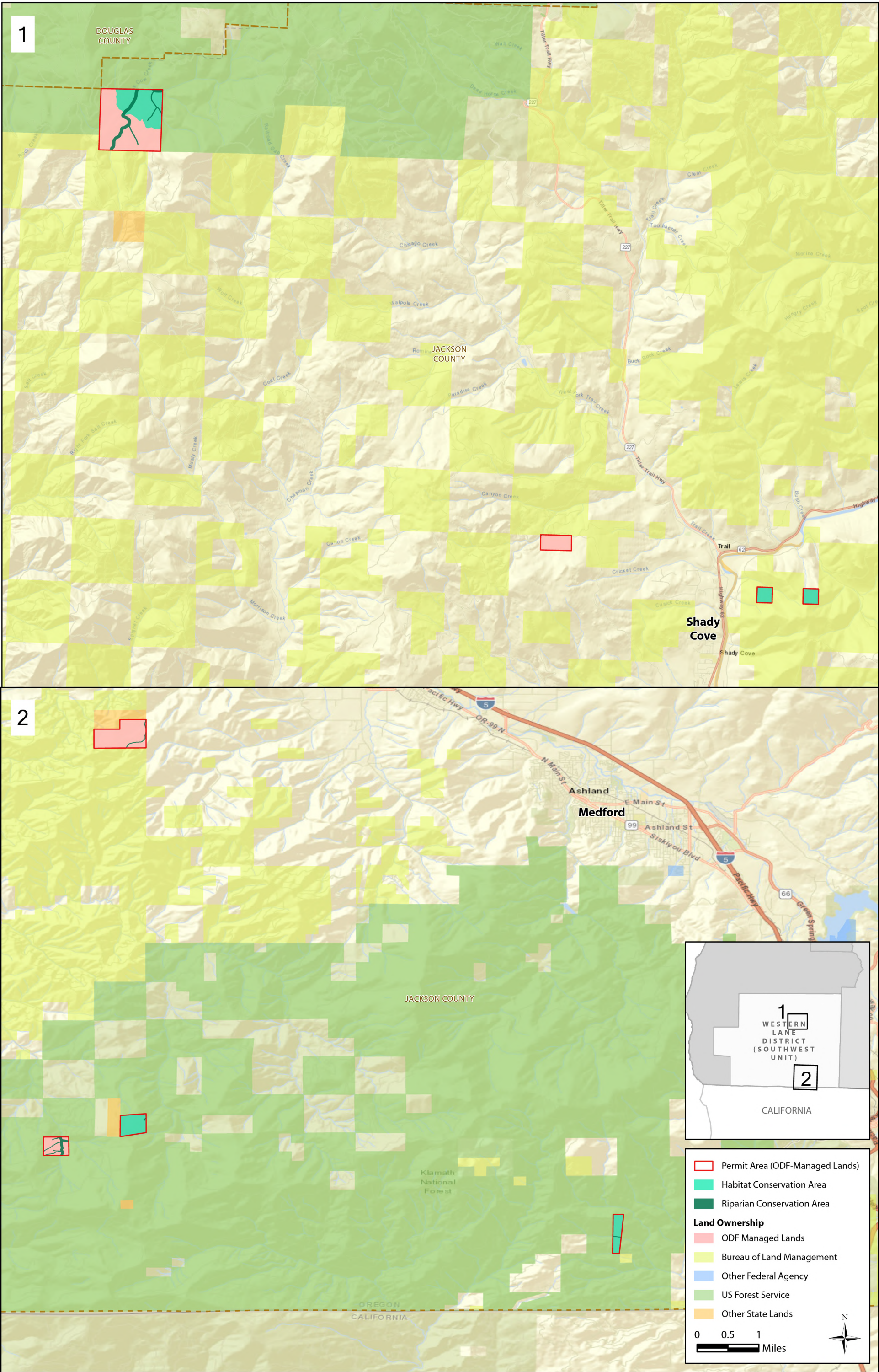


Western Oregon State Forest HCP – Habitat Conservation Areas, Western Lane District (Veneta Unit)



Western Oregon State Forest HCP – Habitat Conservation Areas, Western Lane District (Coos Unit)





Appendix G

HUC 10 Analysis

Table G-1 - Percent of Watershed (HUC 10) and Permit Area within the Oregon Coast Coho ESU that will be less than 10 Years Old During the Permit Term

Population Group	HUC 10	Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
Alsea	Drift Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Beaver	Beaver Creek-Frontal Pacific Ocean	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	4%	17%	17%	13%	44%	34%	4%	25%	25%	4%	4%	4%	6%	13%	12%	15%
Coos	Coos Bay-Frontal Pacific Ocean	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	5%	5%	6%	4%	4%	7%	8%	5%	3%	6%	7%	4%	3%	3%	3%	5%
	Millicoma River	Entire HUC	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
		Permit Area in HUC	3%	4%	5%	5%	5%	6%	11%	12%	7%	10%	12%	8%	8%	10%	8%	8%
Lower Umpqua River	Lower Umpqua River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	6%	2%	2%	2%	2%	4%	13%	11%	4%	13%	15%	5%	15%	15%	4%	7%
	Mill Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	17%	28%	27%	35%	10%
	Umpqua River - Sawyers Rapids	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Upper Smith River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	100%	100%	1%	1%	14%
Middle Umpqua	Elk Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	47%	2%	2%	2%	2%	2%	19%	19%	2%	2%	29%	29%	2%	2%	2%	11%
Necanicum	Necanicum River-Frontal Pacific Ocean	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	12%	5%	10%	10%	10%	13%	20%	17%	23%	23%	10%	11%	6%	5%	10%	12%
Nehalem	Headwaters Nehalem River	Entire HUC	2%	4%	5%	5%	4%	3%	3%	3%	3%	2%	2%	3%	2%	2%	1%	3%
		Permit Area in HUC	8%	14%	20%	18%	14%	12%	10%	10%	10%	8%	9%	11%	9%	6%	6%	11%
	Lower Nehalem River	Entire HUC	2%	5%	7%	6%	7%	9%	10%	9%	8%	7%	5%	5%	7%	9%	10%	7%
		Permit Area in HUC	3%	6%	9%	8%	9%	11%	13%	11%	10%	9%	6%	6%	9%	11%	12%	9%
	Middle Nehalem River	Entire HUC	8%	6%	8%	8%	7%	5%	4%	5%	5%	6%	8%	7%	7%	6%	6%	6%
		Permit Area in HUC	13%	10%	14%	13%	11%	8%	7%	8%	9%	11%	13%	11%	11%	10%	10%	10%
	North Fork Nehalem River	Entire HUC	3%	3%	4%	5%	5%	5%	5%	4%	3%	3%	3%	3%	2%	2%	3%	4%
		Permit Area in HUC	10%	8%	12%	14%	14%	13%	14%	12%	9%	9%	8%	8%	6%	5%	8%	10%
	Salmonberry River	Entire HUC	4%	4%	5%	5%	5%	4%	5%	6%	7%	5%	3%	5%	4%	3%	3%	5%
		Permit Area in HUC	7%	6%	8%	9%	8%	7%	8%	10%	11%	8%	5%	8%	7%	5%	5%	8%
	Upper Nehalem River	Entire HUC	3%	5%	6%	4%	4%	3%	3%	4%	4%	5%	5%	4%	5%	4%	3%	4%
		Permit Area in HUC	11%	18%	21%	14%	14%	11%	10%	12%	13%	15%	17%	14%	16%	12%	11%	14%
	Little Nestucca River	Entire HUC	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
		Permit Area in HUC	4%	16%	18%	24%	31%	15%	12%	10%	8%	8%	4%	9%	19%	16%	5%	13%
	Nestucca River	Entire HUC	0%	1%	1%	1%	1%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
		Permit Area in HUC	3%	7%	15%	19%	20%	23%	26%	19%	15%	14%	11%	9%	11%	18%	19%	15%
Siletz	Lower Siletz River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%
		Permit Area in HUC	4%	4%	4%	4%	4%	4%	4%	4%	4%	24%	27%	6%	4%	4%	4%	7%
	Rock Creek	Entire HUC	2%	1%	2%	3%	5%	5%	3%	4%	3%	2%	3%	3%	2%	4%	3%	3%
		Permit Area in HUC	7%	6%	8%	11%	21%	19%	12%	14%	12%	8%	10%	10%	9%	16%	14%	12%
Siuslaw	Deadwood Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Population Group	HUC 10	Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
South Umpqua	Lake Creek	Permit Area in HUC	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	9%	9%	1%	1%	1%	2%
		Entire HUC	1%	2%	3%	2%	3%	2%	1%	1%	1%	1%	0%	1%	1%	0%	1%	1%
	Lower Siuslaw River	Permit Area in HUC	8%	12%	18%	16%	16%	13%	8%	5%	7%	6%	3%	4%	4%	3%	4%	8%
		Entire HUC	1%	1%	1%	2%	2%	2%	1%	1%	1%	1%	0%	0%	0%	0%	0%	1%
	Upper Siuslaw River	Permit Area in HUC	6%	5%	10%	15%	15%	15%	13%	11%	11%	9%	4%	2%	3%	4%	4%	8%
		Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Wildcat Creek	Permit Area in HUC	5%	5%	2%	2%	2%	5%	19%	16%	15%	22%	9%	7%	9%	4%	3%	8%
		Entire HUC	1%	2%	2%	2%	2%	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Wolf Creek	Permit Area in HUC	11%	12%	17%	13%	12%	6%	3%	6%	7%	6%	6%	5%	4%	4%	7%	8%
		Entire HUC	1%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Clark Branch-South Umpqua River	Permit Area in HUC	22%	13%	28%	25%	13%	10%	9%	13%	20%	12%	3%	16%	17%	4%	3%	14%
		Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Days Creek-South Umpqua River	Permit Area in HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Lower Cow Creek	Permit Area in HUC	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	23%	23%	6%	8%
		Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Middle Cow Creek	Permit Area in HUC	4%	4%	4%	4%	6%	6%	7%	7%	4%	4%	4%	4%	4%	4%	31%	7%
		Entire HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
	Olalla Creek - Lookingglass Creek	Permit Area in HUC	9%	6%	6%	6%	6%	7%	6%	9%	11%	9%	6%	5%	6%	7%	10%	7%
		Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tenmile	Tenmile Creek-Frontal Pacific Ocean	Permit Area in HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Entire HUC	2%	4%	9%	8%	2%	2%	7%	7%	2%	2%	18%	18%	2%	2%	2%	6%
Tillamook Bay	Kilchis River	Permit Area in HUC	2%	2%	2%	4%	6%	7%	7%	6%	4%	3%	2%	2%	3%	4%	4%	4%
		Entire HUC	3%	3%	3%	5%	8%	9%	9%	7%	5%	4%	3%	2%	3%	5%	5%	5%
	Miami River	Permit Area in HUC	1%	3%	4%	4%	6%	6%	4%	4%	3%	3%	2%	2%	3%	3%	3%	3%
		Entire HUC	2%	5%	7%	7%	10%	9%	7%	6%	5%	5%	4%	4%	5%	6%	5%	6%
	Tillamook Bay	Permit Area in HUC	0%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	1%
		Entire HUC	5%	10%	10%	6%	8%	10%	11%	7%	5%	5%	5%	5%	5%	5%	5%	7%
	Tillamook River	Permit Area in HUC	0%	1%	1%	1%	1%	1%	2%	1%	1%	0%	1%	1%	0%	1%	1%	1%
		Entire HUC	3%	5%	6%	5%	6%	6%	10%	10%	4%	3%	3%	3%	3%	4%	4%	5%
	Trask River	Permit Area in HUC	2%	6%	9%	10%	11%	11%	10%	8%	6%	6%	8%	8%	10%	13%	13%	9%
		Entire HUC	4%	10%	16%	18%	20%	19%	17%	13%	10%	11%	14%	14%	16%	22%	22%	15%
	Wilson River	Permit Area in HUC	5%	7%	10%	11%	12%	12%	10%	8%	7%	8%	8%	8%	9%	11%	11%	9%
		Entire HUC	6%	8%	12%	14%	15%	15%	12%	10%	9%	10%	10%	10%	11%	14%	14%	11%
Yaquina	Big Elk Creek	Permit Area in HUC	2%	2%	2%	2%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	1%	2%
		Entire HUC	10%	10%	11%	16%	18%	16%	15%	12%	11%	13%	12%	11%	12%	10%	8%	12%
	Lower Yaquina River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Population Group	HUC 10	Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
		Permit Area in HUC	22%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%
	Upper Yaquina River	Entire HUC	2%	2%	2%	2%	3%	3%	3%	3%	3%	2%	2%	2%	2%	3%	3%	2%
		Permit Area in HUC	9%	9%	9%	12%	16%	16%	18%	16%	14%	13%	11%	10%	11%	17%	17%	13%

Table G-2 - Percent of Watershed (HUC 10) and Permit Area within the Lower Columbia River Coho, Chinook, and Columbia River Chum ESUs that will be less than 10 Years Old During the Permit Term

Population Group	HUC 10	Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
Big Creek	Big Creek-Frontal Columbia River	Entire HUC	2%	5%	7%	6%	6%	4%	3%	4%	4%	6%	6%	5%	6%	5%	4%	5%
		Permit Area in HUC	8%	18%	26%	25%	24%	17%	14%	15%	18%	23%	23%	21%	24%	19%	15%	19%
Clatskanie River	Clatskanie River	Entire HUC	1%	1%	2%	1%	1%	1%	1%	2%	2%	2%	2%	1%	0%	0%	0%	1%
		Permit Area in HUC	10%	15%	23%	16%	8%	14%	20%	24%	28%	33%	32%	17%	6%	5%	5%	17%
	Plympton Creek-Frontal Columbia River	Entire HUC	3%	4%	4%	4%	4%	3%	3%	2%	2%	3%	3%	3%	4%	3%	2%	3%
		Permit Area in HUC	8%	11%	12%	10%	11%	9%	7%	6%	6%	8%	8%	8%	11%	8%	5%	9%
Sandy River	Salmon River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Youngs Bay	Youngs River-Frontal Columbia River	Entire HUC	1%	2%	2%	2%	2%	2%	2%	2%	3%	3%	3%	2%	2%	1%	1%	2%
		Permit Area in HUC	12%	15%	18%	16%	16%	16%	15%	18%	23%	27%	28%	20%	14%	10%	13%	17%

Table G-3 - Percent of Watershed (HUC 10) and Permit Area within the Southern Oregon/Northern California Coast ESU that will be less than 10 Years Old During the Permit Term

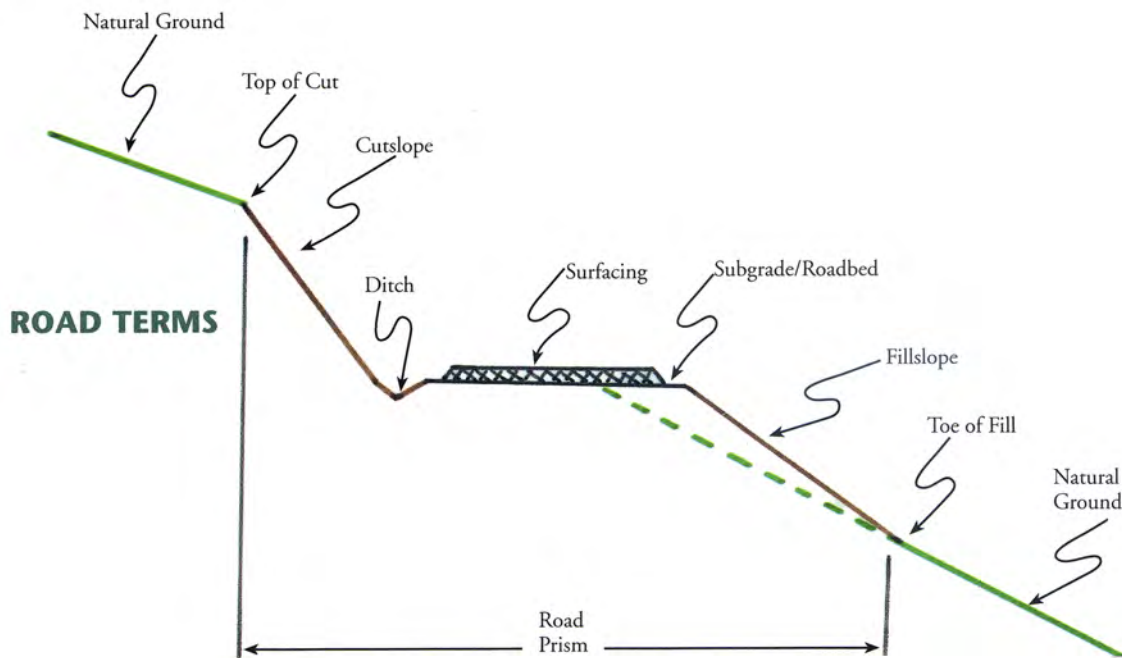
Population Group	HUC 10	Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
Illinois	Althouse Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	9%	9%	4%	5%
	Deer Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
	Indigo Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
	Josephine Creek-Illinois River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%
	Lawson Creek-Illinois River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
	Sucker Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	7%
	West Fork Illinois River	Entire HUC	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
		Permit Area in HUC	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%	56%
Middle Rogue and Applegate	Bear Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
	Grave Creek	Entire HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
		Permit Area in HUC	12%	11%	12%	12%	12%	12%	11%	12%	12%	13%	13%	15%	15%	12%	15%	13%
	Headwaters Applegate River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Hellgate Canyon-Rogue River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	29%	28%
	Horseshoe Bend-Rogue River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	12%	12%	6%
	Jumpoff Joe Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	0%
	Little Applegate River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
	Shasta Costa Creek-Rogue River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Smith	North Fork Smith River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Upper Klamath	Cottonwood Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Upper Rogue	Shady Cove-Rogue River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%
	Trail Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
Winchuck	Winchuck River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

Table G-4 - Percent of Watershed (HUC 10) and Permit Area within the Upper Willamette River Chinook and Steelhead ESUs that will be less than 10 Years Old During the Permit Term

Species	Population Group	HUC 10		2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
Chinook	Willamette	Fall Creek	Entire HUC	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	1%	19%	62%	45%	17%	17%	18%	18%	1%	1%	1%	1%	1%	1%	1%	14%
		Lookout Point Lake-Middle Fork Willamette River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	33%	26%	41%	18%	20%	27%	9%	2%	2%	2%	2%	2%	2%	2%	2%	13%
	Z-Outside	Mill Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Chinook and Steelhead		Abiqua Creek-Pudding River	Entire HUC	1%	2%	2%	1%	1%	1%	1%	1%	1%	1%	0%	1%	0%	0%	0%	1%
			Permit Area in HUC	6%	18%	24%	11%	6%	10%	12%	9%	10%	8%	5%	6%	5%	3%	3%	9%
		Butte Creek-Pudding River	Entire HUC	2%	2%	5%	4%	2%	2%	2%	2%	2%	2%	2%	2%	2%	1%	2%	2%
			Permit Area in HUC	11%	12%	24%	23%	12%	13%	13%	9%	12%	12%	9%	8%	8%	7%	8%	12%
		Crabtree Creek	Entire HUC	1%	0%	1%	1%	0%	0%	0%	1%	0%	0%	1%	1%	0%	0%	1%	0%
			Permit Area in HUC	33%	7%	19%	18%	6%	3%	11%	15%	7%	13%	26%	23%	15%	8%	17%	15%
		Hamilton Creek-South Santiam River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	62%	3%	3%	3%	3%	7%	31%	27%	8%	8%	3%	29%	29%	3%	3%	15%
		Headwaters North Santiam River	Entire HUC	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	3%	3%	32%	32%	17%	17%	3%	5%	9%	9%	5%	3%	7%	7%	5%	10%
		Little North Santiam River	Entire HUC	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
			Permit Area in HUC	14%	11%	13%	16%	21%	22%	14%	15%	15%	12%	21%	19%	12%	12%	17%	16%
		Lower North Santiam River	Entire HUC	1%	1%	3%	3%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
			Permit Area in HUC	10%	17%	34%	31%	16%	7%	5%	4%	4%	4%	4%	4%	4%	4%	4%	10%
		Middle North Santiam River	Entire HUC	3%	5%	8%	7%	6%	6%	5%	5%	4%	3%	2%	2%	2%	2%	3%	4%
			Permit Area in HUC	7%	13%	22%	20%	17%	15%	13%	12%	11%	8%	6%	6%	6%	6%	7%	11%
	Willamette	Quartzville Creek-Green Peter Lake	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Thomas Creek	Entire HUC	0%	1%	2%	2%	2%	2%	1%	1%	1%	1%	0%	0%	0%	0%	1%	1%
			Permit Area in HUC	4%	11%	30%	28%	34%	34%	14%	14%	17%	11%	4%	4%	4%	5%	10%	15%
		Upper Calapooia River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	0%	0%	0%	92%	92%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	12%
		Upper Molalla River	Entire HUC	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%
			Permit Area in HUC	13%	11%	19%	17%	11%	13%	13%	12%	14%	17%	15%	13%	11%	9%	12%	13%
		Upper North Santiam River	Entire HUC	1%	1%	1%	1%	1%	1%	1%	2%	1%	1%	1%	1%	1%	1%	1%	1%
			Permit Area in HUC	15%	13%	13%	13%	13%	13%	16%	17%	14%	13%	13%	13%	13%	13%	13%	14%
Steelhead		Dairy Creek	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
			Permit Area in HUC	27%	25%	31%	13%	12%	12%	21%	21%	7%	17%	17%	7%	7%	7%	7%	15%
		Gales Creek	Entire HUC	2%	2%	3%	3%	3%	3%	3%	3%	2%	1%	1%	2%	1%	1%	1%	2%
			Permit Area in HUC	8%	8%	13%	13%	10%	10%	11%	11%	8%	5%	4%	6%	5%	3%	3%	8%
		Luckiamute River	Entire HUC	0%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	1%
			Permit Area in HUC	9%	21%	37%	30%	18%	20%	22%	16%	17%	11%	6%	7%	10%	9%	6%	16%
		Marys River	Entire HUC	3%	3%	3%	2%	3%	3%	3%	3%	2%	1%	1%	1%	2%	2%	2%	2%
			Permit Area in HUC	15%	16%	16%	13%	15%	16%	19%	15%	11%	9%	7%	8%	10%	10%	9%	13%
		Rickreall Creek-Willamette River	Entire HUC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Species	Population Group	HUC 10	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073	2078	2083	2088	2093	Average
		Permit Area in HUC	9%	99%	99%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	21%
		Entire HUC	3%	3%	6%	5%	5%	4%	3%	3%	3%	2%	2%	3%	3%	1%	1%	3%
		Permit Area in HUC	13%	14%	24%	22%	20%	17%	14%	15%	13%	7%	7%	13%	11%	4%	3%	13%
		Entire HUC	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Permit Area in HUC	3%	46%	69%	26%	11%	15%	7%	10%	10%	3%	3%	3%	3%	3%	3%	14%
		Entire HUC																

Oregon Department of Forestry



State Forests Program

Forest Roads Manual

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Forest Engineering Roads Manual

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State Forests Program Staff Engineer

Area Director

Assistant District Forester/Unit Forester

Timber Sale Layout Personnel

District Engineer

Project Administrator

Geotechnical Specialist

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Roads provide essential access for the active management of the resources found on state-owned forest lands. Forest management, timber removal, recreation, and fire protection, as well as other activities, are all heavily, if not totally, dependent on road access into the forest.

Besides being an asset, roads are recognized as sources of erosion and sedimentation, impact wildlife and aquatic habitats, remove valuable timberland from production and require significant work and expense to build and maintain. For these reasons, an environmentally sound, economically efficient and effective road management program must be utilized on state-owned forest lands.

Road Management Policy

The goal for the management of forest lands owned by the Board of Forestry is to secure the greatest permanent value to the citizens of Oregon as described in OAR 629-035-0000 through 629-035-0100. The goal for the management of Common School Forest Land is to obtain the greatest benefit for the people of Oregon as described in the Oregon Constitution.

Therefore, it is the policy of the Department of Forestry to establish and maintain a road system that will facilitate securing the greatest permanent value on Board of Forestry lands and obtaining the greatest benefit on Common School Forest Lands. This policy is implemented through activities in transportation planning, road

design, road construction and improvement, road maintenance and closing or vacating unneeded roads.

Purpose of the Manual

The purpose of this manual is to provide guidance and standards for road management on state-owned forest lands. The manual contains information that is considered to be the current state-of-the-art. As additional information becomes available through research and monitoring the manual will be updated.

The Vision for Forest Roads on State-owned Forest Lands

(Note to the reader: The vision is written in the present tense as if we were already in the future and actually looking at the idealized forest road system on state-owned forest lands)

The forest road system on state-owned forest lands is providing efficient, effective access that facilitates securing the greatest permanent value on Board of Forestry lands and obtaining the greatest benefit on Common School Forest Lands. The forest road system is managed actively, not passively. Roads are designed, constructed and maintained in the most cost-efficient manner, while providing a high level of protection to other natural resources. The amount of land occupied by roads is at a minimum. Fish are able to move upstream and downstream where roads cross streams. Roads are constructed in the best locations for carrying out anticipated activities, while minimizing the impacts on natural resources. The standard for roads in the forest is a suitable match for the terrain and type of access needed. The roads are effectively maintained to retain their longevity and to prevent adverse effects to natural resources. Unneeded roads are closed or vacated and, where appropriate, the land they occupied is returned to active forest management.

Guiding Principles for Road Management

The guiding principles of state forest road management are presented here, with a brief explanation of each. These principles are some (certainly not all) of the most significant components of the “state-of-the-art” knowledge needed to ensure sound practices in forest road management. The reader is directed to the specific sections of this Forest Engineering Roads Manual for a more detailed explanation and application.

Guiding Principle 1. The amount of road on state-owned forest land will be the minimum necessary to achieve the goals of Forest Management Plans.

Access through the forest is essential to achieve forest management goals. Access requirements are dependent on management goals, geographic location, harvest methods utilized, and other on-site factors. Minimizing total miles of road in the forest reduces road construction & maintenance costs, and reduces land taken out of the forest management base. Less road means less potential for adverse effects on other natural resources.

Guiding Principle 2. New roads will be located to provide the best protection to natural resources and meet the objective of the road.

Determining the best location for new forest roads is one of the first and most important steps in minimizing road impact problems. Road locations will fit the terrain. Ridge top locations are preferred over mid-slope roads. Modifying road grades to avoid undesirable locations will be used wherever possible. To the extent possible, roads will be located away from streams, wetlands, unstable areas, and sensitive resource sites. Alternative route locations will be considered on all new roads. The location that best protects natural resources and meets the objective of the road will be selected.

Guiding Principle 3. High-risk sites will be avoided wherever possible. Where high-risk sites cannot be avoided, state-of-the-art design and construction practices will be used.

The construction of road segments through high-risk sites will be avoided whenever possible through the use of alternate routes or different logging systems.

At times road locations will be necessary through high-risk sites. When this occurs, a geotechnical specialist will evaluate the location. In most cases, the geotechnical specialist will make site visits and develop site specific, state-of-the-art recommendations concerning the site. Those recommendations will be incorporated into the design and construction of the project.

The evaluation of both the risk of a landslide and the values at risk below the site is critical. The road may need to be relocated if either of the risks is considered too high.

Guiding Principle 4. New roads will be located, designed and built for economically efficient and effective forest operations.

Only roads that provide benefits that outweigh the costs of the roads will be constructed. Benefits from roads are measured both from financial gains and for achievement of overall management goals.

By coordinating transportation and forest management plans, a reduction in the total amount of road needed to accomplish management goals will be achieved.

Guiding Principle 5. Roads will be designed to meet access needs, to have low impacts on natural resources and the forest, and to be economical to construct and maintain.

Road design will match road use. This usually means limiting the width of the road to that necessary for the expected use. Minimizing road width and the resultant cut and fill slopes will minimize environmental impacts from roads.

The use of excavated material will be carefully considered in the design of roads. A balanced cut and fill cross section design will be used where slopes are gentle and stable. Where a balanced cross section design is not used, excess material will be used in fills

and/or to raise the road grade. A full bench end-haul design will be used where slopes are steep and risks of landslides are high.

Road designs will provide for proper drainage of surface water. Grade breaks, out-sloping, in-sloping, ditching, road dips, water bars and relief culverts are some of the techniques that must be considered.

Road surfacing will be included in the design of roads that will be subject to use during wet weather. The amount and type of road surfacing will be determined by the expected use of the road.

As mentioned in the Guiding Principle on Fish Passage, stream crossings will be designed to assure fish passage.

Guiding Principle 6. Temporary roads will be used to meet short-term access needs. When the need no longer exists, the temporary road will be vacated.

Temporary roads can be used to minimize road density and associated impacts where resource concerns indicate a need. The use of temporary spurs and special construction practices that provide protection while planning to vacate the temporary road (at a later time) can serve a very specific and beneficial purpose. These roads must be planned and managed properly to ensure the desired environmental protection.

Guiding Principle 7. Forest roads on state-owned forest lands will be designed constructed and maintained to provide effective and efficient drainage of surface water.

Effective drainage systems are needed to protect both the environment (water quality and fish habitat) and the capital investment in the road. These systems must be included in the road design, ensured through road construction and maintained through road maintenance.

Sometimes the efficiency of getting water off the road is in conflict with environmental protection (sediment into streams), and proper design and maintenance may require specific problem solving for the site. For example, where the risk of landslides is high, the location of cross drainage must be carefully considered. The sections of this manual on Forest Road Design, Forest Road Construction, and Forest Road Maintenance discuss the concepts and strategies involved in road drainage.

Guiding Principle 8. Fish passage will be provided where roads cross fish-bearing streams.

Providing fish passage where roads cross fish-bearing streams will ensure that fish can access habitat. Forest Practices Act guidance on fish passage is the state-of-the-art and will be used for evaluating and deciding on proper design and construction of stream crossings.

Stream crossings for new road construction and road improvement projects will be designed and constructed using state-of-the-art practices. Ongoing repair or replacement of stream crossings on existing roads that do not provide adequate fish passage will be conducted systematically within the limitations of workload priorities and the availability of funds.

Guiding Principle 9. Waste areas for depositing excess road excavation material will be located on stable sites.

Where excess road excavation materials are generated, especially where full bench end-haul road construction design is used, waste areas for depositing excess road excavation materials are needed. Waste areas will be located on stable sites.

The proper selection of waste areas is critical. Waste area failures can have serious impacts on water quality and fish habitat. They are expensive to repair and difficult to mitigate.

Foresters or engineers, oftentimes aided by the geotechnical specialist, will thoroughly investigate potential waste area locations in order to ensure a high level of confidence in their stability. Uncertainties of geologic subsurface conditions will prevent complete confidence in the stability of waste area locations. Monitoring of waste areas after construction (during the first few winters) ensures timely action in the case of unrecognized slope instability.

Guiding Principle 10. Rock pits and quarries will be designed and developed to provide for environmental protection and site reclamation.

Design considerations for environmental protection include: drainage of the quarry floor, screening berms, filtering of surface water, proper location of stockpile and overburden, clearing limits, and other site-specific design mitigation. The Geotechnical specialist may be requested to assist in rock pit and quarry design.

At the conclusion of use, rock pits and quarries will be reclaimed to the extent practical.

Guiding Principle 11. An active road maintenance program will be used to protect the capital investment in the road, to minimize adverse effects to water quality and aquatic habitat, and to provide for safe use of the road.

Proper road maintenance minimizes the impacts roads have on natural resources and ensures that roads are available for their intended use. Road maintenance protects the State's investment in the transportation system. An active road maintenance program includes an ongoing and up-to-date inventory of road maintenance needs, a means of systematically addressing the needs, and a response to emergency situations. Road maintenance includes the repair and upkeep of the road prism, road surface, and road drainage. It also includes vegetation management along roads.

Guiding Principle 12. Roads that are determined to be unnecessary for forest management will be vacated. In addition, roads that are causing or likely to cause serious environmental problems, very near fish-bearing streams, or have very high maintenance costs will be considered for vacating.

Vacating roads, when appropriate, can reduce environmental impacts, lessen maintenance costs and move the transportation system toward the desired condition. Roads will be vacated when their use is judged to be unnecessary to forest management. In addition the following roads will be considered for vacating: roads where serious erosion is occurring or likely to occur, where the costs of adequate maintenance (over the long term) will exceed the cost of vacating, or where the road is very near a fish-bearing stream. The section of the manual on Forest Road Vacating describes the processes and techniques for vacating roads.

Transportation Planning

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Introduction

As used in this section “Transportation Planning” means any planning activities involving new road construction, road improvement or road maintenance. This section is intended to guide Oregon Department of Forestry managers of state-owned forest lands (unit foresters, forest engineering supervisors, road specialists, and foresters) in the transportation planning effort for state forest roads. It may also serve to explain the basic transportation planning approach of the department to other interested parties. The levels of transportation planning as well as the goals, objectives and strategies for transportation planning are described.

Goals of Transportation Planning

1. Provide plans for a road system that will facilitate the implementation of Forest Management Plans.
2. Provide plans for a road system that is efficiently, effectively, and environmentally constructed and maintained.

Objectives of Transportation Planning

1. Develop a vision of the desired forest road system.
2. Know and evaluate the condition of the existing forest road system.
3. Develop efficient, effective, and environmentally sound plans that can be used to move from the existing condition of the road system toward the vision or desired condition.

Levels of Planning

Transportation planning for state-owned forest lands will occur at three levels:

Level I This is a broad level, long range planning effort that establishes long term goals and determines strategies for achieving the goals. Road management goals and strategies need to be consistent with legal requirements and the goals and strategies for the management of other forest resources. Specific operations are not identified. Level I planning usually occurs in the development of forest management plans, watershed assessments and similar documents.

Example: The forest management plan provides a broad, general description of the current condition of forest roads on state-owned forest lands, establishes broad, general goals for the access system and describes the strategies for achieving the goals.

Level II This is a mid level, moderate range planning effort that describes the vision for the forest road system of the future, determines the current condition of the road system, and identifies the general needs to move from the current condition to the vision. This level of planning usually does not span more than a decade and needs to be updated periodically. Major activities such as mainline and primary spur road construction and significant road improvements are identified. The Level II plan will be consistent with the goals and strategies determined in Level I planning. Level II planning usually occurs in the development of implementation plans and similar documents. Guidance on the development of Level II transportation plans may be a part of the overall guidance for the development of these documents.

Example: A district implementation plan calls for significant timber harvesting in a given basin in the next decade. A road system is needed to facilitate the harvesting activities. A transportation plan would be developed that would supplement and support the implementation plan for the basin. The transportation plan would describe the vision for the road system in the basin and determine the current condition of the road system. It would then identify any new construction of mainline or primary spur roads that are needed, any significant reconstruction of existing roads, and any road improvement needs such as replacement of stream crossing structures. Approximate locations of activities may be identified on maps or photos. Approximate scheduling of individual projects may also be included.

Level III This is a detailed level of planning that considers specific projects or operations over a relatively short time frame, usually two years or less. Projects or operations must be consistent with Level II planning for the geographic area. Oftentimes the need for the project or operation and a general location has been identified in the Level II plan. In the Level III plan the projects are site-specific and locations are identified on the ground. Some design criteria and specifications may be included in the Level III plan. Projects often are associated with other operations such as timber sales. Level III planning usually occurs as part of the development of annual operations plans, annual road maintenance plans, timber sale contracts, service contracts and similar documents.

Example: A planned timber sale requires access to facilitate harvesting operations. A plan must be developed that will identify the location and standards for roads, landings, waste areas, road surfacing rock, and any other items needed to facilitate the harvesting operations. Alternatives may need to be developed and evaluated. Aerial photos, maps, and reconnaissance on the ground are used to determine the general location of the project. Information from the Level III planning effort is included in the pre-sale plan report.

Transportation Planning Strategies

Transportation planning strategies are the specific actions that will be taken to achieve the goal(s) of transportation planning and move towards the vision for forest roads on state-owned forest land. These strategies will be applied at all levels of transportation planning. As the planning moves from Level I to Level III the strategies will become more detailed and more specific.

Develop a Vision of the Transportation System

Successful planning of a transportation system requires the planner to have a vision of the desired system. This manual describes a vision for the road system across all state-owned forest land. That broad scale vision will be supplemented with a vision that is specific for the local planning area and that is commensurate with the level of planning that is being performed. For example, transportation planning is being done as part of a district implementation plan for a specific basin. A vision statement for the transportation system for the basin will be developed. The vision will include the elements of the vision statement in this manual and then add the details that are needed to describe the desired condition for that specific basin.

Visions are usually written statements that describe the desired condition. They should provide enough detail to provide a clear image of what is desired so that the vision can be used throughout the development and implementation of the transportation plan. For example, the vision statement for a specific road construction project would be used in determining the design specifications and construction standards for the project.

Visions will be consistent with the goals and strategies in the appropriate resource management plans and consider the physical conditions in the planning area. Resource management plans include forest management plans (Level I), implementation plans (Level II), annual operations plans (Level III), etc. The resource management plan that is considered will depend upon the level of transportation planning. Physical conditions include those items that will affect the desired road system. Physical conditions to consider in developing a vision statement include topography, soils, streams, geologic hazards and risks, sensitive resources, special habitats, etc. Before developing a vision for the transportation system in a given area, the planner should have an understanding of the appropriate resource management plans and the physical conditions. Consultation with natural resource specialists (biologists, geotechnical specialists, engineers, etc.) will be used to supplement the planner's knowledge base and understanding.

Inventory and Describe the Current Conditions

The current conditions of roads on state-owned forest lands are the result of weather and other natural processes and of a variety of road construction techniques, road maintenance efforts, and uses over time. There are roads that are in good condition and suitable for continued use. And, there are roads that are not in a desired condition and need improvement work or need to be considered for vacation.

The current conditions and needs of roads on state-owned forest lands will be inventoried. Each district will maintain an intensive inventory of the road network on state-owned lands in the district. The inventory will categorize roads, identify drainage

systems (culverts, ditches, waterbars, outslowing, etc.) and rate their condition, identify and assess road-related slope stability problems, identify barriers to fish passage where roads cross streams, and gather other information that is needed for planning road improvement, road maintenance, or vacation of roads.

As of January 2000 the minimum level inventory system that will be used for roads on state-owned forest land will be the **Road Hazard Inventory Protocol** (see Appendix 1) developed as part of the Oregon Coastal Salmon Recovery Initiative. This inventory system gathers information related to fish passage barriers where roads cross streams, information related to road drainage systems and their condition, and information related to slope stability problems. This information will be useful in describing some but not all of the current conditions of roads. In the future, a more comprehensive inventory system will be developed and added to this manual. Until the new inventory system is in place, districts may gather additional information on the current condition of roads that the district determines to be necessary to efficiently and effectively manage the district road system.

Upon completion of the inventory, the information that was gathered will be processed and/or displayed in a way that will provide a description of the current condition of the road system. As of January 2000 a standard approach for processing and displaying the information was not available. Along with the development of a more comprehensive road inventory system a method for processing and displaying the information will be developed.

Until a methodology is developed, districts will utilize a local system for describing the current condition of the state forest roads in their district. As a minimum the description will include a brief narrative supported by data from the inventory that show the needs related to road drainage, fish passage, and slope stability. Districts may also choose to use GIS to record inventory information and to describe, through maps and tables, the current condition of roads.

Inventories are only valuable if they are current. The inventory of the current condition of roads will be updated as changes are made to the road system and/or new information is obtained. Information in the inventory that is more than five years old should be reviewed and updated or deleted if it is no longer current.

Develop Transportation Plans Consistent With the Planning Level

Transportation plans will describe the means of moving from the current condition to the desired condition (Vision). The amount of detail in the plan will depend upon the level of planning. This will generally mean less detail in Level I planning, more in Level II and the most in Level III. The amount of detail in the plan will also vary with the geographic scope of the plan. In general, plans covering a large geographic area (a district e.g.) will have less detail than plans covering a small geographic area (a timber sale area e.g.).

As mentioned in the discussion of the levels of planning, Level I transportation plans are broad, long-range plans for large geographic areas. They establish goals for moving from the current condition to the desired condition and strategies for achieving the goals.

These plans are generally in a narrative form and will not involve the use of maps or photos. Specific activities or projects are not identified.

Level II transportation plans will describe how the desired condition will be achieved over a span of time for a given area. Generally, these plans are associated with district implementation plans and are developed for a decade of time in a given basin. These plans will have a combination of a narrative description and a graphic display (usually maps and/or photos). These plans provide a description of the vision for the road system, the current condition of the road system, and what is planned to achieve the desired condition. The narrative will describe the amount and type of road maintenance that is planned, the amount and character of minor spur road construction that is planned, and the amount and nature of minor sections of road that will be vacated or closed. Mainline road construction, collector spur roads, significant road improvement projects and closure or vacation of large sections of road should be located on maps or photos. Input from resource specialists (biologists, engineers, geotechnical specialists, etc.) and the use specific resource information (soils maps, fish presence surveys, endangered species surveys, etc.) may be needed in the development of these plans. Level II plans should be updated as new information is obtained or as specific projects are accomplished. As a minimum, these plans will be updated once a decade.

Level III plans describe how the desired condition will be achieved in the near future for a specific area. Many of these plans are site specific and deal with an individual project or a series of projects related to a specific objective. Examples of a Level III plan would be a transportation plan for a proposed timber sale or a specific road maintenance project.. A lengthy narrative is not required. However, the objective of the plan and any critical decision points in the implementation of the plan should be described. These plans will generally contain enough detail that the design of specific projects can be started. Projects are located on maps or photos and critical portions are “ground truthed”. Specifications and standards will be identified and recommended in the plan. District budgets will be developed to include funding for projects not accomplished through timber sale project requirements. A high level of input from resource specialists and site specific resource information will be used to develop the plan.

***Footnote**

As noted in the Northwest Oregon State Forests Management Plan (July 2000 draft) pg. 4-72, "Initial district implementation plans will not contain all of the transportation planning elements described in this Roads Manual. Following completion of watershed assessments and as district implementation plans are subsequently revised and updated the complete transportation planning process will be applied."

Forest Road Design

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Introduction

A well planned, designed, constructed, and maintained system of forest roads is essential to facilitate forest management and protection of natural resources. Road design is the process of determining the “what, where, when, and how” for a new road construction, road improvement, or extra-ordinary road maintenance project. It begins after careful planning has determined that the project is necessary.

The designer of a project will consider the following factors:

- The purpose and intended use of the project. Included in this factor are length of use (temporary or permanent), amount and timing of use, and type of use (commercial, recreational, or administrative).
- The physical conditions affecting the project. Included in this factor are soils, topography, high landslide hazard locations, streams, wetlands, bedrock, weather, etc.
- Environmental conditions affecting the project. Included in this factor are fish bearing streams, threatened and endangered species, environmentally sensitive sites, scenic values, recreational use, etc.
- Benefits, costs, and risks associated with the project. Included in this factor is the consideration of alternative designs and locations for the project. The design will strive for maximizing benefits and minimizing costs and risks.

Goals of Road Design

1. Design roads that meet access needs.
2. Design roads to meet or exceed all Forest Practices Act road design rules to minimize environmental impacts on natural resources.
3. Design roads that are economical to construct and maintain.

Objectives of Road Design

1. Facilitate building roads in the best locations to meet forest management needs and minimize impacts to natural resources.
2. Ensure that the proper standard of road is constructed to facilitate the projected use without overbuilding or excessive cost.
3. Provide drainage that removes water from the road prism before it can cause problems and that will:
 - Allow the use of roads during the seasons of desired use.
 - Minimize the impact on water quality and aquatic habitat that is caused by roads.
 - Maintain the stability of forest slopes that are impacted by roads.
 - Minimize the disruptions to natural drainage patterns.
 - Reduce the amount and cost of road maintenance.
 - Minimize the impacts if drainage failures occur.

4. Provide project direction that will aid efficient, economical construction of the project.
5. Provide road designs that contain accurate information to facilitate:
 - Clear communication of specifications and expectations for road projects. The written specifications should help project administrators and contractors construct projects as designed.
 - Accurate, fair cost estimates for construction projects, which will support doing the project as planned.

Road Design Strategies

Road design strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

Engineering Procedures

The engineering procedures listed in this section are the minimum standards of engineering design work that will be utilized when designing road projects. The road designer should go beyond the minimum engineering procedures when circumstances dictate.

Generally, the engineering procedures that are utilized are dependent upon two factors. The first is the level of risk to natural resources posed by the road. The higher the chance that serious damage could occur to a natural resource as a result of the road project, the higher the level of engineering procedures that should be used to design the project. The second is the grade and alignment of the road. Steeper grades and more difficult alignments require higher levels of engineering procedures.

The road designer should visualize the desired finished road and determine what engineering procedures are needed to be sure that the project can and will be completed as desired. Unneeded engineering procedures waste time and energy in designing projects and may require wasteful construction practices. Likewise, not using adequate engineering procedures can result in the project not meeting objectives and damaging natural resources.

The road designer must be familiar with and understand the relationship between engineering procedures (this section) and road design standards (the following section). Engineering procedures and road design standards are not interchangeable. For example, to design a spur may require upper level engineering procedures if a portion of the road crosses a high landslide hazard location.

Base Level Engineering Procedures

Base level engineering procedures are applicable when all of the following criteria are met:

- Spur roads, usually less than ¼ mile in length, often temporary use.
- Gentle road grades that are less than 10%.
- Gentle side slopes of less than 35%, or ridgetop roads.
- High landslide hazard locations or other Natural Resource concerns are not involved.

Base level engineering procedures include:

- Reconnaissance.
- Flag or stake centerline.
- Reference beginning and ending points and other control points as needed.

Mid-Level Engineering Procedures

Mid-level engineering procedures are applicable when one or more the following criteria are met:

- Spur roads longer than ¼ mile, usually permanent.
- A portion of the road has grades that exceed 10% but are less than 17%.
- A portion of the road is located on slopes greater than 35% but less than 60% and high landslide hazard locations or deep seated landslides are not involved.

Mid-level engineering procedures will be applied to any portion of the road meeting the above criteria. Mid-level engineering procedures include:

- Reconnaissance of P-line(s) and topography.
- Run grade line.
- Field design final centerline location.
- Mark centerline with paint on stumps and hang flagging
- May be slope-staked, but generally reference tags are adequate (see section on “Referencing Centerline”)

Upper Level Engineering Procedures

Upper level engineering procedures are used when one or more of the following criteria are met:

- Mainline roads.
- Portions of the road:
 - a) Are located on slopes over 60%, or
 - b) Cross a high landslide hazard location, or
 - c) Cross a sharp “V” draw, or
 - d) Cross a sharp ridge and horizontal and/or vertical curves are a concern, or
 - e) Have sections of “through cut” or fills where the fill or cut heights exceed 10 feet, or
 - f) Cross fish bearing streams, or
 - g) Have long stretches of continuous road grades greater than 16%, or
 - h) Require end hauling, or
 - i) Require critical alignment, or
 - j) Cross through or are adjacent to environmentally sensitive sites.

Upper level engineering procedures will be applied to roads or portions of roads meeting the above criteria. Upper level engineering procedures include:

- Reconnaissance.
- P-Line.
- Grade Line.
- Plan.
- Profile.
- Office-locate L-line.
- Cross-section.
- Slope stake or reference L-line. (See section on “Referencing Centerline Location”)

Where a planned road has segments that meet the criteria for upper level engineering procedures and the remainder of the road meets the criteria for base or mid level engineering procedures, a combination of procedures may be used. For example, a permanent spur road has moderate grades and is located on moderate slopes. However, it crosses a fish-bearing stream. The stream crossing will be designed using upper level engineering procedures, while the remainder of the road can be designed using mid-level engineering procedures.

Road Design Standards

Roads on state-owned forest land will be designed to meet the planned use of the road. The design will limit the alteration of natural slopes and drainage patterns to that which will safely accommodate the anticipated use of the road, protect water quality and aquatic habitat, and maintain site productivity. The standard of road will be consistent with good safety practices, while keeping construction and maintenance costs to a minimum.

When determining the road design standard, the following factors will be evaluated:

- The volume of traffic that will use the road at any given period of time and that will be expected to use the road over its duration.
- The type of vehicles that will use the road.
- The topography and soils where the road will be located.
- Duration of use (permanent, temporary, seasonal, or year around).
- Public use(s) of the road.
- Sensitive natural resources that may be affected by the road.
- Future road maintenance requirements.

Design Standards for Spurs

Description: These are generally roads that are used for a short term, intermittently and/or have a low traffic volume. Use may be heavy during periods of log hauling but minimal at other times.

Design standards:

Subgrade	12 to 16 feet wide, may have a 2 foot ditch
Running Surface	12 feet wide
Drainage	out-sloped, in-sloped, or crowned with ditch, dips, waterbars, may have temporary stream crossings (removed after road use is completed)
Surfacing	optional (consider pit or jaw run)
Minimum curve radius	50 feet plus curve widening
*Grade limitations	up to 35%, roads over 20% will be closed after use

Design Standards for Collectors

Description: These are permanent roads that access multiple logging units and may receive moderate use by the public during portions of the year.

Design Standards:

Subgrade	16 to 20 feet wide including a 2 to 3 foot ditch
Running Surface	12-16 feet wide
Drainage	Normally crowned with ditch, relief culverts, and stream crossings.
Surfacing	Crushed rock
Minimum curve radius	60 feet plus curve widening
*Grade limitations	up to 20%, usually under 18%

Design Standards for Mainlines

Description: These are permanent roads with high traffic volumes, higher speeds, movement of heavy equipment and/or a high level of public use during portions of the year. They are useable by a lowboy truck, which is a key design vehicle. They may have high public and recreational usage during parts of the year.

Design Standards:

Subgrade	20 to 24 feet wide including 2 to 3 foot ditch
Running Surface	16-20 feet wide
Drainage	Crowned, with ditches, relief culverts, and stream crossings including bridges
Surfacing	pit run, jaw run or crushed rock for base and crushed rock for driving surface
Minimum curve radius	70 feet plus curve widening
*Grade limitations	up to 14%

**Grades over 20% require assist vehicles (OAR 437-80-065). Rock surfaced grades over 16% require special surfacing design to alleviate traction problems (consult geotechnical specialist or staff engineer).*

Road Design Criteria

A number of criteria must be considered in designing roads. These are discussed in the following paragraphs.

Coordinated Planning and Location of Roads

Forest management operations planning and planning for forest transportation are dependent on each other. These two plans must be coordinated to provide for an efficient and effective overall plan. Professional foresters, roads specialists and engineers with knowledge, skills and abilities in the access requirements for forest management operations and the design, construction, and maintenance of forest roads make these important decisions. Management activities will be planned to take advantage of existing road systems when appropriate. Environmental and economical evaluations of both planned management operations and planned road construction/improvement will be performed to achieve the optimum design combination for the two activities. Careful planning and location of roads will ensure that roads are located where potential impacts to natural resources such as water quality and aquatic habitat are minimized. The areas served by each road will be maximized where possible; thus minimizing the amount of road needed to meet management objectives.

Reconnaissance

Reconnaissance involves reviewing the area and then identifying and evaluating the best locations for roads, landings and logging settings. Aerial photos, maps, and local knowledge as well as walking the ground are used to determine the best locations for the road. This is the time to identify potential control points such as landing locations, ridgetops, stream crossings, benches and other locations that may be desirable locations for the road. Location/reconnaissance will include a route assessment of alternatives and ending location(s). Sensitive natural resources on or near these routes will be identified. These include all streams (with special recognition for Type F(ish) and Type D(omestic), wetlands, slopes over 50 percent (especially high landslide hazard locations), and wildlife sites. To avoid these resource areas, the road location will use grade and alignment changes up to the upper limits as defined in the road design standards. Where the sensitive natural resources cannot be avoided, minimize the length of road in these areas and direct the road away from them as quickly as possible. In addition, when it is necessary to cross these areas, the appropriate technical specialist(s) will be consulted (geotechnical specialist, wildlife/fish biologist, hydrologist, staff forest engineer, etc.).

Road Location

Road locations should minimize the risk of materials entering waters of the state and minimize disturbance to stream channels, lakes, wetlands and floodplains. Where viable alternatives exist, avoid locating roads on steep slopes, slide areas, or high landslide hazard locations, and in wetlands, riparian management areas, channels or floodplains. When possible, avoid locating roads parallel to and in close proximity to streams because they have a higher than normal potential to deliver sediments directly into the channel. Roads that are close to and parallel streams also displace part of the riparian management area. Stream crossings will be as close as possible to a right angle in order to enter and

exit the stream zone and the adjacent riparian management area as quickly as possible. Use variable grades and alignments to locate roads on the most suitable terrain.

Alternative road locations will be considered where natural resources are impacted. Locations will be favored that provide the best combination of meeting objectives and minimizing economic and environmental costs.

Make use of good, existing roads to reduce the duplication of road systems and associated ground disturbance. Where roads are present on an adjacent ownership and the roads will adequately serve the planned forest management operation, investigate options for using those roads before constructing new roads.

Road Prism Design

Roads will be no wider than necessary to accommodate the anticipated use. See the ranges listed in the road design standards.

Roads will be designed to be constructed with a balanced cut and fill cross section where possible and where this does not pose a risk of slope instability. Where a balanced cross section is not used, excess excavation material should be used in the road design, when possible, and not wasted. Designs will call for full bench construction and end-hauling of excess excavation material when roads are located on steep slopes, high landslide hazard locations and deep seated landslides

To prevent fill failures, road designs will provide for stable fills by using compaction, buttressing, subsurface drainage, rock facing or other effective means.

Road Drainage

Good road drainage is one of the most important features designed into a road. The prompt removal of water from the road prism will help avoid many problems related to road construction and maintenance. Water is a critical factor affecting:

- Subgrade load bearing capacity (poor subgrade strength results in potential rutting caused by traffic)
- Slope stability
- Stream sedimentation

It is inevitable that roads will intercept, interrupt and interact with natural water flow patterns. The management of this interaction between roads and water is critical to a successful road system. Establishing proper drainage of water from roads and passage of water through roads is one of the most important techniques to minimize adverse impacts on water quality and aquatic habitat.

Surface Drainage

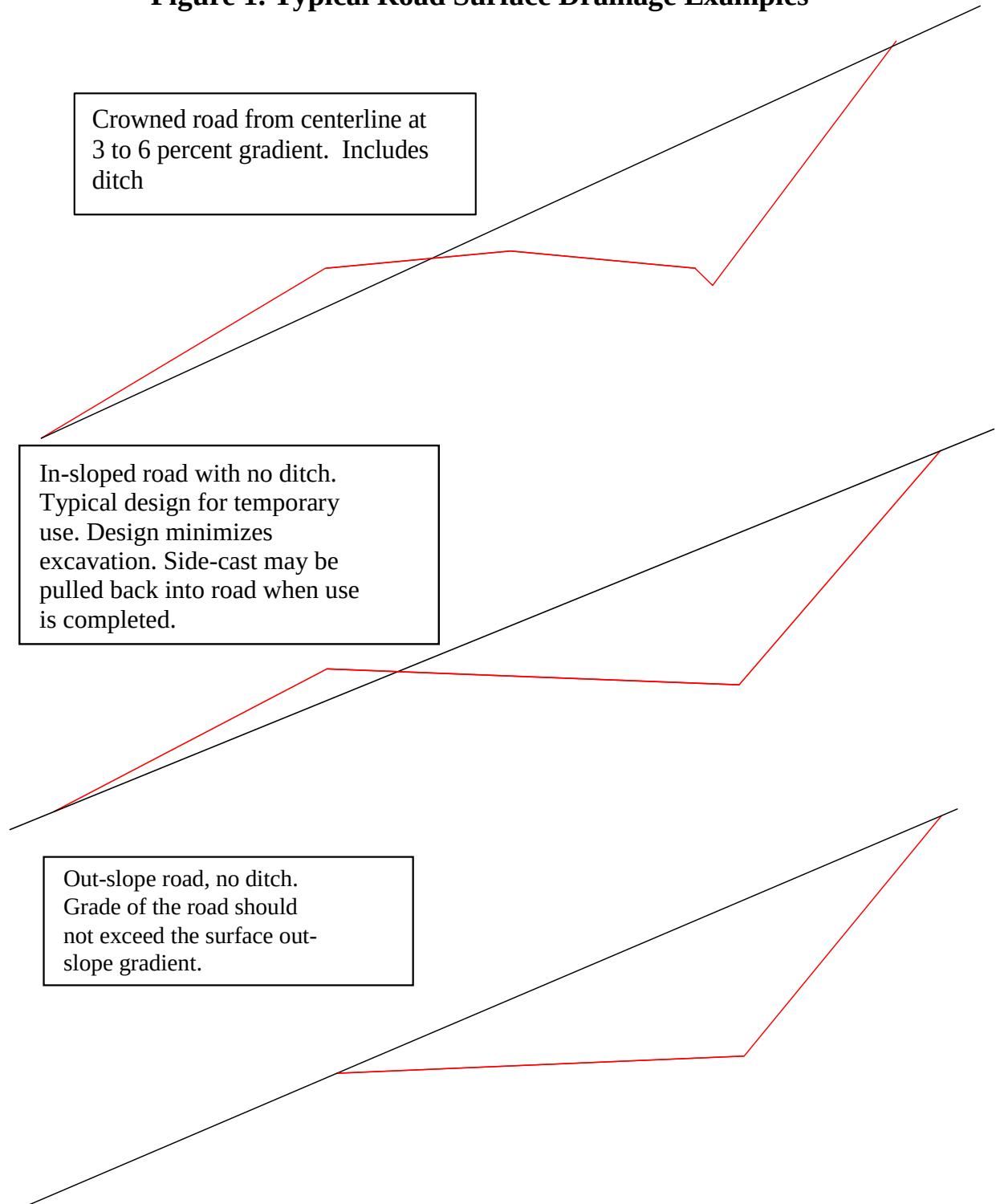
Good road surface drainage is important for keeping siltation to a minimum and to keep subgrades firm and stable to support the designed loads. Water intercepted by roads will be returned to natural flow processes as quickly as practical. Methods of achieving this are listed below.

1. **Subgrade shapes.** The running surface and subgrade must be shaped to move water off the road. Road surfaces will be crowned, in-sloped, or out-sloped for drainage. A “crowned road surface” is often preferred since it provides the shortest distance for

water to travel off the road (from centerline to either road edge). Out-sloped roads can save on excavation and material costs since there is no ditch or cross drain. Outsloping will generally be limited to roads with grades less than 8 percent unless they are temporary and will be closed or vacated after use. Water bars and water dips can also be used on temporary roads and spurs in lieu of a ditch. See "Figure 1. Typical Road Surface Drainage Examples" in this section.

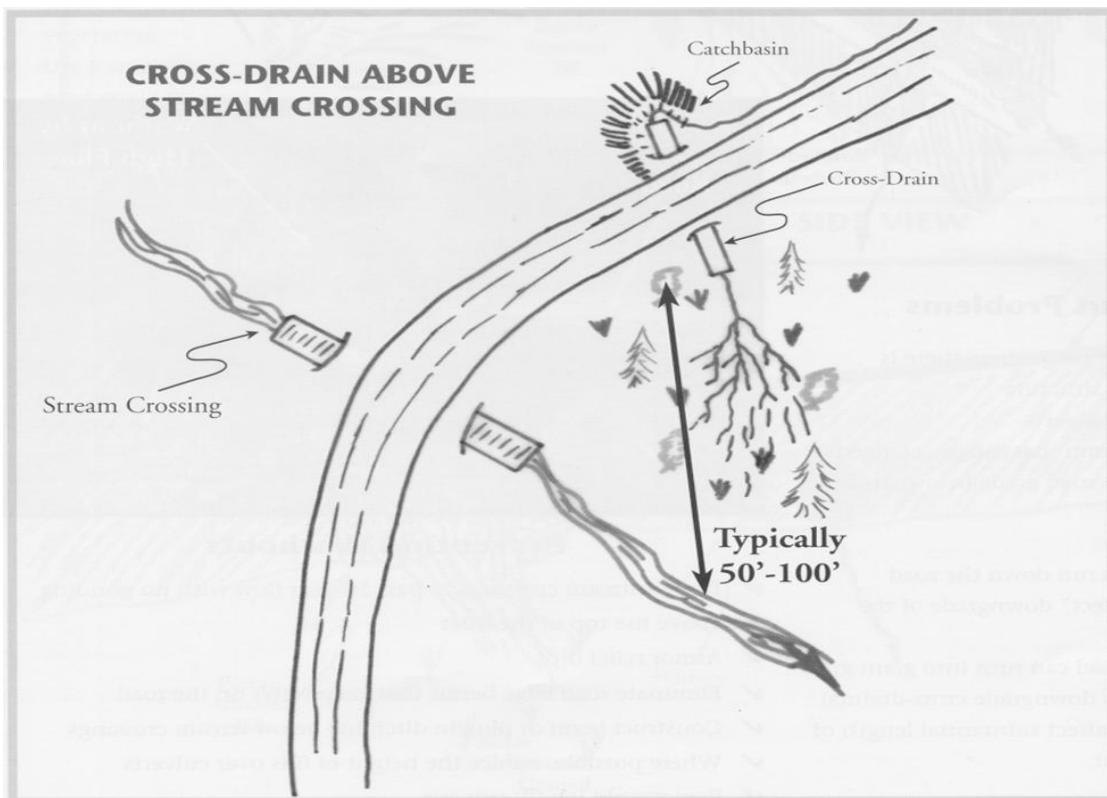
2. **Road Grades.** Road grades will be kept between 2% and 18% whenever possible. Flat grades will be avoided where possible; a minimum of 2% road grade will be favored to help to drain water out of the road prism. Steep grades above 15% should also be avoided. When steep grades are used, closer scrutiny of drainage for proper spacing of culverts, water bars, water dips, road grade reversals, and road surface maintenance is required.

Figure 1. Typical Road Surface Drainage Examples



3. **Drainage Structures.** A properly designed road will provide a drainage system using grade reversals, ditches, culverts, dips and/or water bars as necessary to effectively control and disperse surface water to minimize erosion of the road. Water will not be diverted from normal channels except as necessary to construct stream crossings. Drainage will be provided when roads cross or expose springs, seeps, or wet areas. Road drainage water should not be dispersed into headwalls, slide areas, or high landslide hazard locations.

Dips, water bars, or cross-drainage culverts should be located above and away from stream crossings so that road drainage water may be filtered before entering streams. Wherever possible, locate relief drainage 50 to 100 feet above stream crossings to eliminate the direct connection between road water and streams. The ditch-disconnect structure should be located in an area that will have at least 50 feet of filter distance to the stream.



Ditch relief culverts will be placed at appropriate distances and locations along roads to prevent large accumulations of water running down ditchlines and to prevent direct discharge of ditch water into streams. See "Table 1. Guide Table for Water Bar and Relief Culvert Spacing".

Table 1. Guide Table for Water Bar and Relief Culvert Spacing

Recommended Maximum Spacing in Feet of Lateral Drainage

ROAD GRADE in %	SOIL EROSION RATING*					
		High		Normal		Low
0-4%		800		1000		1500
5-9%		500		800		1000
10-14%		300		400		500
15-19%		200		300		400
over 19%		150		200		300

**High* = *Cohesionless fine-grained soil*

Normal = *Sandy loam*

Low = *Rocky /gravelly soil*

The table above will be used as a guide. The road designer should also examine other roads in the immediate area to find out how well ditches and existing culvert spacing are performing. If necessary, the spacing should be adjusted to fit the local conditions.

The smallest culvert used will be 18 inches in diameter. Culverts smaller than 18" plug easily and present maintenance problems. Smaller diameter culverts will only be used in temporary applications where the culvert will be removed at the end of the use of the road.

Culverts will be located away from high landslide hazard locations and deep seated landslides whenever possible, in order to disperse water on to stable locations (noses or ridges). When this is not possible, the geotechnical specialist will be consulted.

4. **Running surface.** The running surface of the road will be designed for the anticipated use. Rock surfacing can provide two important functions. First, a Layer of rock surfacing will help to spread vehicle tire loads over a larger area of the subgrade to help prevent rutting and subgrade failure. Secondly, a compacted layer of rock helps to seal the running surface, thus serving to move water away from the subgrade. Roads that will be open and used for hauling during wet weather will have rocked surfacing that will provide subgrade reinforcement and resist the erosive effects of water. Surfacing design is **found in Appendix 8** of this manual. There are a number of factors identified below that will influence the decision to use surfacing.

Advantages of rocking a road:

- Allows use of the road during wet periods
- Increases road subgrade strength, thus reducing the chance of wheel rutting during use.
- Provides a more stable, erosion resistant surface to the road, thus improving overall road drainage
- Provides base material (instead of dirt) that a grader can shape into a stable and longer lasting subgrade profile
- Reduces the amount of sedimentation produced by the road
- Reduces road maintenance needed to keep road performing properly
- Improves traction during wet weather
- All season access may increase the value of the area accessed for both commercial and non-commercial purposes. For example: reducing down time for wet weather could enhance the efficiency of a logging operation or a road could provide access for recreation throughout the year.

Disadvantages of rocking a road

- Cost, by far this is the single biggest factor - surfacing expense will often double the total cost of the road.
- May increase the cost to decommission the road in the future

Table 2 will be used as an aid in deciding when a road should be rocked and when it should not be rocked.

Table 2. Guidelines for Rocking a Road

Factors "for" rocking the road

Factors for "not" rocking

Road is in a coastal or valley climate	Road is in a dry climate such as Eastern or Southwest Oregon
Soil type is weak and poor draining, prone to erosion	Well drained gravelly soil
Grade of road is steep, any water will have potential to run down the road and erode the surface	Gentle road grade, less than 8%
Road is close to a stream and could deliver sediments easily	Road is not near streams and there are filtering opportunities for runoff from the road prior to entering a stream
	Road is located on a ridge or high on the hill slope and there is little risk of damage from sedimentation.
The road use is permanent and access is needed throughout the year.	This is a one time or one season road use that could be timed to occur during dry periods of the year
It is not practical or possible to close the road during un-needed periods	The road can be vacated or closed after short-term use.
Heavy use is planned for the road; several million board feet of timber will be hauled over the road.	Only a small amount of timber hauling anticipated on the road, part of one sale for example.
	Operations requiring this road could be shut down during wet periods and access to other parts of timber sale could be operated on at that time.
Rock is readily available and relatively inexpensive.	Rock is scarce, must be hauled long distances and is expensive to apply.
High use recreation area that would make it difficult to keep traffic off road during wet seasons.	Road can easily and effectively be blocked until weather permits use.

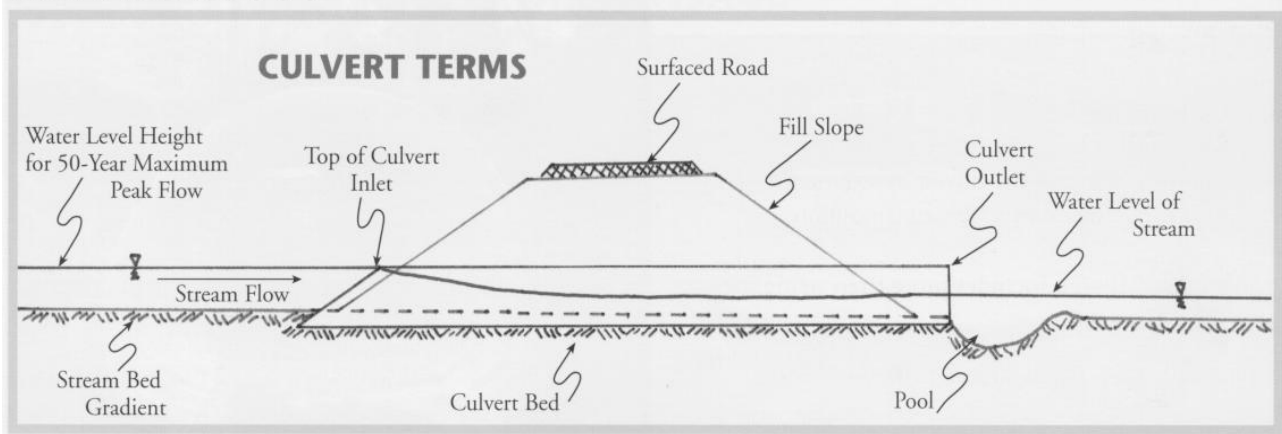
5. **Special Drainage.** Special drainage may be needed for areas containing springs or areas that have slope stability problems that are caused by subsurface water. The geotechnical specialist should be consulted for advice and assistance to design drainage structures that will help alleviate problems in these areas.

Design of Stream Crossing Structures

Stream crossing structures must protect aquatic and riparian habitats and provide fish passage, as well as preserve the stability and use of the road. The following requirements must be considered when designing stream crossings:

1. Streams will be kept in their natural channel and not diverted to crossing structures.
2. The number of acres in the drainage above the stream crossing structure will be determined from orthophotos, maps, aerial photography, or other comparable methods. This information is needed to determine the appropriate size for a stream crossing structure.
3. As a minimum, all new stream crossing installations or replacements of existing crossings will be sized to pass stream flow levels as predicted by the 50-year storm return interval. Oregon **Forest Practices Technical Note # 4** guidance provides a culvert-sizing design method that can be used for minimum design standards of stream crossings on state-owned forest lands.
4. Include design features that will minimize damage in the event the structure becomes plugged and fails. In many cases this is more effective than simply designing larger structures for larger storm events. Designed safety features may include some or all of the following:
 - Lowered fill heights to minimize back-watering effects and dam break floods.
 - Dips in the road, downgrade from the stream crossing, that would divert water off the road and onto the best available locations.
 - Armored fills at stream crossing and/or dip locations.
 - Overflow culverts
5. Road crossings over fish-bearing streams will be designed to allow fish passage. The design of stream crossings will follow the guidance in **Forest Practices Technical Notes 4 and 5**.
6. All permanent bridges will be designed and approved by a licensed civil engineer.

FISH PASSAGE . . .



Temporary Road Design by Purchasers of Timber Sale Contracts

At times the purchaser of Department timber sale contracts will request and/or the Department will require that the purchaser locate, design, and construct temporary roads to facilitate the logging of Department of Forestry timber sales. This approach enables the purchaser to match road and landing locations with the planned yarding system. When this approach is used, the location and design of the roads and landings will be approved by the Department as part of the Operations Plan required by the timber sale contract. Roads and landings designed under this approach will meet all of the goals and objectives of this section of the manual. Variances from the procedures, standards and criteria set forth in this section of the manual must be approved the Department.

Since these roads are temporary, consideration will be given to vacating the road at the completion of use. If the Department does not need the road for management purposes (i.e. site preparation, reforestation, animal damage control, vegetation management, etc.), the Operations Plan should include the requirement for the purchaser to prepare the road for vacation. (See Section 8 on Forest Road Vacating)

Road Design by Easement Holders

At times adjacent landowners will be granted easements to construct roads across state-owned forest land in order to access their property. When these easements are granted, the Department will approve the location and design of the roads on state-owned forest land. The design of the roads will meet all of the procedures, criteria, and standards included in this section of the manual.

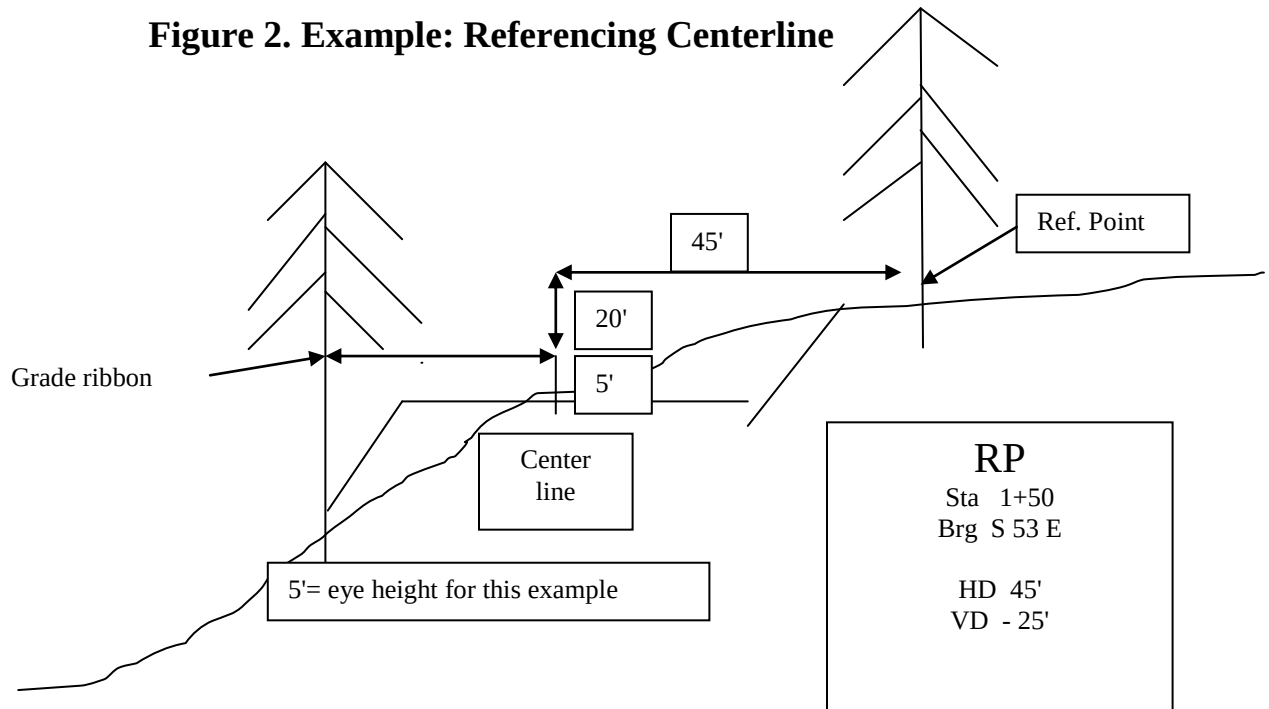
Road Construction

The design of a road construction or reconstruction/improvement project will include specifications that will minimize adverse impacts during the construction phase. Items to include are:

- Limiting construction activities to drier periods of the year, especially any activity involving exposed soil such as grubbing, excavation or grading.
- Curtailing activities on exposed soil during rain events, even when they occur during the dry season.
- Establish and maintain drainage throughout the construction phase.
- Take precautions to prevent siltation when rain is likely to occur. Precautions include hay bales, filter cloth, or other measures placed in ditch lines or other strategic locations to filter runoff water.
- When in-stream work is necessary, it should be accomplished during seasonal periods recommended by a fish biologist. A written plan is required by the Oregon Forest Practices Act and must be approved before working in a Type F (fish bearing) or Type D (domestic use) stream.
- Soils exposed by road construction or improvement that could enter streams will be seeded with grass or other vegetation to prevent erosion. These areas will be seeded at a time conducive to growing new grass and prior to the start of the wet season. Spring and fall periods are generally preferred for grass seeding.

Referencing Centerline Location Centerlines on new roads and road improvement projects are referenced so that the centerlines may be located at any time during or after construction. The number of reference points needed will vary and should be determined by the complexity and sensitivity of the project i.e. the more complex and/or the more sensitive the project, the more reference points that should be established.

Figure 2. Example: Referencing Centerline



A typical reference tag (4" aluminum tag) should have the following information or more if desired:

- Stationing.
- Bearing to centerline.
- Vertical and horizontal distance to centerline.

Reference spacing guidelines are:

- Slopes less than 50%: reference every 200 to 300 feet.
- Slopes greater than 50%: reference every 100 to 200 feet.
- Critical end haul areas: reference every 50 to 100 feet, or as needed.

The most common method of establishing road grade is to tie grade ribbons so that when your eyes are level with the ribbon your feet are on grade. In order to mark a reference tag you need to measure and calculate the following:

- Horizontal distance from tag to centerline.
- Vertical distance from tag to grade ribbon plus eye height.
- Bearing to centerline point and stationing.

The information on the reference tag will represent distances and bearings from the tag (not the ground) to the centerline of the designed road at the grade (ground) elevation.

Culvert Referencing

All culvert installations will be referenced with a 4" aluminum tag prior to the completion of road design work. The standard reference tag shall have the following information as a minimum:

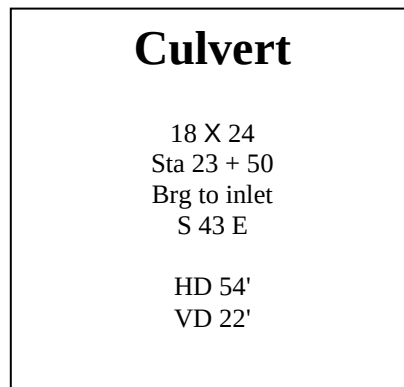
- Structure description, i.e., "culvert".
- Stationing.
- Size of culvert, i.e., "18 x 24'

Optional information:

- Attachments such as 1/2 rounds.
- Horizontal and vertical distance to culvert inlet, outlet.
- Bearing to either end of culvert
- Skew angle of culvert.

It is also a good idea to paint culvert information on the tree in case the tag falls off.

Figure 5. Example: Culvert Tag



Some surface drainage culvert locations are more apparent after the subgrade is constructed. The project administrator may relocate relief culverts in these instances.

Cut and Fill Slopes

The angle of the cut and fill slopes of a road can have a significant impact on the amount of ground taken up by the road and the stability of the hillside in the area around the road. The steeper the road slopes are, the less ground that is taken up by the road prism. The main problem with steep cut and fill slopes is that they can become unstable if they are constructed overly steep. The following table provides guidelines for cut and fills slope angles that will minimize slope instability and the foot print of the road on the hillside.

Table 3. Road Cut and Fill Slopes Angle Guidelines

Material	Compacted Fill Slope	Sidecast Fill Slope	Cut Slope
SOIL			
Silty sand No groundwater *High groundwater	1.5:1 2:1	2:1 3:1	.75:1 1.5:1
Soft clay, silts	Variable		
Sandy gravel No groundwater *High groundwater	1.5:1 1.75:1	1.5:1 1.5:1	.75:1 1.5:1
ROCK			
Solid – Fresh			** .25:1 to Vertical
Weathered – Stained			.25:1 to .75:1
Partially decomposed rock			.75:1 (with extra maintenance for ravel) 1.5:1 (slope with no ravel)
Cemented sands, silts, gravels			Vertical or .25:1

* May require special drainage, buttress, or other means of stabilization.

** With controlled blasting the back-slope will not shatter, and vertical slopes are usually the best design unless there is rock structure, bedding, jointing or fracturing which dips steeply out of the road cut. If this is the case, cut angle should be equal to the angle of the rock structure.

Contact the geotechnical specialist for "special problem rock slope design recommendations."

Landings and Turnouts

Landing size requirements vary with size and kind of equipment, log size, loader configuration (heel boom, front end, etc.), sorting situation, cold decking vs. hot decking, the possibility of skidding logs to a different loading area, yarding configuration, lead (square, straight, V), and other factors.

Landing size should be:

- Large enough to heel and swing logs without striking standing timber, rigging, or other equipment or objects. Operators will be directed to keep landings as small as possible. The maximum size should not exceed 1/5 acre.
- Long and level enough so that at least 2/3 of the longest bucked log to be yarded will rest on the ground. (Exception: this is not intended to restrict the yarding or loading of logs for poles piling, or an infrequent long break or tree length, provided the log is secured before unhooking the choker.)
- See figures 6 and 7 (this section) for landing size examples.

Figure 6. Example of Road Bed Used as Landing

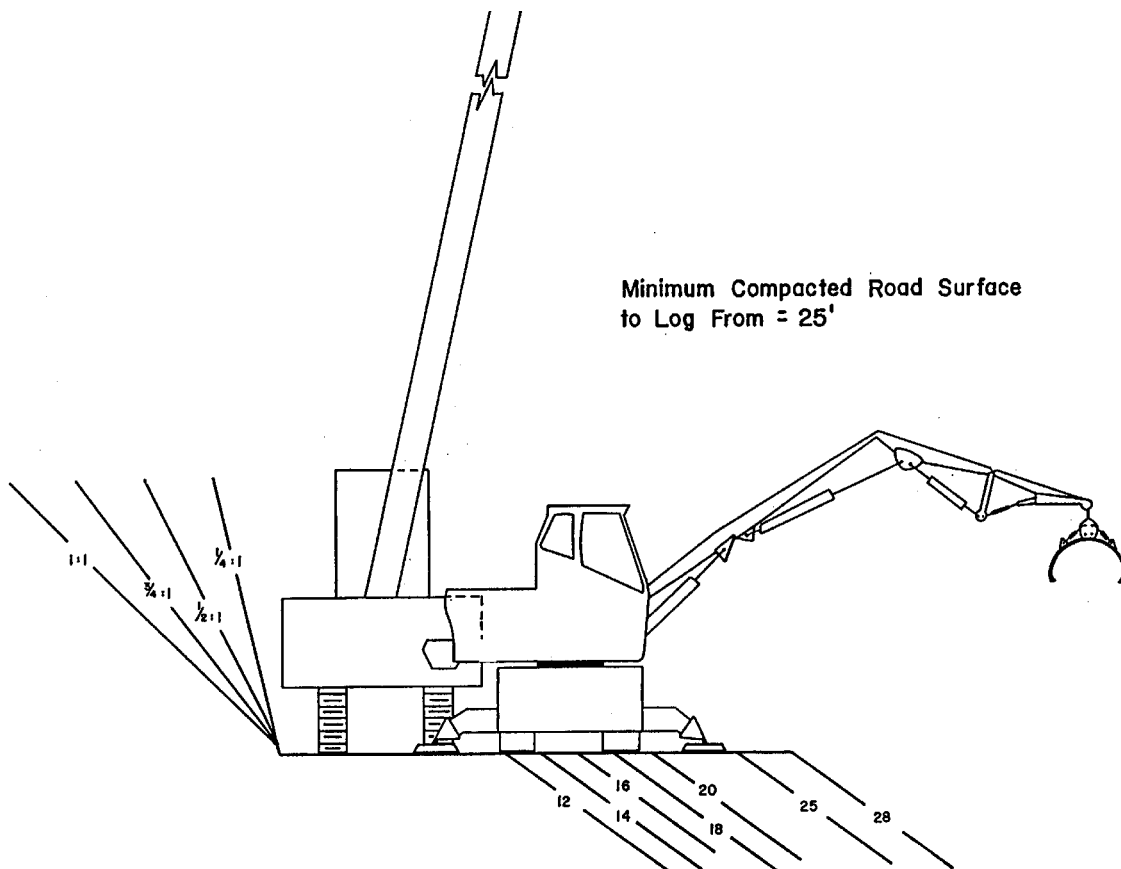
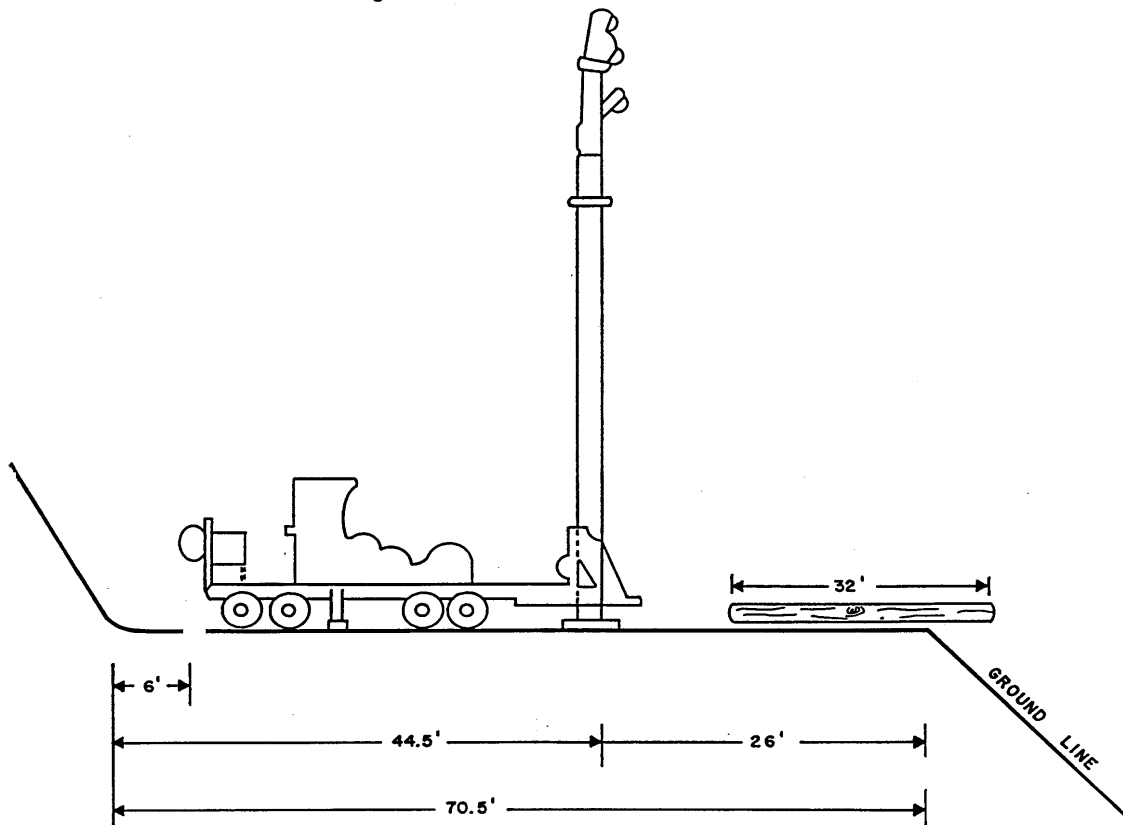


Figure 7. Example of Landing for Large Yarder

70.5 FT Wide Landing with Tower Set Up for Straight Lead.



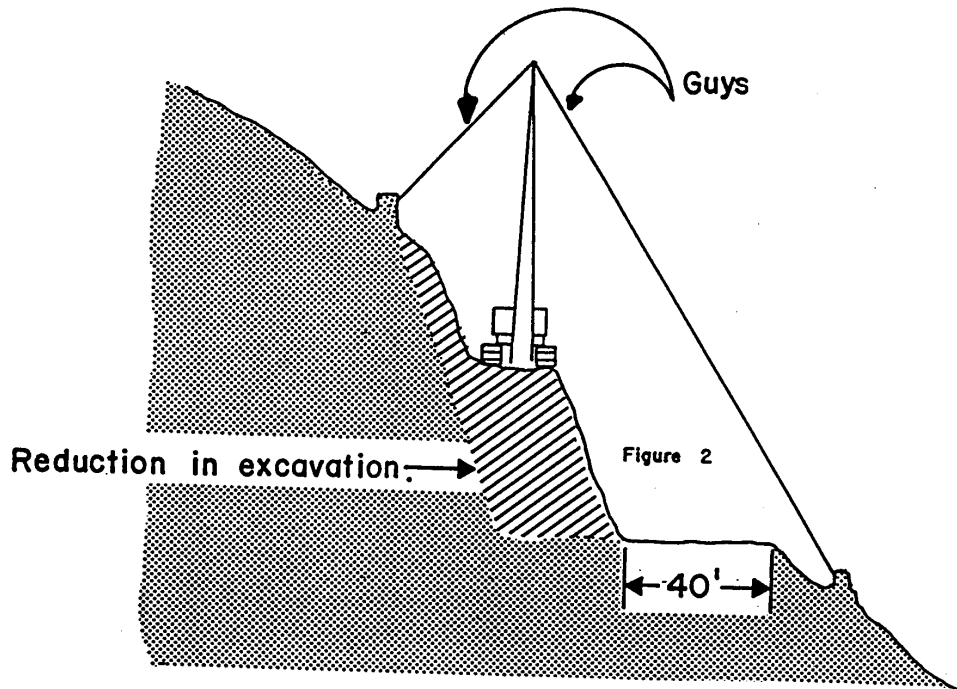
Landing construction should be:

- Reasonably level but with enough slope to provide drainage. Maximum slope should not exceed 8 %.

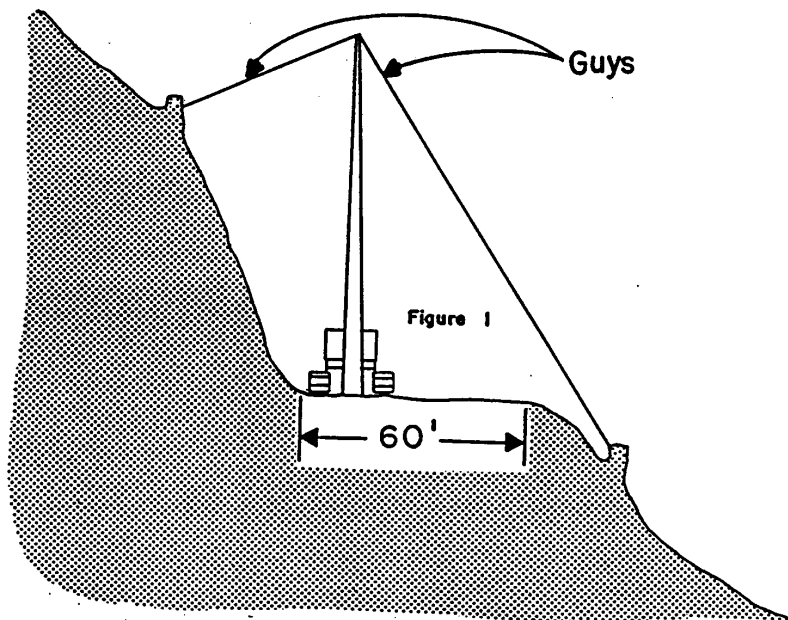
Usually an empty log truck ready for loading can start on about a 6 % grade, on a good crushed rock surface. If the truck has to maneuver on a steep grade, assistance may be needed.

- The slope in log chute areas can be up to 20 % if logs are decked perpendicular to slope. High decks will require flatter areas.
- Split-level construction can often save up to half the excavation required for a single level landing. See Figures 8 and 9 this section for example of split-level landing construction.

Figure 8. & Figure 9.



SPLIT LEVEL UPHILL SETUP



NORMAL UPHILL SETUP

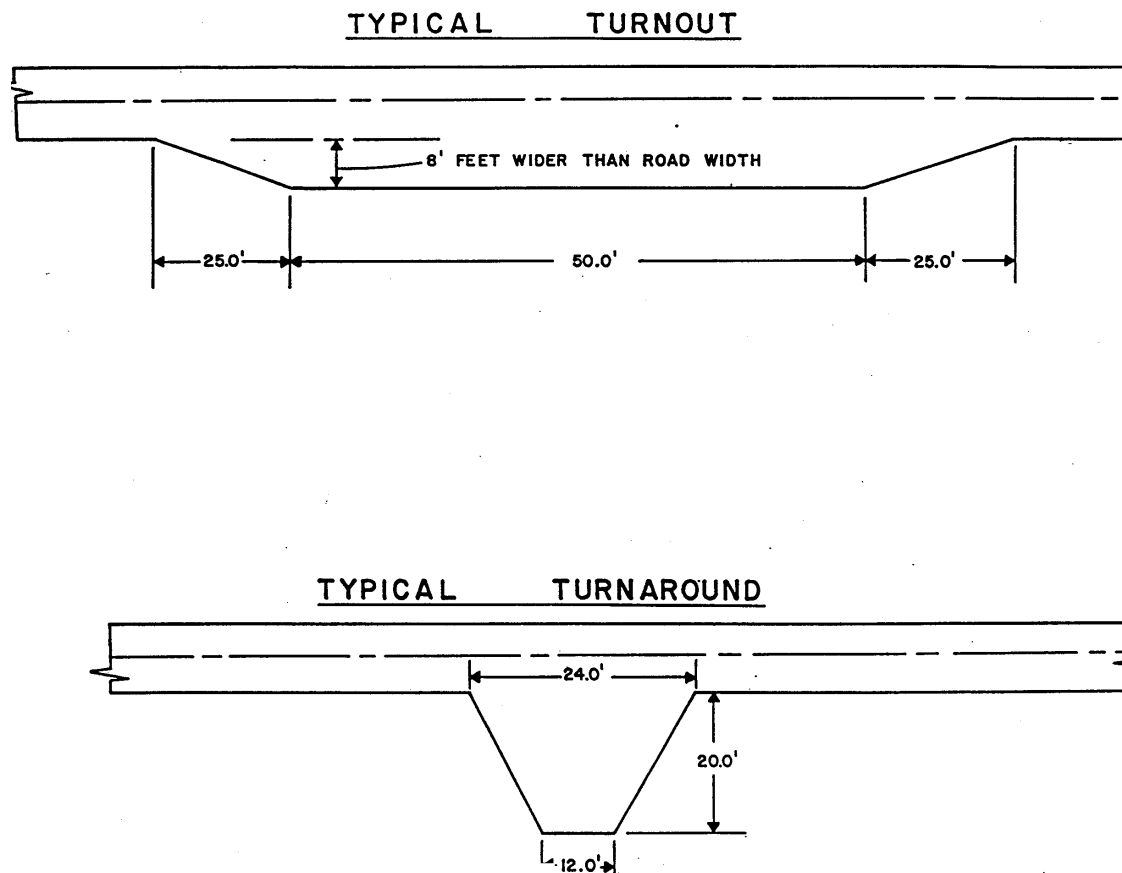
- Cut and fill construction can save excavation, but avoid landing fills on slopes over 50 % because of the likelihood for these fills to become overhangs of mixed dirt and slash during use. Such overhangs may slide out years after use, causing

soil and stream damage below. Consider end hauling the clearing and grubbing debris around landings where slopes are 50% or greater, due to the slope instability potential and safety hazard for the loggers working below the landing. Do not place landing fill on slopes over 65%.

Turnouts are to be intervisible with a maximum road distance of 750 feet between turnouts on mainline roads. Turnouts on shorter spur roads may be placed where the terrain allows. Since speeds are reduced on spur roads and most logging operations now use CBs it is not as important that turnouts be intervisible. They should be at least 8 feet in width and 50 feet long with a 25-foot transition at each end. (See Figure 10 for diagram of typical turnout and Figure 11 for diagram of typical turnaround)

Figure 10. & Figure 11.

LOGGING ROAD SPECIFICATIONS.



Curve Widening

The rear wheels of most vehicles will not track in the same path as the front wheels when traveling around a curve. This is called off-tracking. Extra subgrade and surfacing width may be necessary on the inside of the curve to accommodate the off tracking of the rear wheels. The amount of curve widening needed depends on the type of vehicle, the original subgrade width, the radius of the curve, and the central angle of the curve.

There are three critical types of vehicles that travel forest roads that may be impacted by curve width: the log truck, the logging yarder (on wheels), and the lowboy truck and trailer. The standard log truck tracks the best of these three, due to the configuration of the truck utilizing a stinger as the attachment point for the trailer. The logging yarder does not track as well as a log truck, due to its longer wheelbase. Finally, the lowboy truck will not track as well as the yarder, due to the long wheelbase of the truck and the longer wheelbase of the trailer. The trailer-mounted yarder pulled by a truck will usually off-track somewhere between the lowboy and self-propelled yarder. Sometimes yarders can be moved around corners with crawler tractors or other assist vehicles, which could improve their tracking ability on a temporary basis.

Since roads on state-owned forest land are designed as logging roads and not highways, not every factor will be evaluated in calculating extra curve width. The rule of thumb below, while not exact, will provide adequate curve width for the following vehicles.

Log Trucks and Yarders

Rule of Thumb: 400 divided by the radius = additional curve width

For a narrow subgrade (under 16 ft.), additional widening may be necessary, since the margin of safety or error for off-tracking on a narrow road would be less than on a wider subgrade. The amount of subgrade width less than 16' will be added on to the curve-widening formula as shown below.

Rule of Thumb: $(400 \div \text{Radius}) + (16' - \text{subgrade width}) = \text{additional curve width}$

Lowboy Truck and Trailer

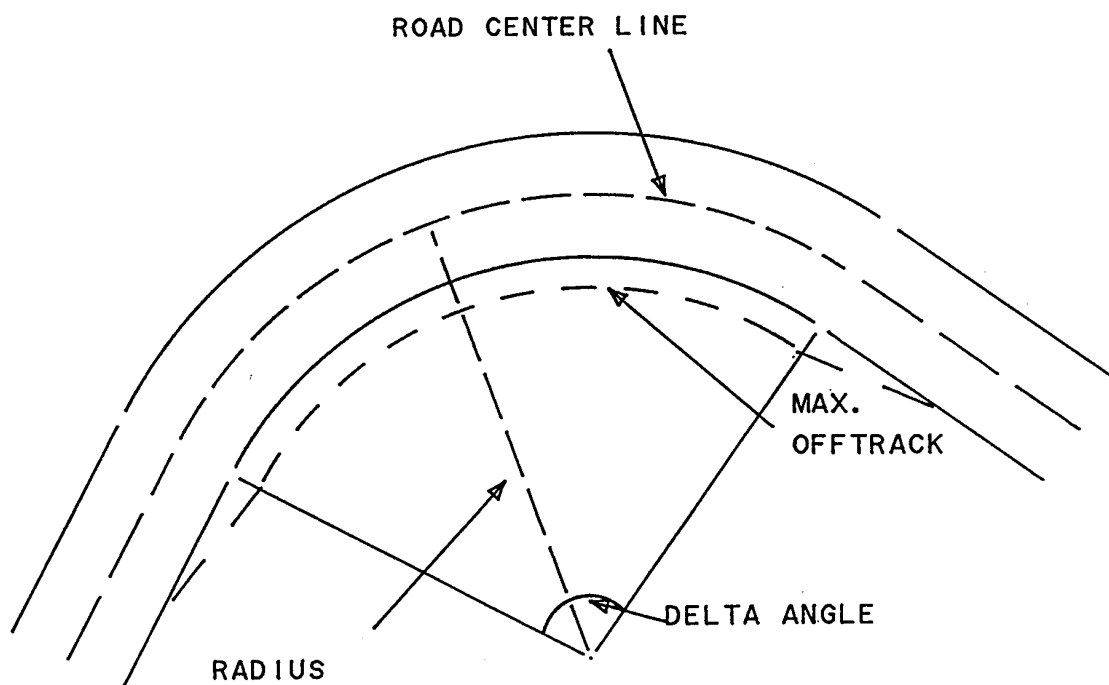
See Appendix 2 for Maximum Vehicle Off-Tracking for lowboy trailer (36'). The amount of off-tracking equals the amount of curve widening needed.

Good judgement and engineering skills must be used to design roads when vehicles with long overhangs will be traveling around curves. A vehicle such as a yarder with the tower down and traveling around a curve may have clearance problems with the cut-slope on the outside of the curve. This is particularly problematic for narrow roads with vertical cut-banks in solid rock.

Note: curve widening is normally added to the inside of the curve. If curve widening is to be put on the outside of the curve, the radius of the curve is effectively changed and the amount of road width needed for that radius curve will be calculated.

Figure 12.

MAXIMUM VEHICLE OFF TRACKING ON SIMPLE CURVES



Maximum Vehicle Off-tracking on Simple Curves

Maximum Vehicle Off tracking

On Simple Curves

Vehicle: 36 ft. Lowboy Trailer

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
50	10	2
50	20	4
50	30	5
50	40	7
50	60	9
50	80	11
50	120	13
50	180	14

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
60	10	2
60	20	4
60	30	5
60	40	7
60	60	8
60	80	10
60	120	11
60	180	12

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
70	10	2
70	20	4
70	30	5
70	40	6
70	60	8
70	80	9
70	120	10
70	180	10

Maximum Vehicle Offtracking

On Simple Curves

Vehicle: 21 ft. BU-199 Yarder (self propelled)

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
50	10	1
50	20	2
50	30	3
50	50	4
50	90	4
50	180	5

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
60	10	1
60	20	2
60	40	3
60	70	4
60	180	4

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
70	10	1
70	20	2
70	40	3
70	180	3

Forest Road Construction

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Introduction

During the construction phase of a road project, the planning and design decisions that were made earlier are carried out on the ground to achieve the desired road standard in a way that is efficient and effective and results in minimal impact to the environment. Each phase of road construction will be conducted according to the formulated plans, unless exceptions are approved by the appropriate supervisor. Poor execution of plans, no matter how well designed, can result in a poorly constructed road that may have a serious impact on the environment. Untrained project administrators or unskilled operators most often are the cause for poor execution of plans. Thus, the skill and experience of administrators and equipment operators selected to complete the road project will play a key part in determining its success.

Plans and designs may need to be modified during construction as changing conditions are encountered in the field. Experienced administrators and equipment operators can accomplish minor changes in the proposed work in the field. However, substantial changes in road design will be made only by qualified personnel and through the proper procedures and approval processes for contract modifications.

Goals of Road Construction

1. Construct roads that will become an efficient and effective part of the overall transportation system by constructing them according to the plans and design specifications and using the best management practices for road construction.
2. Protect water quality, aquatic habitat and other natural resources.

Objectives of Road Construction

1. Construct roads according to design.
2. Minimize soil disturbance during road construction.
3. Minimize impacts to water quality during construction.
4. Minimize impacts to aquatic and terrestrial wildlife habitats.
5. Make on-the-ground decisions and/or changes to the road design specifications that react to unforeseen conditions during road construction in a manner that will achieve the goals of the project. Professional level expertise and input will be utilized in the formation of the decisions and/or changes.

Road Construction Strategies

Road construction strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

Timing

While planning, design and field reconnaissance work can be conducted at any time of year, the timing of each phase of road construction is critical to completing a successful project. Roads must be constructed during the time of year when the best results can be achieved with the least damage to the environment. For example, scheduling road construction on steep slopes during the drier months can be an effective erosion control measure.

The best time for conducting each of the road-building activities (clearing, grubbing, excavation and grading, compaction, stream crossing installation and surfacing) varies.

Some clearing (cutting and removal of trees and brush from the right-of-way) can be performed during wetter weather. However, it must be conducted in a manner that does not result in large amounts of bare soil being exposed to surface erosion and/or the soil is not subjected to rutting, puddling or other damage. The clearing of shrubs, low vegetation and organic material from the soil surface should be delayed until the threat of erosion from the disturbed areas is minimal.

Grubbing (the removal stumps and protruding objects) will result in significant exposure of the soil surface and should be performed only when the threat of erosion from the disturbed areas is minimal.

Grading (the excavation and creation of the road bench) creates large expanses of bare soil, and should therefore be performed only during dry spring, summer or early fall conditions.

Soils require an optimum moisture content to achieve the proper compaction of fill materials used in stream crossings, landings, and along cut-and-fill road benches. Rocky, coarse-textured soils may be compacted under a relatively wide range of moisture content. On the other hand, fine textured soils that are overly dry or very wet often cannot be compacted enough to produce the soil strength needed to support loaded trucks or to remain stable on steep slopes. If the soils are too wet, they should be allowed to dry, and if they are too dry, they should be watered to achieve adequate compaction. An experienced engineer or geotechnical specialist can recognize improper soil moisture conditions by using simple field tests. They should be consulted whenever soil moisture conditions are in question.

The timing of a stream crossing installation is critical to maintaining and protecting water quality. Timing is also important to fisheries in many watersheds. Work should be performed as quickly as possible during the dry period of summer, when streamflows are at a minimum (or the channel has dried up) and there will be minimal soil disturbance and risk of sedimentation. An ODFW Fish Biologist will be consulted for the proper time to construct stream crossings across fish bearing streams.

All road construction activities, including the installation of stream crossings and erosion control work, will be scheduled for completion before the onset of the rainy period, which is usually around the middle of October. Final grading and proper installation of road drainage structures are critical to keeping erosion from the new road to a minimum during the first winter. Likewise, all temporary stream crossings must be removed, and all erosion control measures installed before the winter begins.

The Oregon Forest Practices Act's rules and guidance, Department of Forestry biologists and Geotechnical Specialists, Oregon Department of Fish and Wildlife (ODFW) biologists, or other sources will be consulted for timing guidelines related to road construction, particularly as they pertain to streams, threatened and endangered wild life species, or other sensitive resources. These guidelines will be used wherever they are applicable.

Clearing and Grubbing

One of the first steps in forest road construction is clearing and grubbing. The method of disposal of clearing debris is important to the future stability of the road. The clearing debris must be removed from the area of the road prism to eliminate the bridging effect that occurs when dirt is deposited against the debris. This also eliminates a safety hazard to anyone working below the road.

The clearing and grubbing method used will be consistent with good safety and environmental practices while keeping construction costs to a minimum.

Depending upon the design standard that was used, the road centerline and/or the cut and fill staking should be marked on the ground prior to clearing.

The upslope and downslope boundaries of the right-of-way should be marked prior to clearing and grubbing. The boundaries will provide the minimum width needed to construct the desired road. This will help prevent over-clearing or under-clearing. The lower boundary will be located at the base of the fillslope. The upper boundary will be located at the top of the cut slope plus enough distance to assure that the root systems of remaining trees will not be damaged by the excavation of the road prism.

Clearing. Trees and other large vegetation within the right-of-way boundaries should be felled and bucked. In addition hazardous snags and unsafe trees adjacent to the right-of-way should also be felled at this time.

Merchantable logs should be yarded to decking areas that will not interfere with the construction of the road or turnouts. Unmerchantable material should be disposed of according to the design specifications and follow the guidance listed later in this section.

Grubbing. During grubbing of the surface, all stumps and protruding objects should be removed from within the road prism, and anywhere fill or sidecast material will be deposited. Stumps overhanging the top of cut banks should also be removed. Stumps and other large organic debris in the road fill should never be left in the road prism because the voids that form when the wood decomposes will affect the stability of the fill. All chunks, logs and slash over approximately 3 inches in diameter and 3 feet in length should be removed and disposed of outside of the road prism. Small amounts of miscellaneous fine slash and small limbs are usually not a problem if they are scattered throughout the road prism and not left in concentrations.

On slopes over 35 percent in gradient, the organic layer (duff) on the soil surface should be substantially disturbed or removed prior to fill placement or sidecasting. If substantial amounts of this material are left in place, the material can create a slip plane for fill or sidecast failure when it decomposes.

Options for Disposal of Clearing and Grubbing Debris

There are several options for disposing of clearing and grubbing debris. Oftentimes contract specifications or the road design will indicate the option that will be used. If an option is not specified, the one that is chosen should match the road design and the on-site conditions.

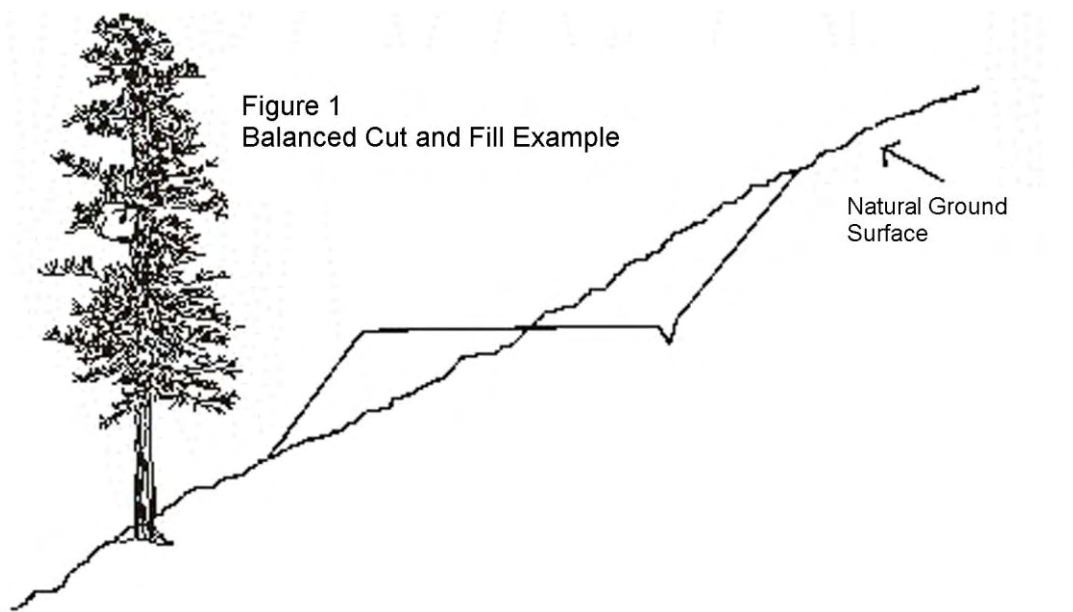
1. **Sidecast.** This is very common and usually the most economical technique used for forest road construction. Clearing debris is pushed outside of the road prism a minimum of 5 feet from the top and bottom of cut and fill slopes. It is very important that clearing debris not be incorporated into any sidecast or fill material supporting the road. Clearing debris that is sidecast on steep ground is difficult to control and can create a safety hazard for logging crews that may be working below the road at a later time. Stumps and logs could become dislodged and roll down the hill during the logging operation. Sidecasting will be limited to slopes less than 55%. Clearing debris should not be left lodged against standing trees.
2. **Scattering.** Debris is pushed or placed outside the right-of-way where natural openings in the stand exist, provided that:
 - a. Debris is not pushed against trees.
 - b. Tops and limbs are lopped to lie flat on the ground.
 - c. Excessive accumulations do not result.

Scattering should be limited to slopes less than 55% for safety and economic reasons. Scattering should also be limited to stands that are open enough to facilitate this technique (e.g., dense reproduction and very thick hemlock stands are not conducive to scattering.)

3. **Pile and Burn.** Right-of-way debris is piled in clean, burnable piles within portions of the right-of-way, or at locations approved by the project administrator and burned. The burning may take place prior to, during, or after subgrade construction, depending on the situation. Right-of-way debris should be burned so that there is no residual material greater than 3 inches in diameter and 3 feet in length. Material remaining after burning should be buried or scattered. Burning should be required when other options are not suitable, the clearing debris must be removed from the right-of-way and there are no waste areas for the debris available within a reasonable distance.
4. **End-haul.** Right-of-way debris is pulled, pushed and/or loaded and hauled to a designated waste area. End-hauling of clearing and grubbing debris should be considered where sideslopes are greater than 55%. It may be more economical to dispose of the limbs, tops and other small debris using another option such as chipping and only require the end-haul of the larger debris such as stumps and cull logs.
5. **Chipping and dispersal.** Right-of-way debris is fed through a chipper and chips are dispersed through openings in the trees in layers less than 36 inches thick. This method works well in thick-growing young trees (less than about 14" in diameter) where there is limited room for scattering debris and the average size of the clearing and grubbing debris is small enough to be chipped.

Balanced Cut and Fill (BCF) Construction

In BCF construction, the dozer starts at the top of the proposed cutslope, excavating and sidecasting material until the desired road grade and width is obtained. Material is pushed or "drifted" in front of the blade to areas where fill is needed. Road fill is used to cover culverts and build up flat or low areas along the alignment. Since fill must support traffic, it needs to be spread and compacted as much as is possible to develop sufficient strength. Unfortunately, this common method of BCF road construction does not always lend itself to standard compaction methods, where fill is placed and compacted in thin layers. Therefore, additional compaction should be required in areas where the stability of fills is important such as adjacent to streams and/or where required in the design specifications of the project.



In BCF construction, some of the waste material moves down the slope below the final roadbed and cannot be adequately compacted or contained. For this reason, BCF construction methods are not suitable on steep slopes (over 55%) or moderate slopes (40% - 55%) that are near streams where uncompacted material could become saturated during wet weather and move downslope.

During BCF construction, it is critical to avoid letting sidecast or waste material enter streams or placing it where it could erode and be delivered to a watercourse.

A good rule-of-thumb is not to sidecast on slopes of over 55%.

On moderate slopes (<45%) sidecast material should not exceed five feet in depth (measured vertical to the original slope). A more protective method of BCF construction is gaining popularity with many road builders. This method utilizes a hydraulic excavator, instead of a dozer, to pioneer the road bench. The excavator is able to cleanly remove slash, stumps and logs and place them at the base of the fillslope so they are not

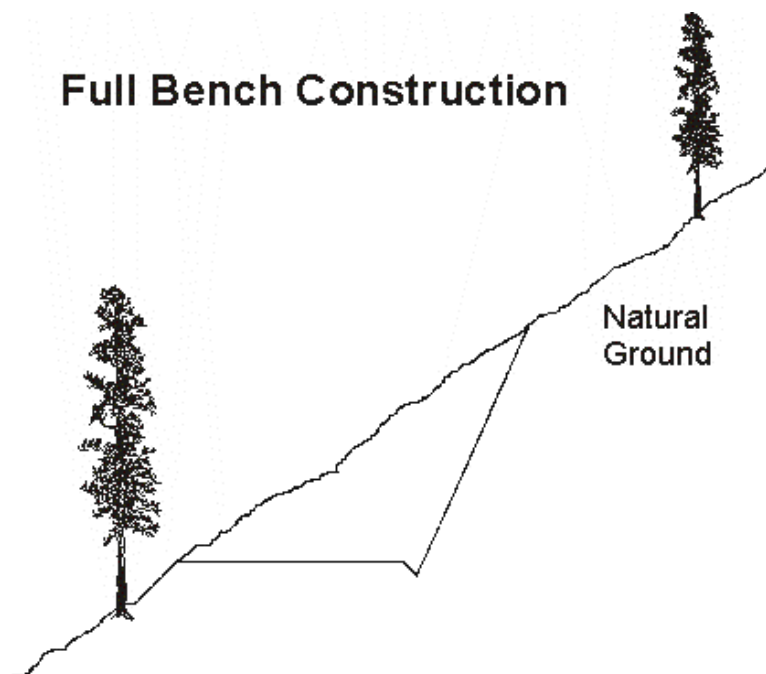
incorporated in the fill. It then grubs or cleans off the organic layer, excavates mineral soil and places it bucket by bucket, beginning at the base of the slope. The powerful hydraulic systems of large excavators permit them to partially compact the fill as it is placed. Waste material carefully placed using this method is more stable and less susceptible to failure than material that is pushed or sidecast by a dozer. Excavators can be used to place free draining fills on natural slopes as steep as 60 percent in some cases. Excavators can carefully set large angular rocks to make stable fill slopes in some cases as steep as 1:1.

Full Bench Construction

Full bench construction typically involves excavation of the roadbed using a hydraulic excavator. A bench is cut into the rock or soil equal to the width of the road plus the width of any ditch that may be required. Normally, no material is sidecast, and excavated waste is used to fill low areas or stream crossings along the road alignment. Usually, only a very minor amount can be safely drifted down the road and compacted on the road bench or feathered over the edge. The most efficient use of the excavated waste is to construct road fills such as in saddles, fills over culverts, or other BCF sections of the road. Excess material can be hauled off-site to a stable storage location.

Full bench road construction is typically reserved for slopes over 55%, or where a road approaches or parallels a stream channel that could be impacted by sidecasting excess material.

Figure 2.



Endhauling of waste material can be expensive, and full bench construction can cost four to seven times more than balanced cut and fill methods. However, full bench road construction on steep slopes without endhauling is very likely to result in sidecast material failing on many sites, with the resultant impacts to downslope stream channels.

Full bench roads often result in tall cut slopes. Several rock and soil types may not support these large cut slopes. Unstable rock, rock structure, including soft or highly fractured sedimentary rocks may not be suitable for full-bench cuts. Cut slopes in these areas can remove critical support at the toe of the natural slope and initiate upslope failure. Silt clays and other unstable earth materials may be unsuitable for tall cut slopes. Special design features must be considered when cut slopes exceed 20 feet in vertical height in these areas. It may not be feasible or possible to build the road where slopes are steep and the rock or soil material is weak. In these cases, alternative road locations should be considered.

Waste material should be endhailed and placed at a stable location. Rock pits, wide stable sections of roads, ridges, benches, and the inside edges of landings are typical locations where waste material can be stored. Sites judged to be of uncertain stability should be reviewed by a geotechnical specialist before they are used. Those sites where emerging ground water, thick organic layers, unstable geology, or other instability factors are present could experience slope failure after loading and should not be used.

In most situations, endhaul material is loaded directly into dump trucks by the excavator and hauled to the storage site, where it is spread in layers that can be reworked by a dozer. In some cases, dozers can economically carry (push) waste material to stable storage sites for distances up to 200 feet. The resulting waste pile at the storage site should generally conform to the local topography to provide for natural drainage, and should be mulched and planted with vegetation to control erosion.

Construction on Marginally Stable Slopes

Marginally stable slopes are areas where, because of steepness, geologic conditions and/or hydrologic conditions, improper road construction could cause landslides to occur. Construction in these areas should only be done after the road is carefully located and designed by qualified personnel, such as forest engineers and geotechnical specialists. The operator performing the construction should know and understand all of the design specifications prior to beginning any work.

Road construction on marginally stable slopes may require techniques as simple as full bench end-haul or as complex as a project requiring a large rock buttress keyed into bedrock. Each area will require a unique design that meets the conditions in that area. Therefore, it is beyond the scope of this manual to define all of the design and construction techniques for these areas. However, the following should be considered during the construction phase of these projects:

- Does the design show that slope stakes have been set in the field? If yes, have they been located?
- Does the design show that reference tags have been set in the field? If yes, have they been located?

- Does everyone responsible for the construction of the project have a copy of the design? If yes, does everyone understand the design?
- Does the design specify special equipment? If yes, is the equipment on the site?
- Does the design specify special materials? If yes, are the materials on the site or readily available?
- Does the design specify a certain time of year or other conditions (such as weather)? If yes, is the time of year appropriate and are the conditions being met?
- Does the design specify the use of unusual construction techniques or practices? If so, does everyone have the knowledge, skills, and abilities to perform the techniques or practices?

If the answer to any of the above questions is no, the construction should not proceed until the answer is yes, or there are justifiable reasons for the answer to be no.

The questions above are not a complete list. More could be asked, depending upon the project. The above list of questions is intended to illustrate and to emphasize the importance of constructing projects on marginally stable slopes according to design specifications.

Grading and Compaction

Most forest roads are built by excavating a roadbed out of naturally sloping ground. Grading is the process of excavating and/or filling the subgrade to final grade. Thus, grading is when the bulk of soil excavation and disturbance occurs. For a given road width, the steeper the ground the greater will be the volume of soil that is excavated or displaced during road construction. Road design and layout (flagging, staking and/or reference points on the ground, together with plans, maps and/or design specifications) show equipment operators the correct alignment and the proper cut slope angle and height to be developed along the new road. Operators may be asked to either construct roads using BCF construction methods on gentle terrain, to use cut-and-fill (with true compaction) on moderate slopes, or to employ full bench construction techniques on steep slopes or where the road is near stream channels.

The methods of compaction and where they are to be applied should be specified in the road design specifications. The importance of compacting excavated material cannot be over-emphasized. The specifications for compaction may be as simple as using loaded rock trucks or crawler tractors, or may require special equipment such as vibratory rollers, vibratory compactors, and grid rollers. Always consult the design for compaction methods and specifications.

Subgrade and Surfacing

Before surfacing the road:

The condition of the subgrade is critical to the performance of the road surfacing. The shape of the subgrade plays a central roll in providing road drainage. Do not rely on producing the surface shape (crowned, insloped or outsloped) of the road by shaping the rock surfacing alone. The ditch, if required, should be shaped and clear prior to applying surfacing. The subgrade should be at or near the optimum moisture content for compaction and then shaped and compacted prior to rocking.

During the rocking project:

Process the rock as specified by the contract. It will enhance performance of the road surfacing. Proper mixing, watering, shaping and compaction of the rock should be done to allow the surface rock to set up correctly.

There are several rocking accountability methods available to assure that operators comply with project requirements. Rock is a very valuable resource and accounting for the volume and quality of rock is important to make sure the State gets its value.

The "depth measurement" method works well when is it easy to verify the new surfacing from the existing road surface. Un-surfaced roads and roads that will be re-surfaced with a continuous new lift of rock are good candidates for depth measurement. Rock spikes driven into the surfacing or digging test holes in the surfacing and measuring depth can be utilized. Re-surfacing projects that are applying very thin rock lifts or spot-rock are not good candidates to be measured by depth, due to the varying road segment lengths and depths of rock of road being surfaced. An advantage of depth measurement is that it does not require that some one monitor the project 100% of the time. Depth measurement may be performed during and at completion of road rocking.

"Rock checking" works well for many types of rocking projects. Rock can be placed where needed only. Rock checkers can direct or monitor the rocking project. Rock checkers track the number of loads of rock and make sure trucks are full. The main drawback with this method is that it is labor intensive and rock checkers are not always available when they are needed.

"Rock Load Receipts" can work if rock is purchased from commercial sources and the other two methods are not suitable for accountability. The provider of the rock submits the number of loads of rock provided for the project. One disadvantage is that the state has little control over the volume of rock in each load.

Erosion Control

Soil erosion and stream sedimentation can occur during and following road construction. Some erosion is the result of poor road location and design, but some clearly occurs as a result of the road construction phase. Proper construction practices will reduce erosion and stream sedimentation. However, even when roads are properly located, designed and constructed, they will still need erosion control measures to minimize soil loss and sediment production.

Both mechanical and vegetative measures are needed to minimize erosion from roads and landings under construction. As mentioned in the design section; effective erosion

prevention is also achieved through proper road design and location, preplanning of cuts and fills, minimizing soil exposure, compacting fills, endhauling loose fill materials from steep slopes and streamside areas, developing stable cut and fillslopes, mulching to control surface erosion for the first year. Seeding and planting will provide for longer-term erosion prevention.

Perhaps the best tool for preventing erosion is to keep vegetation removal and soil disturbance to an absolute minimum during construction. Clearing and grubbing should be limited to the minimum needed to construct the road prism. Cuts and fills on gentle and moderate slopes should be balanced to minimize the amount of excavation and soil exposure.

Most construction activities should be conducted during the dry season. Even during the dry season, construction activities should be suspended if rainy weather is occurring. Soils that are saturated with water and would become muddy when disturbed should be allowed to drain before construction resumes.

All road drainage structures (ditches, outsloping, culverts, waterbars, dips, etc.) should be in place as soon as possible during the construction of the road. In any event they must be in place before the start of the rainy season. Surface water drainage must also be provided for sites associated with road construction such as waste areas, borrow areas and rock pits. All drainage water should be filtered through natural vegetation before it enters streams.

Construction of roads near running water may require silt fences, hay dams or other filtration methods in ditches and streams to prevent eroded material from getting into the water. These structures should be put in place as soon as possible during road construction.

Areas of bare soil, which could deliver sediment to waters of the state, should be mulched and/or seeded before the start of the rainy season. This includes unsurfaced road grades, cut slopes, fill slopes, waste areas, borrow areas, and rock pits.

When the road construction project is partially completed at the start of the rainy period (mid-October), the project should be left in a condition that will minimize erosion and the sedimentation of streams during the rainy period. Drainage measures should be performed on uncompleted subgrades such as smoothing the surface, outsloping, waterbarring, and installing dips. Mulching and/or grass seeding should be done on all cut and fill slopes that are completed and on any other areas of bare soil where erosion and sedimentation could affect water quality. Silt fences and/or hay dams should be used near streams to prevent sedimentation. The road should be barricaded to prevent unauthorized use.

Shallow failures or small slumps on the cut slope or fill slope should be repaired and stabilized. Where the material is blocking a ditch, it should be excavated and removed. Where fill slopes are indicating failure, the fill material may need to be excavated and end hauled to a waste area site. To prevent further failure or slumping of cut or fill slopes, rock buttressing or retaining walls may be needed. A geotechnical specialist or engineer should be consulted if these measures are needed.

Road Improvement

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Introduction

As used in this section, road improvement means the repair and/or upgrade of existing roads. Road improvement is distinguished from road maintenance by the nature and extent of the work. Road improvement includes changes to road alignment, subgrade widening, significant repair/upgrade of road surfacing, repair/replacement of stream crossings, repair/replacement of drainage structures, and repair/removal of unstable material. Road maintenance includes routine shaping of the road surface, cleaning and maintenance of drainage structures, spot treatment/repair of road surfaces, and vegetation control alongside roads.

Conditions commonly leading to a road improvement project:

- Road subgrades, alignments and/or surfacing need to be upgraded to meet current or future transportation needs.
- Fill slopes with old sidecast material are at risk of failure.
- Cut slopes show signs of failure
- Road fills are showing signs of failure
- Drainage structures are in need of repair, upgrading, or replacing.
- Stream crossings are in need of repair, upgrading, or replacing.
- Unsafe conditions in the transportation system must be repaired.
- Other unsatisfactory conditions are in need of repair.

Road improvement provides an opportunity to upgrade, improve, or repair a road that is substandard in one or more of its design elements. Improvements may include, but not be limited to, the following:

- Re-aligning the horizontal and/or vertical alignment of the road.
- Upgrading the size and/or number of culverts to current standards.
- Upgrading stream crossings to current fish passage standards.
- Installing additional cross drainage structures.
- Reshaping the roadbed and/or ditchline for improved surface drainage.
- Upgrading the road surface by adding new rock.

- Removing and/or stabilizing fill slopes that exhibit instability.
- Relocating sections of roads away from sensitive areas such as streams.
- Repair of washouts, fill or cut slope failures, and severe damage to road surfacing.

In general, stream crossings and unstable fill and cut slopes present the greatest challenge to road improvement, and the greatest opportunities for future erosion prevention and rehabilitation.

Goals of Road Improvement

The goals of road improvement are:

1. Upgrade existing roads to meet current and future needs, rather than construct new roads, where it is economically and environmentally feasible to do so.
2. Correct an existing unsatisfactory situation.
3. Update roads to current standards where necessary.
4. Prevent environmental damage.

Objectives of Road Improvement

1. Plan road improvement projects that will efficiently and effectively move the road system from the current condition toward the vision or desired condition.
2. Design road improvement projects that efficiently and effectively correct unsatisfactory conditions, upgrade the road system as needed, and prevent environmental damage.
3. Construct improvements according to design specifications.
4. Minimize soil disturbance during road improvement construction.
5. Minimize impacts to water quality, aquatic and wildlife habitats, and other natural resources during construction of road improvement projects.
6. Utilize professional level expertise and input in the formation of on-the-ground decisions and/or changes during the construction of road improvement projects.
7. Make on-the-ground decisions and/or changes to the road design specifications that react to unforeseen conditions during the construction of road improvement projects in a manner that will achieve the goals of the project. Professional level expertise and input will be utilized in the formation of the decisions and/or changes.

Road Improvement Strategies

Road improvement strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

All of the strategies listed in the sections on Transportation Planning, Road Design and Road Construction apply to Road Improvement as well. To avoid redundancy those strategies will not be listed in this section. However, there are some additional strategies that apply to Road Improvement, which will be listed in this section.

Road Improvement Planning

Road improvement planning will use all of the strategies listed in the section on Transportation Planning. A key strategy from that section is the inventory of the current condition of the road system. The inventory will include information on: road surface drainage; road surfacing condition; stream crossing structures; landslide risks; and areas of the road system that need upgrading to meet current and future needs. The **Forest Road Hazard Inventory Protocol** developed as part of the Oregon Coastal Salmon Recovery Initiative provides a system for gathering much of this information. As mentioned in the section on Transportation Planning, a more comprehensive road inventory system will be developed in the future. Until the new inventory system is in place, districts will need to gather supplemental information to efficiently and effectively plan for road improvement projects.

Information from the road inventory can be used to help identify priorities for road improvement projects. Conditions identified in the inventory that will be considered a priority for repair include:

Stream Crossings/Fish Passage

- Culvert outlet drops in fish bearing streams
- Non-embedded culvert with gradients above 0.5% slope
- Structures such as old log fills
- High washout potential due to an undersized structure and/or long steady grades below a stream crossing
- Scour, oversteepening or other erosion around culvert inlets and outlets
- Structural deterioration of culverts

Sidecast Failures/ Slope Stability

- Steep slopes
- Nearby slope failures
- High cut slopes—over 15 feet high
- Sidecast over two feet deep on steep slopes
- Fills supported by trees and/or organic debris
- Arc shaped cracks in the fill or other evidence of fill movement

Water Quality/Sediment Delivery

- Direct delivery of sediment in runoff water from roads to streams
- Ditch downcutting
- Increase in heavy traffic
- Inadequate depth and/or poor quality road surfacing
- Damaged, collapsing, and/or inadequate drainage structures

- Eroding soil on cut and fill slopes
- Buried culverts
- Fill erosion at culvert outlet

Current/Planned Uses of the Road

- Unsafe conditions are present—width, alignment, visibility, etc.
- Volume of traffic exceeds road design
- Road surfacing will not accommodate current/planned uses

A number of factors will affect the final ranking of road improvement projects. Included are factors such as the need and timing of the planned uses of the road; the costs and benefits of the project; the amount and type of environmental damage that is occurring or could occur; the likelihood that damage will occur and the risk of impacts to human life/safety or private property. Factors such as the availability of funds, equipment, and manpower and the time of the year will affect the scheduling of road improvement projects.

Road Improvement Design

The design of road improvement projects will use all of the strategies listed in the section on Forest Road Design. However, because of the nature of some road improvement projects additional engineering and design work may be needed before construction begins. For example, an engineered solution such as a reinforced fill or a crib wall may be needed to repair a road fill that has failed.

Some design criteria that will be considered for road improvement projects are:

- Roads will be surfaced to handle the wettest road conditions that are expected
- Use geotextiles under the surfacing where the subgrade is wet, soft, and cannot be effectively drained.
- Crossings on fish-bearing streams will meet the design criteria listed in the **Oregon Road/Stream Crossing Restoration Guide**. (See list of useful references)
- Install cross drainage above stream crossings to divert ditch water on to vegetated ground for filtering.
- Revegetate all disturbed cut and fill slopes.
- Install measures such as flumes, downspouts, or armoring on the outlets of cross drains where erosion of steep slopes is occurring.
- Install measures such as armored relief dips, trash racks, or oversized culverts to prevent the road from being washed out.
- Install additional cross drains where downcutting of the ditch is occurring.
- Pull back and endhaul unstable fill material. Pull back should remove all “perched” fill material, flatten upper slopes on “sliver fills,” and create a uniform slope that will drain well.

Figure 1.

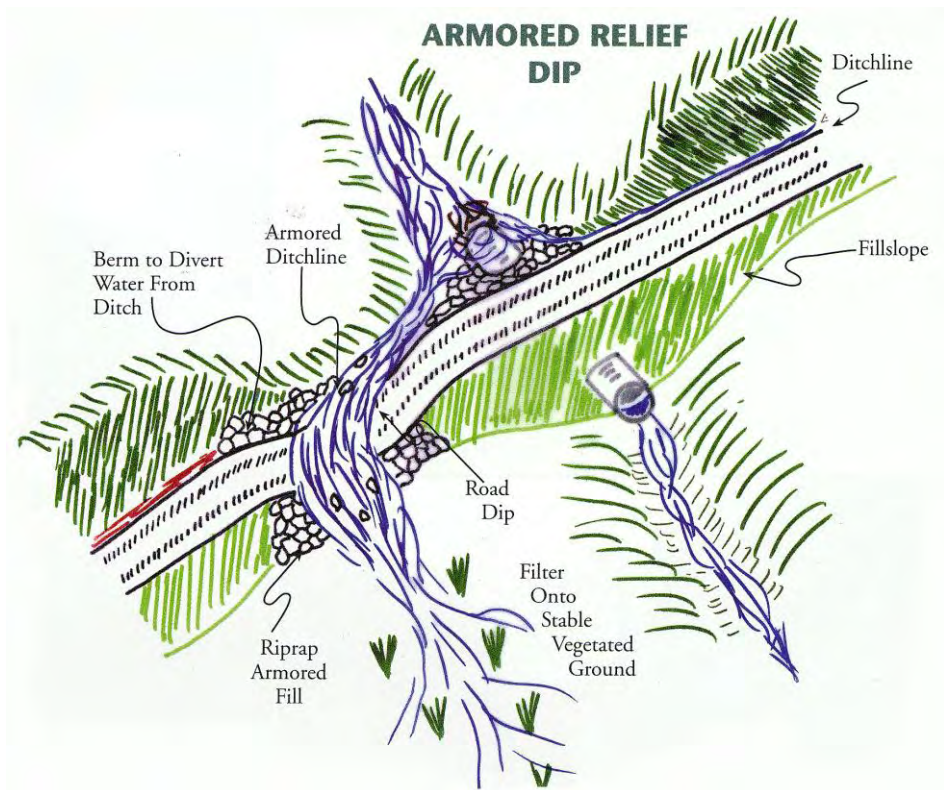


Figure 2.

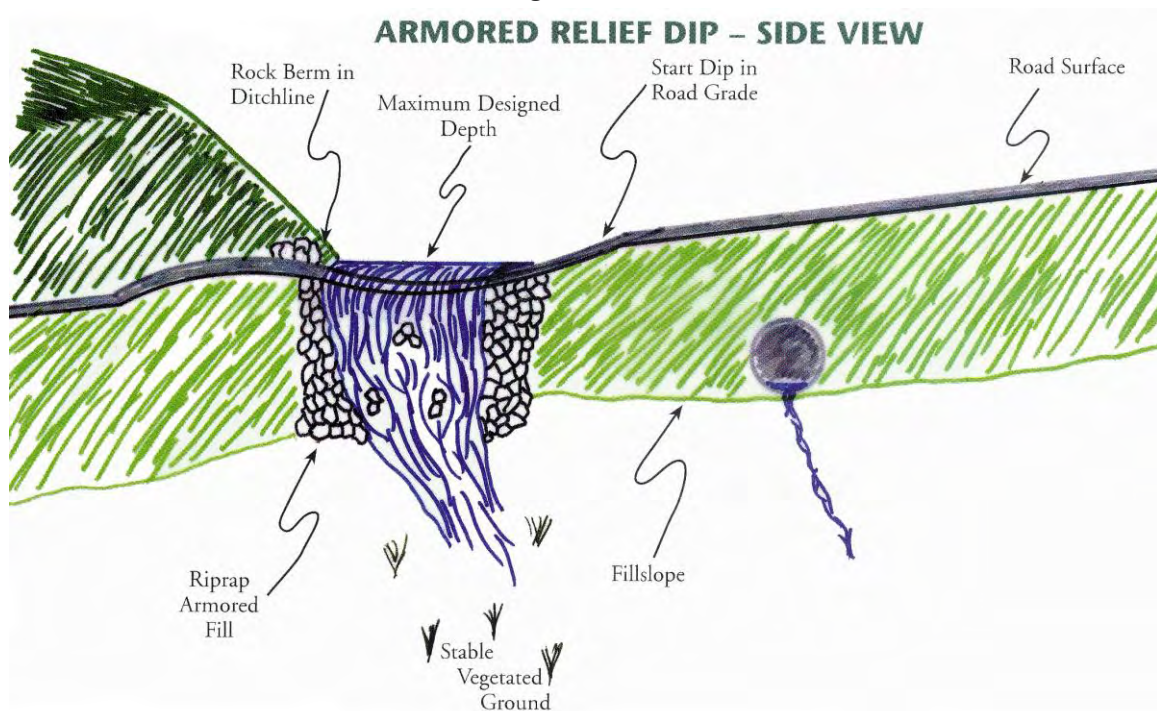
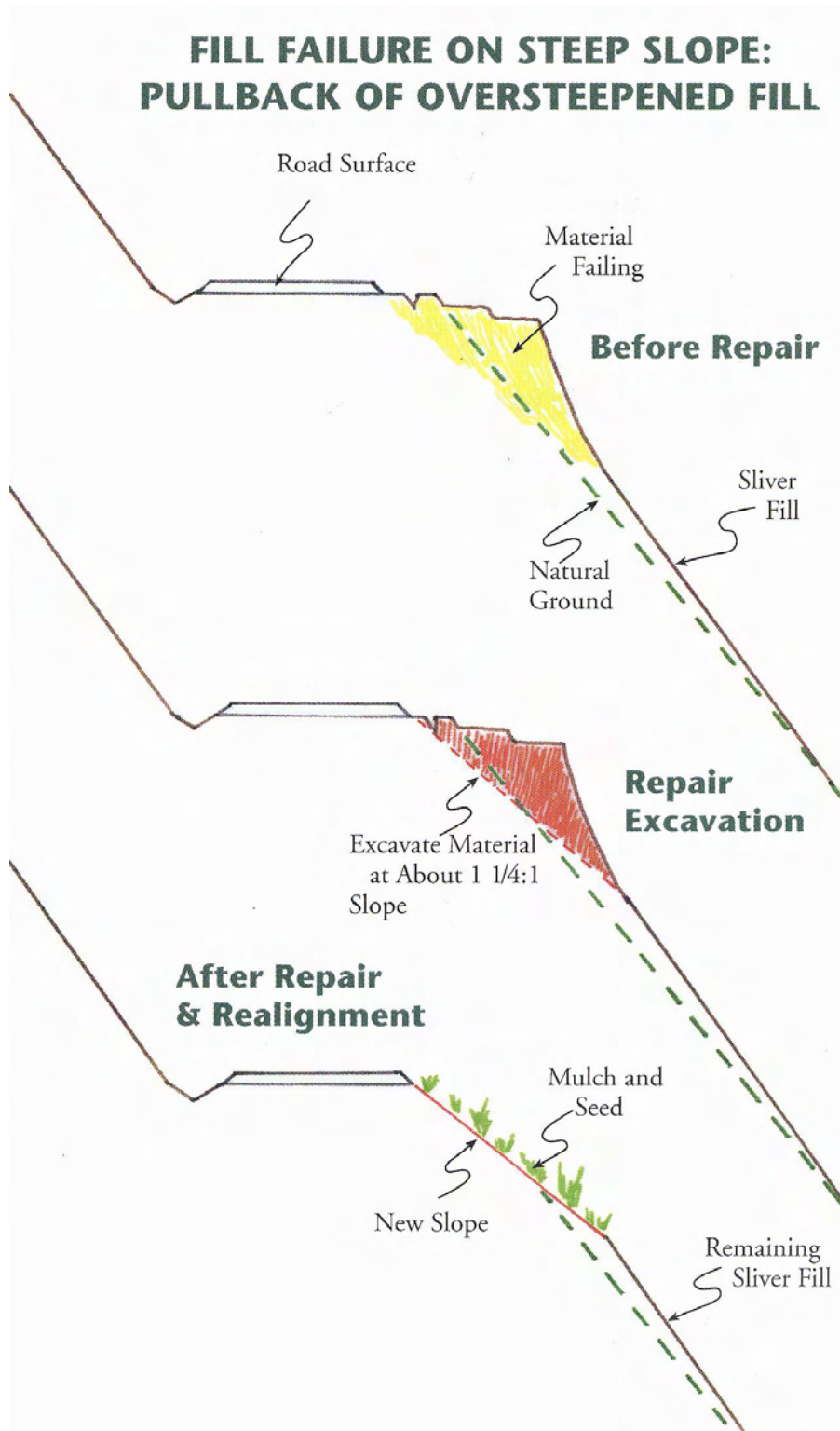


Figure 3.



It is not possible to identify and list all of the additional design criteria and standards for road improvement projects. Each project will be designed to meet the specific goals and objectives for that project. Where needed, additional expertise such as geotechnical specialists, hydrologists, biologists, and civil engineers will be used in the design of road improvement projects.

Construction of Road Improvement Projects

The construction of road improvement projects will use all of the strategies listed in the section on Road Construction. However, because of the unique designs used for some road improvement projects, additional strategies may be required. Some items to consider when constructing road improvement projects are:

- Additional compaction or special compaction techniques may be needed when repairing road fills that have failed.
- Buried organic material must be removed from the road subgrade before replacing or repairing old log fills or log culverts.
- Before replacing some culverts, removing the fill (and the associated old culvert) and allowing the stream to “self excavate” over a winter in order to find its natural channel is often the best solution where stream sediment has built up behind the fill.
- The use of specialized equipment may be required. The equipment will be used within its limitations and capabilities.

It is not possible to identify and list all of the additional construction criteria and standards for road improvement projects. Each project will be constructed to meet the specific design for that project. When it appears to be necessary to modify the project design and or the construction strategy, appropriate expertise such as geotechnical specialists, hydrologists, biologists, and civil engineers will be consulted regarding the proposed modifications.

Project Administration for Road Projects

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Introduction

Virtually all forest road construction and road improvement projects are performed under timber sale contracts, with a few being accomplished by general service contracts or by district road crews. Regardless of the approach that is used a project/contract administrator will be designated for each project.

The construction phase is when planning and design decisions are carried out on the ground. Well-designed projects and good execution of plans will result in well-constructed projects that will minimize impacts to the watershed and environment. Thus, the knowledge, skill and abilities of the project administrator will play a key role in accomplishing successful road construction projects.

Goals of Project Administration

The goals of contract administration are to:

1. Insure that construction/improvement projects are completed according to design/contract specifications.
2. Initiate appropriate changes in the design/contract specifications to accommodate unforeseen problems.

Objectives of Project Administration

The objectives of contract administration are to:

1. Establish good communication with contractors and operators.
2. Make inspections as frequently as needed to ensure contract compliance.
3. Issue clear written and verbal instructions in timely manner.
4. Answer operator's questions in a timely manner.
5. Utilize professional level expertise and input (geotechnical specialists, engineers, biologists, etc.) for sensitive and/or unique operations. The same level of expertise will be utilized when it is necessary to make changes to the design/contract specifications.

Project Administration Strategies

Project administration strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

KSA's for Project Administrators

Project administrators will have the following knowledge, skills, and abilities (KSA's) to successfully administer road construction/improvement projects:

- Knowledge and understanding of the project's design and/or contract specifications and the ability to efficiently and effectively administer them.
- Knowledge of Oregon Forest Laws, rules, policies and administrative procedures related to forest practices, fire protection and the management of state-owned forest land.
- Knowledge of basic engineering practices related to forest road construction/improvement and the ability to evaluate their application on the ground.
- Knowledge of basic geology, forest soils, and hydrology for the local area and the relationships between these factors and forest road operations.
- Knowledge of basic water quality management, aquatic biology and wildlife biology; and the impacts forest road operations might have on these factors; and knowledge of the appropriate measures for avoiding or lessening adverse impacts to these factors caused by forest road operations.
- Ability to give clear oral and written instructions.
- Ability to work effectively with operators, contractors, and other agencies.
- Ability to develop and maintain an effective record keeping system including reports, instructions, and records.
- Ability to recognize when corrective action is needed and to take appropriate measures to get the desired results.

Before Construction Begins

The supervisor responsible for the project will assign a project administrator with the appropriate KSA's, as listed above. The project administrator will review and understand all requirements of the project. Any unclear requirements will be reviewed with the supervisor and/or the designer of the project. The project administrator will be the State's designated field representative(s) and will be authorized to receive notices, inspect progress of the work, and issue instructions in regard to performance on the project.

A pre-operations meeting is required by all timber sale contracts to be held between the State (Department of Forestry) and Contractor, and an Operations Plan is required to be submitted and approved by State, prior to the contractor beginning any work. All designated representatives of the contractor and the State should attend this meeting. The purpose of the meeting is to explain the requirements of the contract and to answer any questions from the contractor. The contractor will be given copies of any special designs required by the contract. The project administrator will explain:

- Any threatened or endangered species concerns or requirements.
- Oregon Forest Practices Act requirements such as written plans.
- Timing of construction for projects.

- Specifications and requirements for all projects.

The pre-operations meeting is the ideal time for the project administrator to begin the important process of communication. The project administrator should be prepared to answer most questions at this meeting. Any questions not answered by the administrator at the meeting will be researched, and the answers provided to the contractor within a reasonable time.

The project administrator will thoroughly understand the operations plan and pre-operations meeting requirements of the contract.

Similar meetings will be conducted when road construction/improvement projects are completed through a service contract or by Department of Forestry personnel and equipment.

Responsibilities of Project Administrators During Construction

The project administrator should attempt to establish a good working relationship with the contractor early in the contract. In addition, the administrator will make every effort to ensure that the contractor and their representatives fully understand all of the contract requirements and will explain the reasons for the requirements and what will be expected of the contractor.

After the pre-operations meeting, the administrator will document the meeting with the use of the standard form letter developed for this purpose. The letter will summarize what was discussed at this meeting.

Administrators will make sure that other required written documents have been submitted and approved prior to the contractor beginning any work, such as Notifications of Operations, Written Plans required by the Forest Practices Act, and Rock Pit Development Plans.

Administrators will make field inspections as often as required to make sure that the contractor is complying with all specifications required by the contract, and to answer questions from the operator. This may be a minimum of two per week for normal road construction, or continuously during critical road construction projects. Whenever the administrator cannot be on site continuously during critical road construction projects, he/she will arrange for an on-site observer for the critical projects. Critical projects may include:

- Installation of fish passage culverts.
- Removal of existing road fills over 15 feet in height.
- Full bench road construction.
- Installation of road fills over 15 feet in height.
- Areas of critical alignment such as switchbacks.
- Installation of special structures such as retaining walls

Administrators are responsible for recognizing and initiating needed changes during construction that were unforeseen or unrecognizable in the design phase. Prior to initiating any changes to a contract, the administrator must first verify the need to make a

change. This may require review and input from a geotechnical specialist, engineer, and/or biologist. New design specifications will be developed for substantial changes. The administrator will review proposed changes with his/her supervisor prior to initiating any changes. Guidance on changes to a timber sale contract is well covered in the “Timber Sale Contract Administration Handbook” and these guidelines will be followed for any contract changes.

The contract administrator will keep a log of all inspections and telephone conversations with the contractor and/or their representatives.

Administrators will issue written and verbal instructions as necessary to direct the contractor to comply with all specifications and requirements of the contract and/or other written plans. These will be on standard forms when applicable, such as: Weekly Inspection Reports, Status Reports, Important Notice, and Work To Do letters.

Administrators will take immediate action anytime a contractor violates the Forest Practices Act, does not operate within the scope of the contract, or causes unnecessary environmental disturbance.

The approved operations plan becomes a part of the contract and the administrator should refer frequently to the operations plan to determine if the contractor is complying with the plan. If the contractor deviates from the original plan and fails to file a supplemental plan or begins work that is not covered by the plan, those portions of the operation not adequately covered by a plan will be halted until the appropriate plan is submitted.

Final Inspection and Approval

As required by the timber sale contract, the project administrator will inspect projects within 10 days after a written notification of completion has been received from the contractor. Work in this case must be an entire project or projects, and not a portion of a project. If, for some reason, the contract administrator cannot make an inspection within the 10-day period, the contractor will be notified in writing of this fact and given an estimate of when the inspection will be made.

After a final inspection has been made, the administrator will complete an inspection report and indicate whether the work was acceptable or not acceptable. If the work was acceptable, the administrator will also submit a status report to the division office indicating the work that has been accepted.

If the work is not fully acceptable, the administrator will issue an inspection report specifying the work that is acceptable, and what work is not acceptable. For work that is not acceptable, clear instructions must be given to the contractor that describe what will be required to make the project(s) acceptable.

The administrator cannot approve a project until all portions of the project are completed according to the contract. The State’s ability to collect costs for uncompleted project work may be forfeited if final approval is given prior to the total completion of a project.

Forest Road Maintenance

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Introduction

The Oregon Department of Forestry has made a significant investment to develop and improve the road system on state-owned forest land. The road system provides access to the forest for a full range of activities, including timber management, fire protection, recreational use, and many others.

There are a number of reasons to maintain the road system on state-owned forest lands and to keep it in good condition. The first is that properly maintained roads will have a minimum impact on natural resources. The commitment to good stewardship will be a driving force for any road maintenance program. Secondly, a good road maintenance program will ensure that the roads are available for their intended use. The third reason is to protect the investment that has been made in the development and improvement of

the road system on state-owned forest land. Finally, the Oregon Forest Practices Act establishes a regulatory obligation to maintain forest roads.

Goals of Forest Road Maintenance

The goals of road maintenance are to:

1. Minimize the adverse impacts to water quality, fish habitat, wildlife habitat and other natural resources that may be caused by the presence of the road system on state-owned forest land.
2. Ensure continued access to state-owned forest lands for the planned uses.
3. Protect the State's investment in the infrastructure.
4. Comply with the regulatory requirements of the Oregon Forest Practices Act.

Objectives of Forest Road Maintenance

1. Maintain existing roads and structures to the intended design standards.
2. Maintain a fully functional drainage system.
3. Minimize soil disturbance during maintenance activities.
4. Minimize impacts to water quality, aquatic habitat, wildlife habitat, and other natural resources during maintenance.
5. Combine professional level expertise and operator experience in the formation of on-the-ground decisions.
6. Provide a protocol for identifying and responding to immediate maintenance needs.

Road Maintenance Strategies

Road maintenance strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

Planning and implementation of a road maintenance program is a complex task. Districts will designate a person in each district with the overall responsibility for road maintenance. This person will be responsible for identifying maintenance needs, developing a plan to accomplish the maintenance, and ensuring that the plan is properly implemented.

Inventory

The basis for the development of a road maintenance plan is a thorough understanding of the road system, its characteristics, and its needs. This is accomplished by establishing and maintaining an intensive inventory of the road system. The inventory provides the information necessary for identifying and prioritizing required maintenance. In addition, the inventory will also provide the basis for the development of road improvement plans.

Each district will maintain an intensive inventory of the road system on state-owned forest lands in the district. As a minimum, this inventory will categorize roads, identify

drainage structures and rate their condition, identify and assess potential slope stability problems, and maintain information related to the condition of the road surface.

As of January 2000 the minimum level inventory system that will be used for roads on state-owned forest land will be the **Road Hazard Inventory Protocol** developed as part of the Oregon Coastal Salmon Recovery Initiative. This inventory system gathers information related to fish passage barriers where roads cross streams, information related to road drainage systems and their condition, and information related to slope stability problems. This information will be useful in describing some but not all of the current conditions of roads. In the future, a more comprehensive inventory system will be developed and added to this section of the manual. Until the new inventory system is in place, districts may gather additional information on the current condition of roads on state-owned forest land that the district determines to be necessary to efficiently and effectively maintain the road system.

Information for the inventory can be gathered and kept in many different forms, but it makes sense to take advantage of available technology to manage the data. Data can be recorded electronically, transferred to appropriate data management programs, and extensively queried using existing technology. Data will ultimately reside in the Department's GIS database, where it can be seamlessly integrated with all resource information.

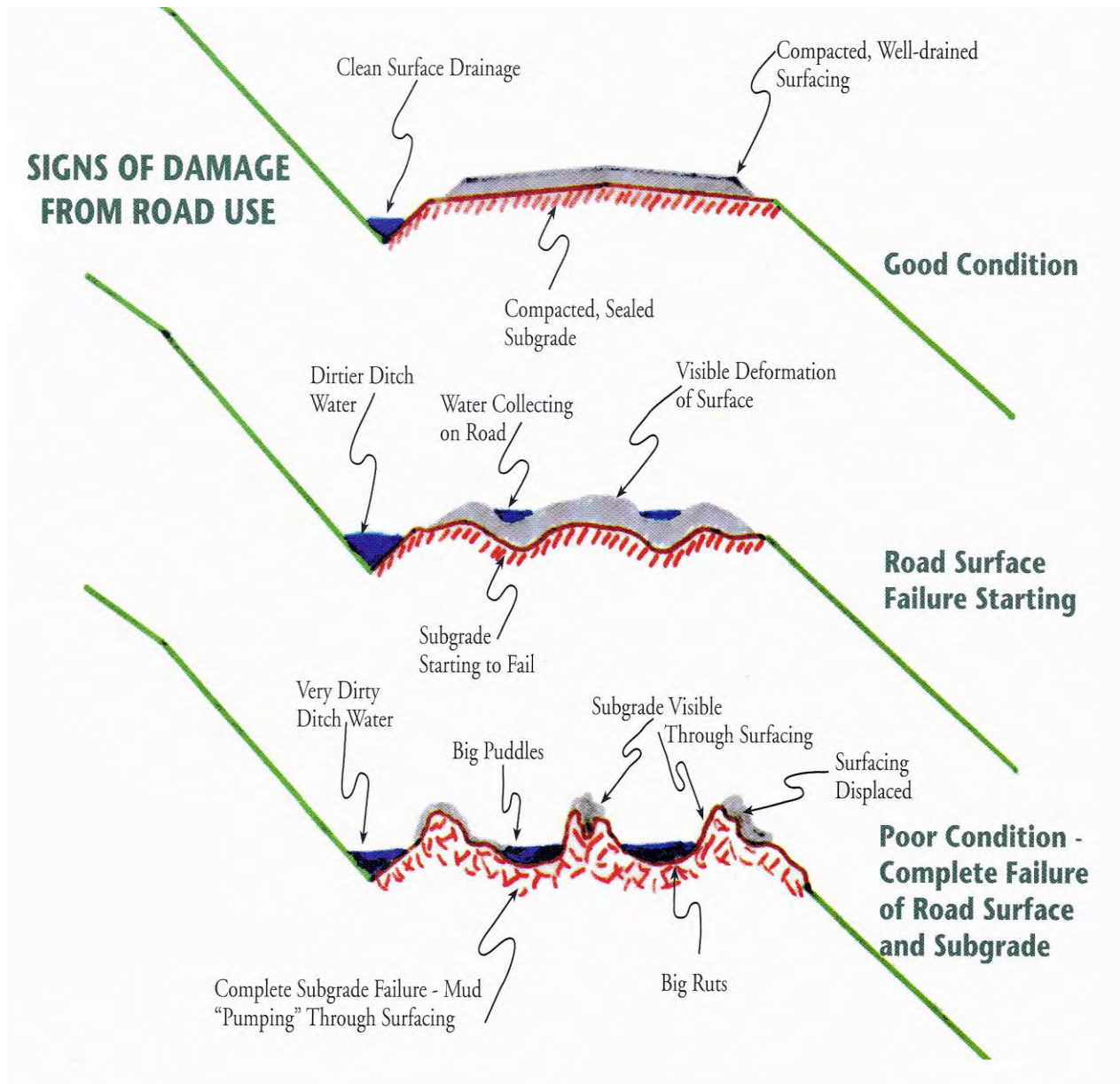
Since the road system is dynamic and constantly changing, regular updates to the inventory are essential. These updates will reflect new roads that have been added to the infrastructure, changes made to a road through maintenance or road improvement work, damage caused by storms or other environmental factors and changes caused by road use.

Inspection

Roads will be inspected on an annual basis or more frequently as the level of road use varies or local conditions warrant. The inspection will assess the condition of the road, identify any maintenance activity that is required, and provide information necessary to update the inventory. Particular attention will be paid to culvert inlets and outlets, ditches, road surface drainage and cut slope or fill slope stability. The inspection will take place early enough that any work identified can be completed prior to the start of the fall rains.

Roads will also be inspected regularly during periods of heavy hauling in order to detect early signs of damage. Standing water or ruts indicate that the strength of the road subgrade and/or the road surface is deteriorating and that immediate attention is needed. Often, a small amount of maintenance early can save thousands of dollars in road repairs later.

Figure 1. Signs of Damage From Road Use



Planning

As the inventory, supplemented by frequent inspections, reveals the required maintenance needs, it becomes important to develop a plan for accomplishing the required work. The plan will identify the work to be accomplished, the timing, the resources required to efficiently complete the work, and the methods for implementing the plan. Priorities will be assigned to each task, with the highest priority being assigned to sites that have the highest potential for damage to the road or damage to downslope natural resources.

When allocating road maintenance resources, it is important to match the type and size of maintenance equipment to the maintenance activity being performed, and to ensure that operators are properly trained to perform the function. For example, using a 1-1/2 cubic yard hydraulic excavator to clean culvert catch basins is generally not efficient, and can easily cause more damage than a more appropriate piece of equipment such as a tractor-mounted backhoe. Conversely, the larger hydraulic excavator would be a more appropriate choice when excavating and loading large amounts of material as opposed to the backhoe. If adequate resources are not available, plans must be made to secure the necessary resources.

It must be remembered that because forest road systems exist in a dynamic environment, any plan for road maintenance must also be dynamic. Rather than a static plan that covers a specific period of time, the plan must constantly adjust to changing conditions. Enough flexibility and adaptability must be built into the plan to allow for changing conditions and needs.

Factors that need to be considered when planning maintenance include:

1. Design Standards. Earlier sections in this manual related to the planned use and selection of appropriate design standards for any given road. Once the design standard has been established and the road has been constructed accordingly, that road will be maintained to the original design standard. If the road is not to be maintained to the original design standard, it must be due to a conscious decision to alter the design standard.

Equally as important as maintaining a road to its original design standard is limiting its use to the designed standard. This will prevent maintenance problems from developing and prevent damage to natural resources. A road that is surfaced with a minimal amount of crushed rock will not support timber hauling in the winter months, and will not be expected to do so. Likewise, heavy hauling on well surfaced roads will not be permitted during periods of heavy rains, melting snow, or during thawing periods. Care must be taken during the planning process to ensure that roads are adequately designed, constructed, and maintained for the planned use. If a road is not capable of supporting its planned use, then the plan will be modified or the road standard will be upgraded accordingly.

2. Frequency of Maintenance. Several factors help determine how frequently road maintenance activities will need to be performed:

A. Planned Use and Design

A road that has been planned and designed to accommodate a large volume of traffic will require more frequent maintenance. This applies to routine maintenance as well as the replacement of surfacing material. These roads might be mainline logging roads or roads that will carry a high level of recreational traffic. A road that is designed for occasional use, such as a short spur to access a timber sale will require less frequent maintenance. To reduce the maintenance load, roads that are seldom or occasionally used become good candidates for road vacation or closure at the end of their primary use.

B. Position on Slope

Roads located on ridge tops will require less frequent maintenance due to fewer drainage structures, shorter cut banks, and a higher degree of slope stability. Roads located in valley bottoms require somewhat more frequent maintenance, due to the greater number of drainage structures and their proximity to larger streams. Depending upon their proximity to valley slopes, roads in valley bottoms may or may not have greater cut and fill slope stability than roads on ridge tops. Roads located on side hills require the greatest maintenance frequency. Cut banks are higher and more prone to raveling, cut and fill slope stability issues are more frequent, and there are generally a large number of drainage structures.

C. Local Knowledge of Chronic Problem Areas

Local conditions may dictate more frequent maintenance on certain roads or at certain sites, such as culverts that are prone to beaver activity, recurring slide areas, or streams that carry unusually high sediment loads. The knowledge and experience of district employees are important in identifying these sites and ensuring that they get the attention they need. Solutions will also be explored to determine if the particular chronic problem could be mitigated.

Timing

Regular and timely road maintenance helps to ensure that the forest road system remains fully functional. Conversely, poorly timed maintenance can create problems that might have greater consequences than not maintaining a road. As examples, cleaning ditches during wet weather can cause excessive sedimentation, and grading a road during a hard rain event can lead to the contamination of the surfacing material. On the other hand cleaning culvert inlets and minor blockages of ditches during rain events can prevent more serious damage.

It is extremely important that any maintenance activity be conducted at a time when weather conditions allow for a minimal amount of soil disturbance and sediment movement. It is essential to maintain the integrity of the road surface and subgrade while conducting maintenance activities.

Coordination

At times, multiple users will be utilizing the same segment of road, each with its own maintenance obligation. For example, purchasers of State timber sales and third party users of roads under easement or permit are responsible to perform road maintenance activities related to their use of the road. When the use is simultaneous, it is necessary to coordinate the maintenance activities. Each district will coordinate these maintenance activities to ensure that there is no duplication of effort, and more importantly, that there are no gaps in the maintenance effort. All responsibilities for road maintenance must be fully identified, understood and fulfilled.

In the conduct of their normal day-to-day activities, district employees may observe or identify road maintenance needs. Districts will develop a methodology for recording the information and forwarding it to person or party responsible for maintaining that segment of road.

Districts will utilize geotechnical specialists, biologists, or other professionals to provide design input for mitigation of chronic maintenance problem areas.

Implementation Options

Three options are available to accomplish needed road maintenance. Each district will analyze its maintenance requirements and select the option or combination of options to efficiently accomplish the work.

1. Department of Forestry Personnel and Equipment

This road maintenance option provides the greatest flexibility. Personnel and equipment are in place and can easily be allocated to projects. Employees' experience and local knowledge can be invaluable in identifying chronic problem areas and developing appropriate road maintenance solutions. In addition, the personnel and equipment are available to support other functions, such as fire suppression.

The greatest advantage of Department personnel and equipment is the ability to react promptly to high priority situations, especially when unplanned emergencies arise.

The cost of maintaining the staff and heavy equipment that is required to accomplish the work is the biggest disadvantage of this option.

2. Timber Sale Purchasers

Purchasers of timber sales are responsible for the normal maintenance of all roads used in connection with a given sale during those periods that there is activity on the sale. While timber sales are a good way of accomplishing road maintenance, they may not meet all of a district's maintenance needs. The district is still responsible for maintaining roads during periods of inactivity and maintaining those roads not associated with a timber sale.

3. Service Contracts

Road maintenance can also be accomplished by entering into agreements with contractors who have the experience, equipment, and personnel necessary to properly do the work. Large districts with enough maintenance to provide full-time work for a contractor enjoy the same degree of flexibility that having district crews and equipment might provide. However, districts with a smaller workload will not provide full-time work to a contractor and may have to compete with the contractor's other commitments. Care must be taken to ensure that the contract is constructed with enough flexibility to satisfy the contractor and enough certainty to meet the district's needs.

Advantages to using service contracts include the ability to accomplish required maintenance at a lower cost by not incurring the full-time cost of personnel and equipment and by taking advantage of competitive bidding to minimize the cost. Disadvantages are the risk of reduced flexibility and the extra workload and costs associated with administration of the contract.

Knowledge, Skills, and Abilities for Maintenance Personnel

Regardless of the method employed, the road maintenance knowledge, skills, and abilities (KSA's) of supervisors, contract administrators, and equipment operators, are crucial to the successful maintenance of the road system. The following KSA's are the minimum for Department personnel involved in road maintenance:

Department of Forestry Maintenance Supervisors and Maintenance Personnel

- Knowledge of the Department's road maintenance standards for roads on state-owned forest lands and the ability to maintain roads according to the standards.
- Knowledge of good road maintenance practices and the ability to apply them in the proper situations.
- Ability to recognize unusual conditions that may require the use of specialized equipment and/or input from technical specialists.
- Knowledge of the road maintenance requirements of the Oregon Forest Practices Act.

Contract Administrators (Timber Sale Contracts and Service Contracts)

- Knowledge of the contract specifications and the policies and procedures related to administering the contracts.
- Knowledge of road maintenance standards and practices and the ability to apply them properly.
- Ability to recognize unusual conditions that may require the use of specialized equipment and/or input from technical specialists and the ability to initiate appropriate action.
- Knowledge of the road maintenance requirements of the Oregon Forest Practices Act.

Documentation

An important aspect of a road maintenance program is documentation. Maintenance activities will be documented for a number of reasons such as planning future maintenance needs and the tracking of maintenance costs. Documentation can also provide some protection in the event that there is a legal dispute relating to road maintenance. Each district will develop and use an interim system that documents road maintenance activities. When the Information Management section of this manual is completed, it will contain guidance on the documentation of road maintenance activities.

Monitoring

The success of a maintenance program can be determined only through observation. Roads will be checked on a regular basis to see if the maintenance work has been effective. For example, an inspection of a road during the first fall rains will determine if the culverts have been properly cleaned, whether or not the ditches are functioning properly, and if the road surface is properly crowned. Where monitoring identifies an ongoing maintenance need, actions will be taken to correct the situation.

Priority Maintenance

Each district will develop plans for patrolling roads during periods when there is a high potential for damage to the road system such as periods of high intensity rainfall. The plan will include established patrol routes and a protocol to report observed problems. Conditions that represent high risk of imminent damage to waters of the state will be repaired as soon as safety and weather conditions allow. These conditions include; actively failing road sidecast; blocked drainage structures; and repeated road cut slope failure areas.

Established patrol routes ensure that there is no duplication or skips in the patrol effort. Patrol routes will be mapped and available on short notice to the personnel that will be doing the patrolling. Routes will be prioritized to emphasize attention to areas where there is a prior history of problems.

A reporting protocol will be specified and will contain the following elements:

- Who receives the report. This will usually be the person on the district that is responsible for coordinating normal road maintenance.
- The nature and location of the problem.
- Other resources that might be threatened.
- What will it take to correct the problem, including an estimate of the equipment and time required to do the work.

Because of the severe nature of the weather usually associated with these periods, safety of personnel must be given the highest priority.

Road Closure or Vacation

One strategy that can be used to minimize the amount of maintenance required and the associated costs is to close or vacate roads that are not necessary for planned activities. See the section on Forest Road Vacating in this manual for additional information.

Road closure involves limiting access to the road while keeping the road in a useable condition. Road closure reduces the amount of traffic on a road and the amount of maintenance required due to wear and tear. It does not completely eliminate the maintenance obligation, but may reduce the frequency of maintenance. Road closure can be accomplished either by the installation of a gate or by the construction of a physical barricade. When choosing one of these methods, keep in mind that gates are themselves a high maintenance item, while barricades require extra effort to open when access is needed for maintenance or some other management activity.

Vacating a road involves leaving it in a condition where traffic cannot use the road and where erosion is unlikely. Road vacating is a semi-permanent/permanent technique that, if done properly, completely eliminates the need to maintain a road.

Maintenance Functions

Road maintenance activities can be divided into five basic categories: drainage, surface maintenance, cut and fill slopes, erosion control, and vegetation control. Each district will ensure that these categories are properly addressed during maintenance work. Improper maintenance of a road will reduce the useful life of the road, increase erosion and sediment transport to streams, and may represent a safety hazard to the road's users.

Drainage Maintenance

Culverts, catch basins, and ditches will be cleaned as necessary to ensure proper drainage. Often, culvert cleaning is done in the summer months as part of routine maintenance. Culverts also need to be inspected and cleaned during high rainfall events to prevent plugging. Problems found during high rainfall events must be corrected immediately, because delay can result in serious road damage and costly repairs.

During cleaning, floatable debris and accumulated sediment will be removed from the catch basin and placed where it cannot reenter the drainage system. Culvert ends that have been bent or damaged will be straightened and opened. Culvert outlets that show signs of erosion will be armored with riprap, fitted with a downspout, or use some other erosion control technique.

Ditch maintenance is important in order to maintain the flow capability required to remove surface runoff. Inspecting ditches during periods of high rainfall is a good time to determine if ditches need cleaning to improve their capacity, or if ditches are carrying too much water. Ditches that show signs of erosion or down cutting will have additional culverts installed or be armored with riprap to prevent further erosion.

Frequent grading or "pulling" of ditches is usually unnecessary, and can actually cause excessive erosion, undermine cut slopes, and expose the toe of cut slopes to erosion. If cut slope failures have blocked the ditch, clear out the material and place it in a stable disposal site. Remove other debris and vegetation only if obvious drainage problems are

evident. Do not remove any more grass or vegetation than is necessary, as they prevent scouring and filter out sediment.

When “pulling” a ditch, avoid pulling the material across the road surface. This can lead to contamination of the surfacing material and increased erosion, especially during the first rains. Material pulled from the ditch can be windrowed on the inside road shoulder and hauled away for proper disposal.

Road Surface

Road surfaces should be graded only when needed to maintain a smooth, stable running surface and to retain the original surface drainage. Excessive grading can result in increased rock wear and loss and can actually lead to unnecessary erosion.

Grading should cut deep enough into the surfacing material so that loosened material will mix, compact, and bind with underlying materials. If deep chuckholes or ruts cannot be graded out, the surface will be ripped and then graded and re-compacted to achieve proper binding. Otherwise, holes and ruts that are just filled or patched will quickly reform in the same locations.

Oversized material that is brought to the surface during grading can be moved off to the side of the road.

Berms from road grading will concentrate water and prevent the drainage system from working properly. In most cases berms will be removed either by grading or by hauling the material away to a disposal sites. Where roads cross high-risk sites, berms may be used on the outer edge of the road to keep drainage water from flowing over the high-risk site and to direct the water on to stable ground.

Over a prolonged period of use and maintenance, surfacing materials gradually break down or are lost to the side of the road. Steep road segments and curves experience the highest rate of rock loss. Eventually, the road will not match its designed standard. At such a time, it will be necessary to add surfacing material in order to bring the road back into standard.

Cut and Fill Slopes

The key to maintaining cut and fill slopes, including sidecast materials, is to regularly observe them and note when and how changes to these features occur. Often, small slope failures can be symptoms of larger slope stability issues. Left untreated, these unstable features can fail suddenly and develop into debris flows and landslides that cause considerable downslope damage. When changes to cut or fill slopes are noticed or suspected, consultation with geotechnical specialists can help ensure that the real problem is identified and the proper solution is formulated. Proper corrective measures can then be planned and implemented.

Typical cutslope problems include raveling, erosion, or slumping, each of which can lead to blocked ditches or contaminated surfacing. These areas often require more frequent ditch cleaning and maintenance. Long-term solutions might be to flatten the cut slope, revegetate areas of bare soil, widen the ditch so it doesn't plug as easily, or build a retaining structure to contain or prevent slope movement. Often, simply loading the toe of

a small cutbank slump with heavy riprap can provide sufficient support to stabilize the feature. Again, consultation with a geotechnical specialist may be needed to ensure that the real problem is identified and the proper solution is formulated.

Local slides and slumps in the road bed or shoulder often occur where material was placed or pushed over groundwater springs or seeps, where the road crosses deep draws, where organic material such as stumps, logs, or other organic debris has been buried, or where material has been sidecast onto steep slopes. Instability in fill slopes and sidecast materials often shows up on the surface or outer shoulder of the road as tension cracks and small scarps along the boundary of the unstable material. Some settling of recently placed sidecast can be expected, but if movement persists and scarps continue to develop, appropriate action needs to be taken before the slope fails. These actions might include improved drainage (extra culverts and ditches, free-draining structures), retaining structures, or the excavation and removal of unsuitable or excess materials. Any materials that have been excavated must be properly placed in a waste disposal area. For older roads on slopes over 65 percent, however, cracks in the road are likely evidence of a potential landslide. If drainage does not arrest movement immediately, or if the slope is directly above a stream, pullback may be required very quickly to prevent damage. Consultation with the geotechnical specialist may be needed.

Erosion Control

Erosion and sediment control structures will be maintained or repaired as necessary to ensure their proper function. Culvert downspouts will be inspected regularly to see if they are long enough and are carrying all the water passing through the culvert. Silt fences (used only for temporary measures) will be inspected to see if they are properly located and functioning. Fences that have trapped considerable sediments may have to be cleaned or replaced. Filtering devices such as straw bales or “bio-bags” may also need to be cleaned or replaced. Exposed soil on cut or fill slopes needs to be reestablished with appropriate vegetation such as grass seed and mulch.

Vegetation Control

Over time various species of trees and shrubs will be established on the surface of the road prism. This vegetation may cause safety problems by reducing visibility. In some cases the vegetation may also reduce the effectiveness of the drainage system or the stability of slopes. Where these conditions exist, some form of vegetation control may be needed.

Vegetation can be controlled manually, mechanically, or chemically. The method used will depend upon the characteristics of the vegetation, its location, and other factors.

When using chemicals, precautions will be used to avoid harm to non-target plants to prevent any of the pesticide from contaminating water.

Forest Road Vacating

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Introduction

Road access management is necessary to help meet management goals and objectives for fisheries, wildlife, recreation, timber and other forest resources as well as to reduce maintenance costs and sediment loads by restricting traffic. Roads can be grouped into four management categories:

- **Active Use.** Active use roads are those that are part of the permanent road system and those temporary roads that are currently in use or will be in use in the near future. These roads are usually available for use at any time of the year. Use may be continuous or intermittent. Roads in this category require active maintenance and have a full maintenance obligation under the Oregon Forest Practices Act.
- **Road closure.** Road closure involves restricting access to the road for part or all of the year. This may be as simple as placing a sign or other marker at the start of the road as might be the case in a cooperative travel management area for wildlife protection. Or, it might involve placing a semi-permanent barricade at the start of the road. This barricade can be a gate, large boulders, stumps and logs, or a trench. This strategy does not significantly alter the nature of the road, and the obligation to maintain the road remains. Road maintenance needs and sediment loads are reduced due to the elimination of traffic-related wear.
- **Partial vacation.** Partial vacation involves barricading the road and installing minor drainage structures, which might include the construction of water bars or rolling drains. This strategy is best suited for roads that will be needed again after long periods (perhaps as much as 15 to 20 years) of inactivity. Ridge top roads or other roads where drainage and sediment issues are negligible are good candidates to consider. The nature of the road may be somewhat altered through the addition of waterbars and other drainage structures, but the obligation to maintain the road

remains. Sediment loads are reduced due to the elimination of traffic-related wear, and road maintenance needs are greatly reduced.

- **Full vacation.** Full vacation involves removing all stream crossing structures, installing maintenance-free drainage (outsloping, water bars, rolling dips, etc.), pulling back any sidecast material, grass seeding disturbed soil, and barricading the road. The road is effectively “put to bed.” All access is prevented, and there is no maintenance obligation. Cross drain culverts may be left in place but will not be considered as a functional drainage feature.

There are many reasons for proactively vacating a forest road. Most involve excessive maintenance costs, lack of continued need, or continuing water quality problems. Not all roads need to be part of a permanent road system. For example, temporary roads are used once, then “put-to-bed” until they are needed again. In addition to newly built temporary roads, there are existing roads that may no longer be needed, and older abandoned roads that are now overgrown. The same techniques can be used to erosion-proof these roads to prevent further erosion and sediment yield, and, as an added benefit or incentive, save the work and expense of continued maintenance.

All forest managers that may have a future management need for a road should be involved in the decision to vacate a road. See the Road Proposed for Vacating form at the end of this section.

Landings associated with any road that is vacated must also be left in a maintenance free condition. The considerations used in vacating roads will also be applied to landings.

This section of the manual will cover goals, objectives and strategies for forest road vacating.

Goals of Forest Road Vacating

The primary goal for vacating forest roads is to leave the vacated road in a condition where road related damage to the waters of the state is unlikely. Achieving this goal contributes to the achievement of the following supplemental goals:

1. Reduces the impacts of roads on water quality, aquatic habitat, wildlife habitat and other forest resources.
2. Reduces the amount of forestland occupied by roads.
3. Reduces the overall costs of road maintenance.
4. Provides opportunities to use vacated roads for other uses such as hiking trails.

Forest Road Vacating Objectives

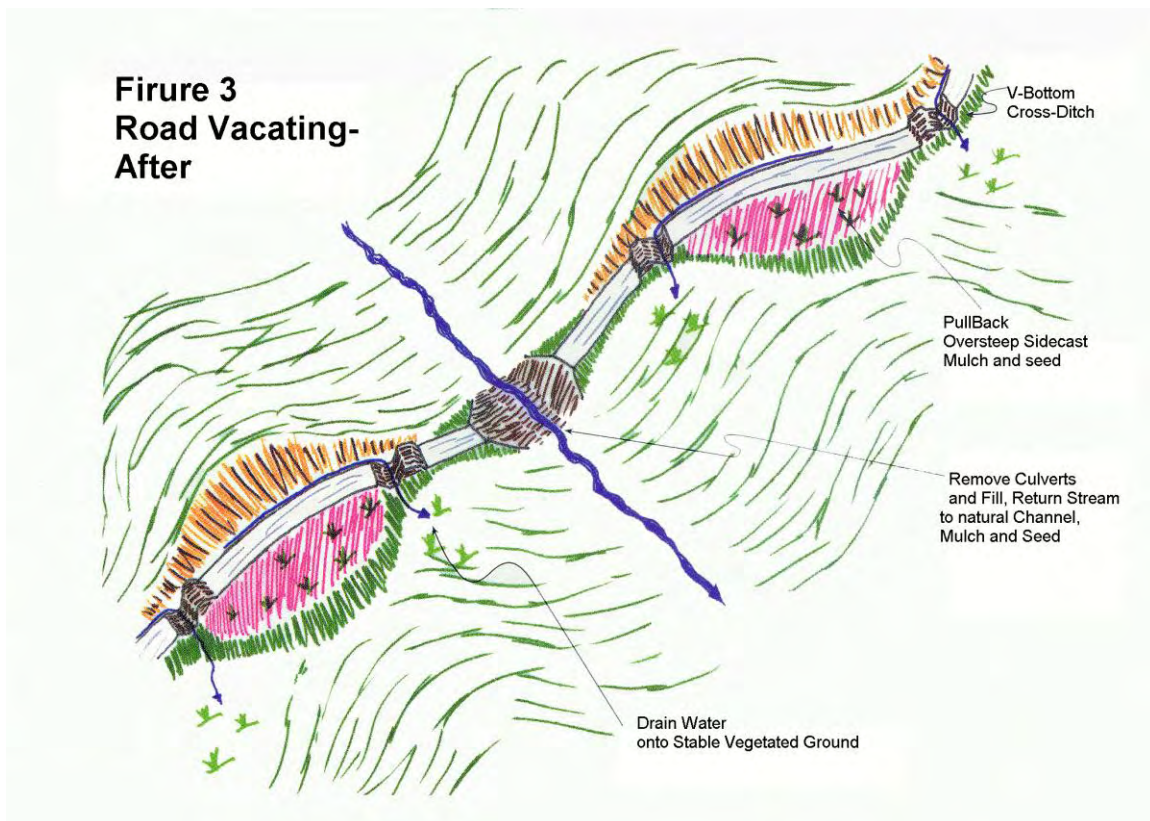
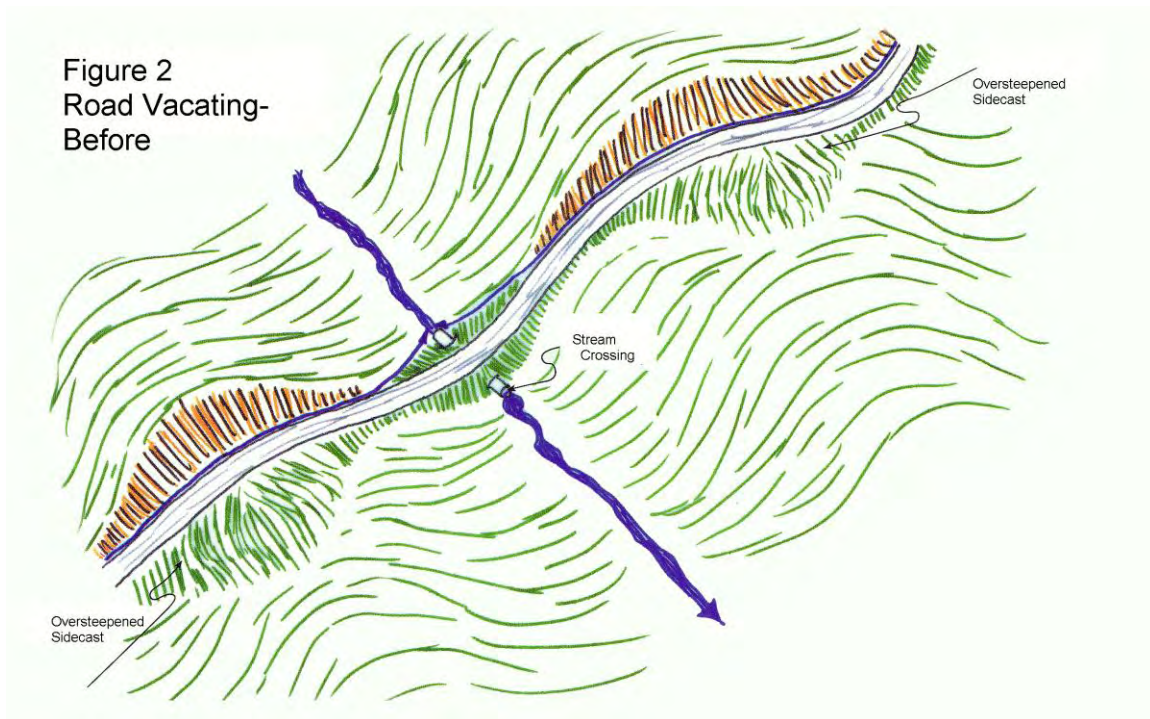
When a road is to be vacated and taken off the active road network, erosion prevention work will be performed so that continued maintenance is not necessary. All vacated roads will be “erosion-proofed” by excavating stream crossings and removing culverts, excavating unstable road and landing fills, treating the ditch and road surface to disperse runoff and prevent surface erosion, and revegetation of exposed soils.

Vacating a road does not imply that every foot of the road needs intensive treatment to prevent future erosion. Segments of a road that have near natural levels of risk for sediment delivery can be left intact and receive minimal road drainage improvements. When or if the road is needed again, it can be reconstructed with minimal effort.

The objectives for forest road vacating include:

1. Returning stream channels to natural conditions by removing all stream crossing structures including any fill associated with the crossing.
2. Establishing maintenance free surface drainage by removing berms and installing drainage structures such as water bars and drainage dips.
3. Eliminating unstable or potentially unstable road or landing fills or sidecast material by removing the material to a stable location.
4. Preventing surface erosion by revegetating all areas of exposed soils.
5. Preventing the use of the roadbed by mechanized equipment by installing permanent barricades.
6. Complying with the requirements of the Oregon Forest Practices Act regarding the vacation of roads.

Figure 2. Road Vacating – Before



Road Vacating Strategies

Road vacating strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

Road Vacating Assessment

The first step in vacating a road is to determine in a logical manner those roads that are candidates for vacating. Factors to consider include the need for current and future use of the road, the amount of environmental damage that road is currently causing or likely to cause, and the short-term cost of vacating the road versus the long-term cost of maintaining the road.

Implementation plans and forest management operations plans can be used to help determine the current and future use of the road. The Road Proposed for Vacating form provides a checklist for determining the current and future uses of a road. It also serves a review mechanism for the managers that are involved in making the decision to vacate a road.

The assessment will also include an evaluation of the environmental damage that is currently occurring or likely to occur at some time in the future from the road. The proximity to streams, the stability of road fills and sidecast material, the condition of the road's drainage system, and chronic maintenance problems are some of the factors to be considered in the evaluation. Roads that are causing significant damage or likely to cause significant damage will be considered as a high priority candidate for vacating.

A comparison of the short-term cost of vacating the road with the long-term cost of maintaining the road should be made. Any time the cost of vacating a road is less than the cost of maintaining the road and the road is not essential for management purposes, the road will be considered as a candidate for vacation.

There is no formula that will determine when a road should be vacated. Managers will need to weigh all of the factors affecting the decision and estimate the costs and benefits of vacating the road. The following is a list of roads that might be candidates for vacation:

1. Roads constructed for temporary access.
2. Roads that will not be needed for fire protection, forest management, recreation or other uses for several years.
3. Roads with excessively high maintenance costs.
4. Roads with persistent erosion and water quality problems.
5. Roads crossing steep slopes where landslide risk is high.
6. Roads exhibiting potential for fill slope or cutbank failures, often showing tension cracks.
7. Roads built with excessive sidecast or fill, in unstable locations, or perched above stream channels.
8. Roads built in, along or immediately adjacent to stream channels.

9. Old roads that have not been used for some time and have overgrown with vegetation, especially those with washed-out stream crossings and/or fill failures.

Stream Crossing Excavations

Removing a stream crossing involves removing the stream crossing structure (bridge, culvert, etc.) and excavating and removing all fill materials placed in the stream channel when the crossing was built. Fill material will be excavated to recreate the original channel grade, width and orientation.

All drainage structures in streams (live or intermittent), and culverts covered with over 2 feet of fill, in gullies or draws will be removed. Natural drainage will be restored during vacating.

Removal of stream crossing structures and fill material will be at a time that does not conflict with any restrictions on in-stream activities.

Road Surface Runoff and Other Drainage Structures

Roads that are to be vacated will have adequate, self-maintaining surface drainage. The drainage system will disperse rather than concentrate surface water and should maintain natural drainage patterns. Drainage water will be kept away from steep slopes and unstable areas.

Cross road ditches will be installed and take the place of cross-drainage culverts. The cross road ditches should intercept water from inside ditches, be deeper than standard waterbars, and drain onto stable, vegetated ground. As a minimum, cross road ditches will use 1/2 distance of spacing guidelines used for culverts. (See **Table 1. Guide Table for Water Bar and Relief Culvert Spacing** in the section on forest road design)

Removal of outside berms and/or outsloping of the road surface may also be needed to aid in the dispersal of drainage water.

Treatment of Unstable Areas

Any unstable or potentially unstable road or landing fills or sidecast will be excavated and placed in a stable location so that material does not enter a stream or destroy downslope vegetation. A stable location may be the inside part of the road prism or may be a waste area some distance away. Excavated areas will be shaped for natural drainage as will the excavated material that is deposited in a stable location.

Consult with the geotechnical specialist where risk assessment and confidence in technical design is needed. A slope stability investigation may be needed to ensure the proposed action is appropriate for the site. A slope stability investigation can provide interpretation of the geology in the area and increased confidence in the risk and design of the project.

Erosion and Sediment Control

Erosion control measures will be used where soil has been exposed. Vegetation is the ultimate, long-term erosion control agent. Seeding with grass and legumes will reduce surface erosion and can improve soil productivity. However, because it may take time to grow a thick, effective cover, some short-term erosion control measures (such as straw mulch or silt fences) may be needed for the first year or two after a road is vacated.

Planting with trees and shrubs can provide a long lasting vegetative cover and provide stronger root systems, which enhance soil stability for long term erosion and sediment control.

Blocking the Road

The vacated road needs to be blocked to vehicular traffic to prevent road surface rutting and damage to vegetation and crossroad ditches. One method used to block a road is to construct a trench across the entrance that is large enough to make it difficult to bridge or fill. Other methods include piling large stumps, boulders, concrete blocks or other debris in the entrance to block access.

Posting a sign stating that the road is closed may be helpful in advising the public that the access to the road is restricted to prevent damage to forest resources and that the road may be unsafe for use by mechanized equipment.

Timing

To prevent unnecessary damage or erosion, the work needed to vacate roads will be performed during periods when soil moisture is low. The work will also be timed to be in compliance with any restrictions on in-stream activities.

While it is assumed that properly vacated roads will not need further maintenance, their condition will be monitored. If unforeseen road drainage or stability problems develop after the road is vacated, consideration will be given to correcting the problems. The decision to take corrective action will depend upon the feasibility and practicality of the action.

Guidelines for Areas of Special Concern

Removal of fills over 10 feet in vertical height will have a project administrator present during removal. The project administrator should have some background regarding the removal of large fills. Natural slopes associated with large fills will be reestablished as closely as is feasible.

Removal of stream crossing structures in fish-bearing streams, including round culverts, arch pipes, bottomless arch pipes, and bridges, will have a project administrator present during removal. These structures will be removed with the least soil disturbance feasible. Removal of structures in fish-bearing streams will involve consultation with an ODFW fish biologist to ensure that removal will have a minimal impact on aquatic habitat and the fish.

Any unstable slopes or wet areas encountered during vacating must have immediate action taken to minimize the risk of failure. Consultation with a geotechnical specialist may be needed to determine the proper course of action.

All activities conducted while vacating forest roads on state-owned forest land will meet or exceed the requirements of the Oregon Forest Practices Act.

Road Proposed for Vacating Form

The Road Proposed for Vacating form will be found on the next page. The form provides a checklist for determining the current and future uses of the road. It also serves as a review mechanism for the managers that are involved in making the decision to vacate a road. Managers should keep in mind; there may be other uses besides forestry for a road that will warrant keeping the road in an active state. The Recreation Coordinator is one example of a check off point that will help make a road vacating decision. Additional input or approvals may be added to the forms approval list as needed.

ROAD PROPOSED FOR VACATING

ROAD NAME _____

The road on the attached map is being considered for vacating. This may involve culvert removal, water barring and blocking to vehicular traffic. Please look over your needs and check [yes] or [no] in the appropriate areas. If you are currently using the road but will have no future use after the project is completed, please fill in project completion date under -NO-(DATE). If you are not currently using the road, but expect a future use, please fill in date under -YES-(YEAR).

CURRENT USE	ROAD USE	FUTURE USE	FUTURE USE
-NO- -YES-		-NO-(DATE)	-YES-(YEAR)
_____	Fire Protection Net	_____	_____
_____	Management Net	_____	_____
_____	Timber Sales - Clear cut	_____	_____
_____	Commercial Thinning	_____	_____
_____	Cedar Sale Activities	_____	_____
_____	Woodcutting Activities	_____	_____
_____	Bough Sales	_____	_____
_____	Slash Burning	_____	_____
_____	Tree Planting	_____	_____
_____	Spray Projects	_____	_____
_____	Hand Release	_____	_____
_____	Precommercial Thinning	_____	_____
_____	Tree Pruning	_____	_____
_____	Stocking Surveys	_____	_____
_____	Progeny Site Access	_____	_____
_____	Property Survey Access	_____	_____
_____	Recreation Access	_____	_____
_____	Easements	_____	_____
_____	Other (describe):	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

TYPE OF VACATING RECOMMENDED: _____

APPROVED:

Reforestation Unit Forester

District Engineering Supervisor.

Management Unit Forester

Recreation Coordinator

Assistant District Forester

Information Management

It is recognized that the efficient and effective management of a road system requires the collection and management of a large amount of information about the system. Construction costs, maintenance costs, road condition information, construction plans and maintenance plans are a few of the many types of information that need to be collected and managed. Where possible, modern technology such as Global Positioning Systems, Geographic Information Systems, data recorders and data base software will be used to collect and manage the information.

The details of this chapter will be developed and added to the manual as soon as possible.

Responsibilities

The effective implementation of the elements of this manual involves numerous people at different levels and different locations in the Department of Forestry. The following listing of responsibilities is intended to provide a general view of how responsibilities are assigned for road management on state-owned forest land. In some cases staffing levels are different and responsibilities may be shifted to different personnel. In other cases responsibilities may be shifted to different personnel for organizational reasons. It is not as important where the responsibilities are assigned as it is that all of them are assigned to someone. Managers and supervisors are responsible for assuring that qualified personnel are assigned to carry out the responsibilities for road management identified in this manual.

State Forests Program Director

The State Forests Program Director is responsible for developing the overall policies, goals and objectives for forest road management on state-owned forest land.

State Forests Program Staff Engineer

The State Forests Program Staff Engineer is responsible for:

- Providing input and assistance to the Program Director in the development of policies, goals, and objectives for forest road management.
- Providing guidance, including training, on the implementation of the policies, goals, and objectives for forest road management.
- Providing technical assistance in the implementation of the policies, goals, and objectives for forest road management.
- Providing technical assistance in planning, designing, constructing, maintaining, and/or vacating specific road projects on state-owned forest land.
- Track and evaluate new methods and technology such as GIS and computer software for possible use in The State Forest Program.

Area Director

The Area Director is responsible for ensuring the elements of forest road management identified in this manual are efficiently and effectively accomplished in his/her geographic area.

District Forester

The District Forester is responsible for:

- Ensuring the elements of forest road management identified in this manual are efficiently and effectively accomplished in the district.
- Providing oversight and support in the staffing, budgeting, and organizing of road management on state-owned forest land in the district.

Assistant District Forester/Unit Forester

The Assistant District Forester/Unit Forester is responsible for:

- The overall supervision and management of the road management program on state-owned forest land in the district or unit.
- Identifying the long-term, mid-term, and short-term needs of the road management program in the district or unit and then staffing, budgeting, and organizing to meet the identified needs. Assuring that transportation plans have been developed and are being followed.
- The review and approval of critical and/or sensitive road construction, improvement, maintenance or vacation projects.
- The review and approval of significant changes to contracted road projects.
- Approval and documentation of exceptions to the standards and processes specified in this manual.

Timber Sale Layout Personnel

Timber Sale Layout Personnel are responsible for:

- Reconnaissance of proposed locations for roads and landings, including alternative locations that will be used to access planned timber sales.
- Marking proposed road and landing locations on the ground.
- Developing design specifications for roads that require basic level engineering procedures.
- Recognizing when proposed roads and/or landings will cross a critical or sensitive location and requesting the appropriate technical assistance in the location and design of that portion of the project.

District Engineer

The District Engineer is responsible for:

- Designing roads or portions of roads that require the use of mid-level or advanced level engineering procedures.

- Designing critical road structures such as culverts on fish bearing streams, bridges, or retaining walls.
- Assisting timber sale layout personnel in locating roads in sensitive areas such as high-risk sites or wetlands.
- Assisting project administrators in the review of unforeseen problems on road construction or improvement projects.
- Designing modifications to road construction or improvement projects when unforeseen problems arise.
- Providing technical assistance to project administrators and/or equipment operators on the use of various road construction, improvement, maintenance or vacating practices.
- Maintaining an inventory of the current condition of roads in the district on state-owned forestland and using the inventory to identify, plan, and schedule the road improvement and road maintenance needs in the district.
- Supervise the maintenance program for roads in the district that are on state-owned forestland.
- Developing and implementing a plan for “emergency road maintenance” during periods of severe weather.
- Provide input for transportation planning at the level II planning level in coordination with forest management planning.

For districts that do not have a district engineer, the above responsibilities must be assigned to other district personnel or fulfilled through other means such as assistance from adjacent districts or contracts.

Project Administrator

The Project Administrator is responsible for:

- Administering contract and/or project specifications to result in the project being completed as planned and designed.
- Documenting work on the project through diaries, inspection reports, instructions, and other written communications.
- Recognizing and initiating needed changes to contract and/or design specifications when unforeseen problems arise.
- Requesting technical assistance and/or input from geotechnical specialists, engineers, biologists, or other professionals for critical or sensitive situations.
- Taking appropriate administrative action when results are not consistent with contract or design specifications.

- Making progress inspections including a final inspection at the completion of the project. Approving or recommending approval of the project at its completion.

Geotechnical Specialist

Geotechnical specialists are a part of the area organization and provide assistance to several districts in the area. The Geotechnical Specialist is responsible for:

- Providing technical assistance in the location, design, and construction of roads and landings especially when high-risk sites, unstable areas, or other critical or sensitive geologic formations are involved.
- Providing technical assistance in designing modifications to projects when unforeseen situations are encountered.
- Providing technical assistance in the design and construction of road improvement projects especially when high-risk sites, unstable areas, or other critical or sensitive geologic formations are involved.
- Providing technical assistance in the vacating of roads especially when high-risk sites, unstable areas or other critical or sensitive geologic formations are involved.
- Providing technical assistance for repair of road prism failures especially when high-risk sites, unstable areas, or other critical or sensitive geologic formations are involved.

Appendixes

Appendix 1. Protocol for Road Hazard Inventories.

Appendix 2. Exhibits for Timber Sale Contracts/Service Contracts

Appendix 3. Costs Related to Road Construction/Improvement

Appendix 4. Work Forms

Appendix 5. List of Useful References

Appendix 1. Protocol for Road Hazard Inventories

Road Hazard Inventory

Background

The most common sources of sediment in rural and forested areas are from unsurfaced roads. Monitoring source areas of sediment can identify inputs of sediment to the stream system that may need to be mitigated. Ideally this should be done on a watershed scale. There are undoubtedly other sources of sediment in the watershed. This protocol only addresses road-related sources of sediment. Erosion associated with roads and ditches typically includes both surface erosion and landslides. Road construction disturbs and compacts soils and prevents revegetation. Therefore, in the forested

landscape, roads are the greatest potential source of sediment outside the stream channels. This can occur in the form of surface erosion or landsliding. Past monitoring indicates three major areas of concern for road erosion. One concern is excess spacing of cross drainage on steep gradient roads. Another is a side ditch routed over long distances with direct discharge into channels. Finally, road-related landslides are typically associated with steep sidecast material. There are three major elements (Table F-1) of the road hazard inventory that address these road concerns.

Table F-1. Elements of road hazard inventory

Inventory Elements	Area of concern
Stream crossing structures	Washouts of crossings and fish passage through culverts
Sidecast fill on steep slopes	Sidecast-related landslides entering channels
Road surface drainage systems	Muddy drainage waters delivered to streams

In order to use this protocol, several terms need to be understood by monitoring participants:

Road prism

Cross section of roadway from the top of the excavated area (cut) to the toe of the fill.

Cutslope

Slope created by excavation into the natural hillslope, is steeper than the natural slope.

Sidecast

Unconsolidated excavated material pushed to the slope below the road, generally not used as part of the road, and steeper than the natural slope.

Fillslope

Excavated material placed below the road and intended to serve as part of the road.

Inslope

Road surface that is sloped so that all water drains toward the ditch or cutslope.

Outslope

Road surface that is sloped so that all water drains toward the fillslope or sidecast.

Berm

A continuous pile of fill and/or aggregate, usually on the outside edge of a road which prevents surface water from leaving the road.

Cross drain culvert

A culvert installed under and across a road to carry ditch water to the downslope side of a road..

Stream crossing culvert

A culvert installed in a stream channel intended to carry stream flow under the road.

Bridge

A structure intended to carry vehicles over a stream or other feature, usually consisting of a span and abutments.

Log puncheon

A drainage structure made of logs (often cedar) and no longer in common use.

Ford

A stream crossing where stream flow covers the crossing for all or part of the year.

Waterbar

A constructed ditch and berm designed to direct water across the road.

Dips

A cross drainage structure where a low spot is excavated along the profile of the road and where surface water of stream flow is directed across the road.

Grade break

Location where road grade reverses (typically on a saddle or ridge) and surface water automatically is drained away from the road surface in question.

Ditch

Trench constructed at the toe of a cutslope and intended to keep water off the road surface. Ditch water is drained down slope along the road to some point of relief or cross drain.

Landing

An area constructed for logging equipment and log handling operations. Landings may be at the end of roads, or constructed as wide spots in the road. They are typically wider than the rest of the logging road.

Ridge Road

Ridge roads are located on or near the ridgeline (most or all of the road on the top one-third of the slope).

Midslope Road

A road located between a ridge and stream channel

Valley Road

Any road which generally parallels a stream in places, usually in the former riparian area of the stream.

Equipment Needs

In order to successfully and efficiently collect road data, the following equipment is needed.

- Vehicle—a vehicle (pick-up or utility rig) is preferred for road access, although a mountain bike can also be used where access is poor.
- Two person crew—a single person can collect the necessary data, although a crew of two can be more effective. The inventory person or crew can also be used to mark culverts and to flag locations needing immediate maintenance attention.
- Distance Measuring Instrument (DMI) and Hip Chain (String Box)—a DMI or other device that records vehicle travel distance in feet is recommended to accurately record distances while traveling along roads. Impassable roads are measured with a hip chain (string box).
- Clinometer—a clinometer is used to determine average road gradient and hillslope steepness. More accurate measurement tools (engineer's level) are required for any actual repair activity.
- Scaled rod or staff and a measuring (loggers) tape—lengths of culverts and bridges will be measured with these tools.
- ODF stream classification maps—on USGS 7.5 minute quad maps and/or other maps showing roads and streams are also needed.
- Global Positioning System (GPS)—GPS may be used to map road features. However, use of GPS to date has significantly slowed data collection, and is not an essential component of this protocol. GPS efficiency is poor in areas of narrow canyons or when the canopy is wet.

- Data Logger—direct data entry into a field data-logger as it is being collected can be very efficient.
- Computer System and Software—inventory information should be entered into relational databases. Relational databases are probably the most effective tool for making sense of large amounts of information. Commonly available software can be used to query the database to find high erosion hazards or barriers to fish migration.
- Geographic Information System (GIS)—data can be entered into a GIS system without GPS data using *dynamic segmentation*. If GPS has been used, the locations of features can be directly input to a GIS system.

Site Selection

The road hazard inventory is designed to assess all roads under a given ownership or within a given watershed. The protocol provides information to help landowners identify roads of concern and prioritize repair activities. It does not provide all the information necessary to implement those repairs. Timely inspection and subsequent maintenance or repair activity on forest roads will benefit fish and fish habitat. Therefore, it should eventually be conducted on all road miles that potentially affect fish habitat. Prioritizing site selection depends on the monitoring question being asked. However, in general, road inventories should first be conducted in areas where roads pose higher risk to anadromous fish and their habitats. This can be determined from:

- Landowner knowledge
- Topographic maps showing:
 - stream crossings of fish bearing streams,
 - midslope roads on steep slopes, and/or
 - steep, long road grades leading to channel crossing

Landowners are encouraged to use this protocol for road management purposes other than erosion hazard reduction. Possible uses include routine maintenance and surfacing decisions.

Road Hazard Field Methods

Overall Methodology

Begin at a road junction or other landmark. Take measurements described in the **Surface Drainage Section** below. As you travel along the road, measure the distance (DMI or other device starting at 0), until encountering a drainage feature and or stream crossing. This is referred to as road stationing. Record distance traveled, repeat surface drainage measurements and take **Culvert/Bridge and/or Stream Crossing Details** (described below), whichever are applicable. Record observations of general road characteristics (described in next section) for the entire road.

General Road Characteristics

Each road should be identified by name or number, according to the system normally used by the landowner. General characteristics are normally collected only once for each road. The following observations are used to classify each road and can be documented on a form as in Table F-2:

Road identification by name, numbering system or other means.

Road use by management activity.

active roads: have been used for timber haul in the past year

inactive roads: include all other roads used for management since 1972; and

orphaned roads are overgrown roads or railroad grades not used since 1972.

Surfacing material is described as asphalt, clean rock (new quarry rock); old rock (more common); or dirt.

Road location is described as ridge, midslope, or valley as the location of most of the road.

Width of the entire road is estimated (from the outside edge to the base of the cutslope).

For ownerships where *georegion*, *geology* or *soils* are variable and have a great influence on erosion, these classifications should also be documented.

Record whether the road is *outsloped* or has a *ditch*.

Record the *location* of the road with respect to a landmark. This may be done with the GPS unit or on a map.

Surface Drainage

Between drainage features, information is collected on the erosion potential and sediment delivery potential of the roadway. The typical road conditions between each drainage feature are categorized to identify erosion problems. The following observations and measurements are made to identify symptoms of high erosion on road segments that best describe the condition of the entire segment:

Road Grade

Road grade (slope) is measured in percent, with an estimated average when the slope changes. Slope is recorded as positive if the direction is up from the measuring point or feature, and negative when the direction is down from the feature. A positive slope drains toward the feature, a negative slope drains away from the feature.

Road Surface Condition

Road surface condition is described as good, rutted, bermed, or eroded (gullied).

Ditch

Ditch is described by function as good (capable of holding runoff without serious erosion), cutting, diverted, or full.

Cutslope

Cutslope is described as good (stable), ravel problems, or slides into the road.

Delivery

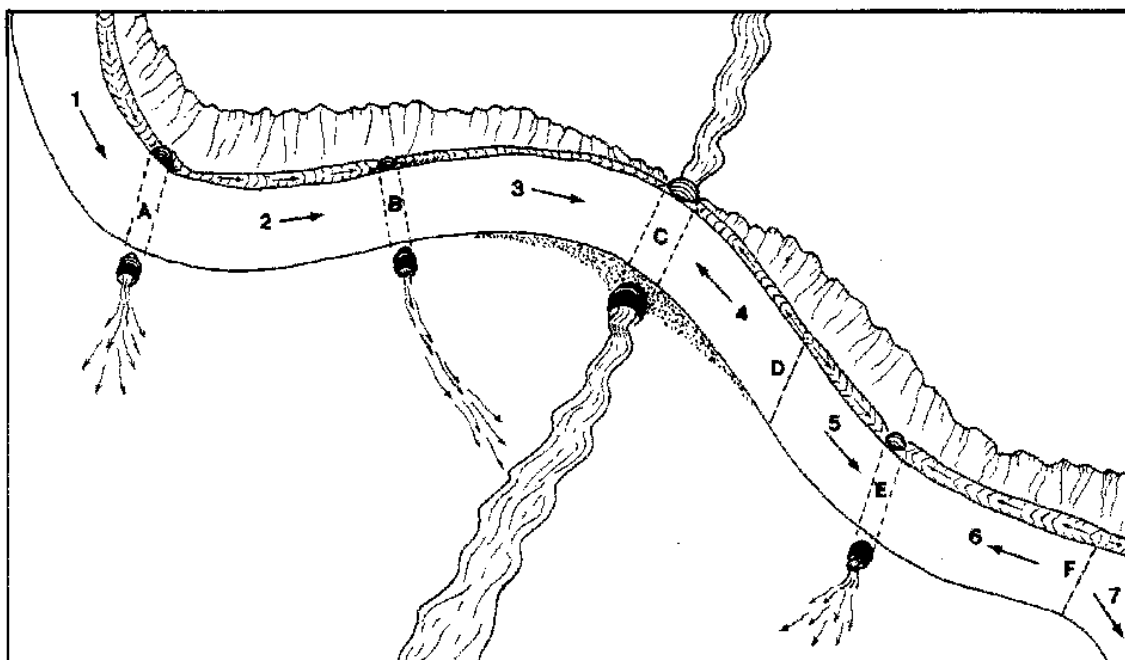
Delivery of sediment to streams from that length of road is described as “yes,” “possible,” “no,” or “bypassed” (water flows past the drainage feature and not off of the road).

Road length draining to drainage.

The length of road draining to each drainage feature can be calculated by use of several commonly available database or spreadsheet programs. For properly functioning outsloped roads there are no cross drainage features, only stream crossing features.

Drainage and Stream Crossings

Drainage data is collected at each drainage feature where collected drainage water is directed away from or under the roadway, and also at drainage divides. Drainage features include: stream crossing culverts, bridges, log puncheons, fords, cross-drain culverts, waterbars, dips, other relief, landings, and grade breaks. For each drainage feature, record the distance from road stationing and the type of feature so that drainage spacing can be determined. Landowners may also choose to locate features such as gates and water pump chances. A typical length of road with drainage patterns and features is shown in Figure F-1.



- A. Cross-drain culvert, sediment filtered and not delivered to stream.
- B. Cross-drain culvert with sediment delivery from segment 2 to stream.
- C. Stream-crossing culvert, sediment from road segments 3 and 4 delivered to stream.
- D. Drainage divide.
- E. Cross-drain culvert, possible sediment delivery to stream.

Figure F-1. Typical road surface drainage and drainage features.

Culvert (and bridge) Detail

The following information is collected for all culverts (stream crossing and cross drain) and bridges.

Diameter/Span

Diameter/span of the culvert (diameter for round, rise and span for arch) or span length (for bridge) is measured in inches (for culverts) and feet (for bridges).

Condition

Condition of the culvert is described as good; mechanical damage, sediment blockage, rusted, bottom out, collapse, animal (beavers), wood blockage, natural bottom (gravel) [more than one description may be appropriate in this category].

Inlet Opening

Inlet opening is estimated as a percent or original (design) opening.

Stream Crossing Detail

Stream crossings are an extremely important part of the road system. Improperly functioning stream crossings can result in loss of the roadway through washouts and channel diversions. Stream crossings can also be barriers to fish movement. At each crossing structure, information should be collected by getting out of the vehicle and taking measurements at the inlet end and near the outlet end of the structure. In addition to the culvert detail, the following information should be collected at each stream-crossing culvert (Figure F-2).

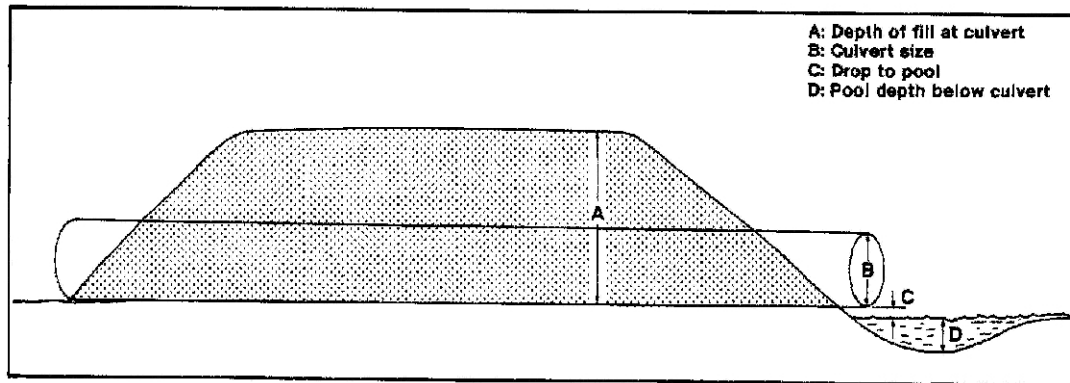


Figure F-2. Stream-crossing culvert with key dimensions.

Fish Presence

Fish presence (species, if known, from ODF classification maps or other sources) as fish use known; unknown fish use; no fish use; or anadromous fish use.

Diversion Potential

Diversion potential (for streamflow directed down and eroding the roadway) is described as high, medium or low.

Culvert Slope

Culvert slope is measured for fish use, or unknown fish use streams only.

Fill Height

Fill height is estimated from the channel bottom to the road surface at the downstream end.

Outlet Drop

Outlet drop is the distance from the bottom of the pipe to the elevation of the pool, in feet (countersunk outlets get a negative drop). This can vary with discharge so measurement should generally be taken during summer flow.

Resting Pool

Resting Pool below the pipe is categorized for fish use, or possible fish use streams only as good (at least two feet deep and six feet long); fair (at least one foot deep and four feet long); or absent.

Sediment Filtering

Sediment filtering opportunities around the crossing are noted as utilized, not utilized, or not available.

Sidecast Detail

Sidecast-related landslides are reasonably expected along particularly steep sections of road (Table F-3). Depending on georegion, geology, soil, and drainage, the natural slopes (below the road) for a steep section can be as gentle as 50% (in wet areas with weak sidecast and drainage problems). In areas with well-drained materials with uniform slopes and no or very limited signs of old slides, the appropriate slope may be 65 or 70%. Sections of road which have experienced past sidecast-related landslides should also be inventoried. The beginning and ending points used to characterize sidecast stability will be different than those used to characterize drainage. Therefore, a separate database is used (Figure F-3). Begin characterizing sidecast stability at the point in the road where steepness indicates there is a slope failure hazard. This may be, and usually is, at some distance between drainage features. Record this station distance from the road junction or landmark the same as the drainage features. Also record the ending point in the same manner. The following features are then used to describe typical conditions over the steep sections:

Average Natural Slope Steepness

Average natural slope steepness under the sidecast (if present).

Indicators of Movement

Indicators of movement described as none; cracks, a drop in the outside of the prism; or signs of old sidecast slides.

Vegetation

Vegetation on the sidecast is described as none, cover (grass or brush), reproduction (plantation), or forest.

Fill Condition

Fill condition is described as “at least 15% steeper than the natural slope,” logs exposed, or good.

Fill Depth

Fill depth at the outside edge of the road is estimated to the nearest foot, vertical measurement.

Downslope Risk

Downslope risk to streams is described by a qualitative rating of slope to nearest stream channel

low, moderate, or high based on the presence and size of bench terrain between the site and the nearest channel.

Forms

Example data sheets suitable for relational databases are shown in Tables F-2 and F-3. There is one data sheet for surface drainage and stream crossings (Table F-2), and another data sheet for sidecast (Table F-3), since the beginning and ending points of areas of sidecast concern rarely coincide with drainage location. Codes for the data sheet are explained on the pages following the data sheets. The codes have been designed with one or two digits (underlined) to reduce the size of the code sheets.

Table F-2. Field data sheet for surface drainage and stream crossing details and examples of collected data. In this example attention is required on the last entry because the culvert is partially blocked.

Road name/number _____ Road Use: Active, Inactive, Orphaned Surfacing: Dirt, Rock, Clean rock
 Road Location: Ridge, Midslope, Valley _____ Avg. Width _____ Ditch: yes/No Outslope: Yes/no
 Inventoried by: _____ Date _____ Geology/Soils _____

[illegible]

Feature codes:

SC = stream crossing culvert

DR = any other ditch relief

PC = pump chance

CC = cross drain culvert BR = bridge

I = features requiring immediate attention

G = gate

JN = road junction

WB = waterbar

GB = grade break
PN = log puncheon

$$\text{DP} = \text{dip}$$
$$\text{weakPN} = \log \text{puncheon}$$

LD = landing

Table F-3. Field data sheets for sidecast details. Example included.

Road name/Number: _____ Date _____

Inventoried by _____

Sidecast Detail								
Station Start (ft)	Station end (ft)	% slope Below	Movement Indicators.	Vegetation	Fill condition	Fill depth	Downslope Risk	Remarks
3413	3814	70	S	F	C	2	H	Stream has washed out road.

Codes:

Cracks

Drop

Slide Activity

None

Codes:

None

Veg.

Reprod.

Forested

Codes

Steep 15

Logs

Good

Codes:

Low

Moderate

High

Road Data Analysis

Road data should be analyzed to determine which roads, drainage systems, and/or stream crossings:

- are not functioning properly,
- may be delivering sediment to fish-bearing streams,
- do not pass fish (calculated from the data collected, refer to ODF&W fish passage protocol),
- and/or pose a risk to fish bearing streams (road-related landslides).

There are a number of red flags to look for. Examples include:

- Average distance to first cross drain is over 500 feet and road grade is greater than 6%,
- Culverts that are more than 50% blocked,
- Logs in fills,
- Steep sidecast with high downslope risk,
- Fish bearing streams with culverts that have a >0 foot outlet drop, gradient over 1%, and are not retaining sediment or do not have baffles.

Calculations of the road data can be done with a spreadsheet or database to address these road maintenance, sediment, and fish-passage related concerns.

Road-related results can be combined with turbidity and channel information to understand erosion and sediment processes in your watershed. It is important to recognize that a correlation between the three measurements may not reflect cause-and-effect relationships. In general such relationships can only be achieved with a properly designed and controlled study. However, over time the data will be useful for understanding environmental trends.

Appendix 2. Exhibits for Timber Sale Contracts/Service Contracts

State Timber Sale Contract
No. 341-00-__

Page __ of __

[Sale Name]

(XB1)

EXHIBIT "** __"

FOREST ROAD SPECIFICATIONS

SUBGRADE WIDTH	SURFACED WIDTH	POINT TO POINT	STATION TO STATION	DRAINAGE
*feet	feet	to	to	
feet	feet	to	to	
feet	feet	to	to	
feet	feet	to	to	

CLEARING. This work shall consist of clearing, removing, and disposing of all trees, snags, down timber, brush, surface objects, and protruding obstructions within the clearing limits.

Where clearing limits have not been staked, the clearing limits shall extend 10 feet back of the top of the cutslope and 5 feet out from the toe of the fill slope, or as directed by STATE. Clearing debris shall not be placed or permitted to remain in or under any road embankment sections. Clearing debris shall not be left lodged against standing trees.

All danger trees, leaners, and snags outside the clearing limits which could fall and hit the road shall be felled.

All stumps shall be completely removed within the limits of required grubbing. Stumps overhanging cutslopes shall be removed. Grubbing debris shall not be placed or permitted to remain in or under any road embankment sections. Grubbing debris shall not be left lodged against standing trees. Grubbing classifications are as follows:

New construction - From the top of the cutslope to the toe of the fill.

Improvements and reconstructions - 4 feet back from the shoulder of the subgrade or ditch, whichever is widest, or as marked in the field.

CLEARING AND GRUBBING DISPOSAL. * Scatter through openings in the timber outside of the cleared right-of-way, except areas where end-haul is required.

Rev. 5/99

[Sale Name]

(XB2)

EXHIBIT "** __"

FOREST ROAD SPECIFICATIONS

EXCAVATION. Excavation and grading shall not be done when weather and/or ground conditions are such that damage will result to existing subgrade or cause excessive erosion.

Excavation shall conform to STATE-engineered lines, grades, dimensions, and plans when provided.

All suitable excavated material shall be used where possible for the formation of fills, shoulders, and drainage structure backfills. Embankment materials shall be free of woody debris, brush, muck, sod, frozen material, and other deleterious materials. All fills and drainage structure backfills shall be machine compacted in lifts not to exceed 8 inches in depth.

Unless road design plans show otherwise, all roads shall be on a balanced cross section, except when the slope is over 50 percent; the road shall be on full bench for the width specified.

Excess excavation shall not be sidecast where material will enter a stream course or where material will accumulate in areas deemed a high-risk site by STATE.

ROAD WIDTH LIMITATIONS. PURCHASER shall obtain advance written approval from STATE to construct the road to a greater width than specified. Extra subgrade width shall be required for:

Fill Widening. Add to each fill shoulder 1 foot for fills 3 feet to 6 feet high; 2 feet for fills over 6 feet high.

Curve Widening. Widen the inside shoulder of all curves as follows: 400 divided by the radius of the curve equals the amount of extra width.

DRAINAGE

TURNOUTS. Increase roadbed width an additional 8 feet for both subgrade and surfacing. Length shall be a minimum 25 feet, or as staked on the ground, plus 25-foot approaches at each end.

Location: *() Intervisible but not greater than 750 feet.

*() As marked in the field.

GRADING

Rock
Common - side slopes 50% and over
Common - side slopes less than 50%
Common - turnpike (level) section

Back Slopes
Vertical to 1/4:1
*1/2:1
*3/4:1
2:1

Fill Slopes
Not steeper
than 1½:1

Top of cutslope shall be rounded.

*() **LANDINGS.** Landings shall be constructed no less than 50 feet wide and no more than 70 feet wide. Surface is to be crowned for drainage, with general grade no more than 3 percent. Surface as shown on Exhibit *__, Page *__.

*() **TURNAROUNDS.** Increase subgrade width an additional 20 feet for a length of 20 feet at locations marked in the field.

[Sale Name]

(XB3)

EXHIBIT "*" __"

ROAD IMPROVEMENT INSTRUCTIONS

[NOTE: Use this separate page when instructions are too lengthy or detailed to be contained in the project work section.]

[Sale Name]

(XB3a)

EXHIBIT "** __"

ROAD CONSTRUCTION INSTRUCTIONS

[NOTE: Use this separate page when instructions are too lengthy or detailed to be contained in the project work section.]

[Sale Name]

(XB4)

EXHIBIT "*"__"

LOGGING ROAD BRUSHING SPECIFICATIONS

REQUIREMENTS

Brush and trees shall be cut to a maximum height of 6 inches above the ground surface or obstructions such as rocks or existing stumps.

Debris resulting from the brushing operation shall be removed from the roadway, cutslope, ditches, and water courses and may be scattered downslope from the road or placed in other stable locations. Large debris, 6 inches or larger in diameter, shall be cut into lengths of 6 feet or less to facilitate rapid decay, unless otherwise approved by STATE.

Conifer trees larger than 6 inches in diameter at stump height, located within clearing limits but outside of the ditchline or shoulder, shall not be cut down, but shall be limbed for road visibility.

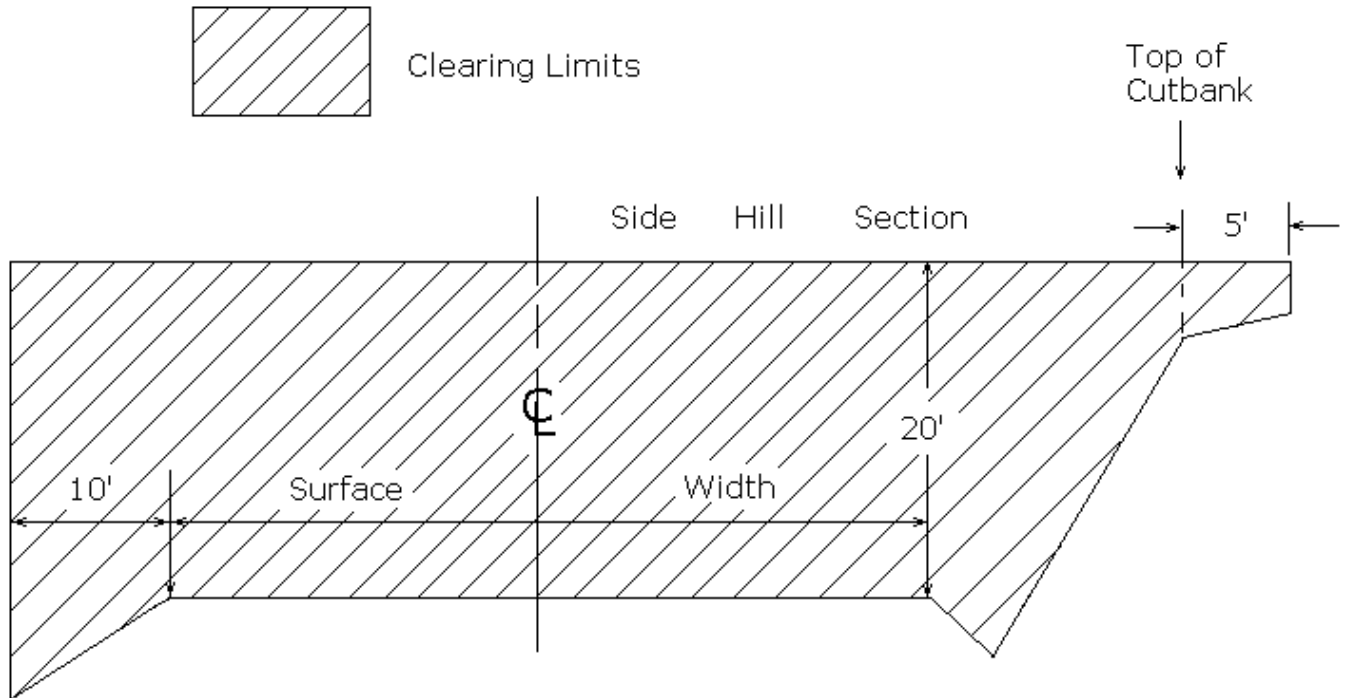
[NOTE: Clearing widths must be filled in on the diagram.]

[Sale Name]

(XB5)

EXHIBIT "** __"

LOGGING ROAD BRUSHING SPECIFICATIONS



REQUIREMENTS

The minimum height of clearing shall be 15 feet, and the minimum width of clearing on the cutslope side(s) of the road shall be 5 feet beyond the top of the cutbank.

Brush and trees shall be cut to a maximum height of 6 inches above the ground surface or obstructions such as rocks or existing stumps.

Debris resulting from the brushing operation shall be removed from the roadway, cutslope, ditches, and water courses and may be scattered downslope from the road or placed in other stable locations. Large debris, 6 inches or larger in diameter, shall be cut into lengths of 6 feet or less to facilitate rapid decay, unless otherwise approved by STATE.

Conifer trees larger than 6 inches in diameter at stump height, located within clearing limits but outside of the ditchline or shoulder, shall not be cut down, but shall be limbed for road visibility.

[NOTE: Clearing widths must be filled in on the diagram.]

[Sale Name]

(XB6)

EXHIBIT "** __"

END-HAULING REQUIREMENTS

POINT TO POINT	STA. TO STA.	CONTAINMENT	WASTE AREA LOCATION	WASTE AREA TREATMENT
to	to			
to	to			
to	to			
to	to			

End-Haul Areas General Requirements

Material shall not be intentionally sidecast.

Clearing and grubbing debris shall be end-hauled.

When blasting is required, it shall be accomplished using timing devices, delayed charges, low intensity shots, or other suitable means to contain as much material as possible within the road prism.

Containment

- (1) Full containment: The amount of material lost over the outside edge of the road shall not exceed 6 inches in depth measured perpendicular to the natural ground slope. Pioneer excavation shall be removed by digging, loading, and hauling rather than by pushing or scraping methods.
- (2) Average containment: The amount of material lost over the outside edge of the road shall not exceed
*__ inches in depth measured perpendicular to the natural ground slope.

Trees and stumps may have up to 12 inches of material directly above them. Any amount of material exceeding the containment requirements shall be removed by operator from the slope, by whatever means necessary, and end-hauled to a designated waste area.

Waste Area Location

- (1) As shown on Exhibit A and as marked in the field.
- (2) *

Waste Area Treatment

- (1) Deposit at waste area, spread evenly, compact, and provide adequate drainage.
- (2) Pile woody debris separate from other waste material.
- (3) *

[Sale Name]

(XC1)

[DEPTH MEASUREMENT]

EXHIBIT "*" __

ROAD SURFACING

TYPE OF ROCK	SIZE OF ROCK	COMPACTED DEPTH	POINT TO POINT	STATION TO STATION	APPROX. TOTAL TRUCK MEASURE VOLUME
		"			CY
		"			CY
		"			CY
TURNOUTS:			NO. OF T.O.	POINT TO POINT	
		"			CY
		"			CY
		"			CY
TURNAROUNDS:			NO. OF T.A.		
		"			CY
		"			CY
		"			CY
LANDINGS AND JUNCTIONS:			NO. OF LDGS.	NO. OF JCTS.	
		"			CY
		"			CY
		"			CY
MISCELLANEOUS: [Riprap, drain rock, etc.]		AMOUNT	POINT TO POINT	STATION TO STATION	
		CY			CY
		CY			CY
		CY			CY

Additional rock for curve widening is required and has been included in the volume estimates.

Roads shall be uniformly graded and approved by STATE prior to rocking. For typical cross section, see Forestry Department Drawing Nos. 351-C and 351-D at the Forestry Department district office.

[Sale Name]

(XC2)

[ROCK CHECKERS
OR
LOAD RECORDS]

EXHIBIT "** __"

ROAD SURFACING

TYPE OF ROCK	SIZE OF ROCK	VOLUME PER STATION	POINT TO POINT	STATION TO STATION	TOTAL VOLUME
		CY			CY
		CY			CY
		CY			CY
		CY			CY
		CY			CY
TURNOUTS:			NO. OF T.O.	POINT TO POINT	
		CY			CY
		CY			CY
		CY			CY
TURNAROUNDS:			NO. OF T.A.		
		CY			CY
		CY			CY
		CY			CY
LANDINGS AND JUNCTIONS:			NO. OF LDGS.	NO. OF JCTS.	
		CY			CY
		CY			CY
		CY			CY
MISCELLANEOUS:		AMOUNT	POINT TO POINT	STATION TO STATION	
		CY			CY
		CY			CY
		CY			CY

Roads shall be uniformly graded and approved by STATE prior to rocking. For typical cross section, see Forestry Department Drawing Nos. 351-C and 351-D at the Forestry Department district office.

[Sale Name]

(XC3)

EXHIBIT "** __"

CRUSHED ROCK SPECIFICATIONS

Materials. The material shall be fragments of rock or other hard, durable particles crushed to the required size and a filler of finely crushed stone, sand, or other finely divided mineral matter. The material shall be free from vegetation and lumps of clay.

Quality and Grading Requirements. The stone base materials shall be crushed rock, including sand.

- *() River gravel shall not be used. [Fracture of Gravel deleted]
- *() River gravel shall conform to the specifications listed below under Fracture of Gravel.
- *() River gravel may be used for 3/4"-0" crushed rock and shall conform to the specifications listed below under Fracture of Gravel.

The material from which base material is produced or manufactured shall conform to the general requirements of Section 2630 of the "Standard Specifications for Highway Construction" prepared by the Highway Division, Oregon Department of Transportation, and shall meet the following test requirements:

Hardness - Test Method AASHTO T 96 35% Maximum

Durability - Test Method ODOT TM 208
Passing No. 20 Sieve: 30% Maximum
Sediment Height: * _____" Maximum

Fracture of Gravel. Base materials produced from river gravel shall be crushed as required to provide at least 1 mechanically fractured face to a prescribed minimum percentage of materials retained on a 1/4-inch sieve.

The minimum percentage of fractured material in the "1/4-inch plus" fraction of each designated size of material shall be as follows:

2½"-0", 2"-0", 1½"-0"	50%
1"-0", ¾"-0", ½"-0"	70%

[NOTE: Fracture of Gravel requirements do not apply to quarry rock.]

[Grading requirements to follow.]

[Sale Name]

(XC3-a)

EXHIBIT "** __"

CRUSHED ROCK SPECIFICATIONS

[OPTIONS – PARAGRAPHS]

- () For the purpose of crushing rock specified under the projects in the section titled, "Project Work," PURCHASER shall utilize a three-stage rock crusher, or equivalent, unless otherwise approved by STATE.

- () A sample of the rock shall be supplied to STATE for testing and approval prior to crushing. The rock crusher must be calibrated to produce rock as specified in Exhibit *____. Rock must be accepted by STATE prior to any production by the crusher. Any rock crushed prior to such acceptance shall not be credited to the required rock quantity. Rock is to be stockpiled according to STATE instructions. Crushing equipment shall not be removed until all stockpiling and measurements have been accepted by STATE.

- () The rock crusher shall be calibrated to produce rock as specified in Exhibit *____. Prior to the commencement of production crushing, PURCHASER shall sample, test, and provide rock test results meeting STATE specifications. STATE may then sample and test crushed rock for approval to proceed. PURCHASER shall take one sample of each 2,000 cubic yards of crushed rock material produced thereafter, using approved AASHTO sampling procedures. PURCHASER shall submit samples to a certified laboratory or shall perform testing for gradation requirements using AASHTO T 11 and AASHTO T 27 testing procedures. Prior to testing, each sample shall be split, making one-half of the sample, with proper identification, available for testing by STATE. Each sample and the results of PURCHASER testing shall be made available to STATE within 24 hours of sampling. Any rock crushed prior to STATE approval to proceed shall not be credited to the required rock quantity. Any subsequent rock tests not meeting STATE specifications shall be reason for rejection of that portion of crushed rock produced after that test and shall not be credited to the required rock quantity. STATE may sample the crushed rock at any time during the operation. Results of STATE's tests shall prevail over all other test results.

[Sale Name]

(XC4)

[STATEWIDE]

EXHIBIT "*" __

CRUSHED ROCK SPECIFICATIONS

Grading Requirements

<u>For 3/4"-0"</u>	Passing	1" sieve	100%
	Passing	3/4" sieve	90-100%
	Passing	3/8" sieve	55-75%
	Passing	1/4" sieve	40-60%

Of the fraction passing 1/4" sieve, 40% to 60% shall pass the No. 10 sieve.

<u>For 1½"-0"</u>	Passing	2" sieve	100%
	Passing	1½" sieve	95-100%
	Passing	3/4" sieve	55-75%
	Passing	1/4" sieve	35-50%

Of the fraction passing 1/4" sieve, 40% to 60% shall pass the No. 10 sieve.

<u>For 2"-0"</u>	Passing	2½" sieve	100%
	Passing	2" sieve	95-100%
	Passing	1" sieve	55-75%
	Passing	1/4" sieve	30-45%

Of the fraction passing 1/4" sieve, 40% to 60% shall pass the No. 10 sieve.

<u>For 2½ "-0"</u>	Passing	3" sieve	100%
	Passing	2½" sieve	95-100%
	Passing	1¼" sieve	55-75%
	Passing	1/4" sieve	30-45%

Of the fraction passing 1/4" sieve, 40% to 60% shall pass the No. 10 sieve.

Passing	3" sieve	95-100%
Passing	1½" sieve	55-75%
Passing	¾" sieve	30-45%

Of the fraction passing 1/4" sieve, 40% to 60% shall pass the No. 10 sieve.

<u>For 4"-0"</u>	Passing	4½" sieve	100%
	Passing	4" sieve	95-100%
	Passing	2" sieve	55-75%
	Passing	1/4" sieve	30-45%

<u>For Jaw-Run</u>	Passing	6" sieve	100%
	Passing	3" sieve	45-65%

<u>For 6"-0" Pit-Run</u>	Passing	10" sieve	100%
	Passing	6" sieve	65%

The referenced sieve shall have square openings as set forth in AASHTO M 92, Woven Cloth Series.
The determinations of size and gradings shall be as set forth in AASHTO T 27.

[Sale Name]

(XC5)

[COOS ONLY]

EXHIBIT "** __"

CRUSHED ROCK SPECIFICATIONS

Grading Requirements

<u>For 3/4"-0"</u>	Passing	1" sieve retained on 3/4" sieve	0-10%
	Passing	3/4" sieve retained on 3/8" sieve	30-60%
	Passing	1/4" sieve	30-50%
<u>For 1½"-0"</u>	Passing	2" sieve retained on 1½" sieve	0-10%
	Passing	1½" sieve retained on 3/4" sieve	10-50%
	Passing	3/4" sieve retained on 1/4" sieve	20-60%
	Passing	1/4" sieve	10-30%
<u>For 2½"-0"</u>	Passing	3" sieve retained on 2½" sieve	0-10%
	Passing	2½" sieve retained on 1¼" sieve	30-60%
	Passing	1/4" sieve	24-40%
<u>For 3"-0"</u>	Passing	3½" sieve retained on 3" sieve	0-5%
	Passing	3" sieve retained on 1½" sieve	20-50%
	Passing	1½" sieve retained on 1/4" sieve	20-40%
	Passing	1/4" sieve	15-30%
<u>For 4"-0"</u>	Passing	6½" sieve retained on 4" sieve	0-5%
	Passing	4" sieve retained on 2½" sieve	20-50%
	Passing	2½" sieve retained on 1/4" sieve	20-50%
	Passing	1/4" sieve	10-25%

The referenced sieve shall have square openings as set forth in AASHTO M 92, Woven Cloth Series.
The determinations of size and gradings shall be as set forth in AASHTO T 27.

[Sale Name]

(XC6)

[MULTIPLE METHODS]

EXHIBIT "** __"

ROCK ACCOUNTABILITY

The rock shall meet the quality and size specifications in Exhibit * __. A sample of the rock must be supplied to STATE for testing and approval prior to rocking. Subgrades must be approved by STATE prior to rocking. Rocking must be done only when weather conditions are acceptable to STATE, and must be suspended when muddy water could enter streams from runoff.

Rock accountability shall be determined by the following methods, as directed by STATE. STATE shall be given 24 hours' notice prior to rocking.

Rock Checking. All rock spreading shall be done only when a STATE representative is present. STATE shall issue a receipt for each load delivered, and rock shall be measured without allowance for shrinkage or shakedown during hauling. Total truck measure volume for each road segment shall be as shown on Exhibit

* __. Deliver at least * __ cubic yards per 8-hour shift, unless otherwise approved by STATE. A penalty of

\$* __ for each 10 cubic yards which are not delivered during a single shift shall be billed, and payment shall be required prior to final acceptance of the project by STATE.

Depth Measurement. Rock shall be spread and compacted according to the depths specified in Exhibit * __. Truck measure volumes are given, but shall not limit the amount of rock spread.

Depth shall be determined in the most compacted area of the surface cross section. If additional rock is required because of insufficient depth, it shall be added by truck measure to those areas that were slighted. The conversion from compacted yardage to truck yardage is 1.3 multiplied by the compacted yardage equals truck yardage.

The depth of compacted aggregates shall not vary more than 1 inch from the depth specified in Exhibit * __. The average depth for each road segment shall be the specified depth or greater. Surfacing areas shall be staked by STATE.

Junctions shall have a surfaced area of at least * __ square yards each at the compacted depths specified in Exhibit * __.

Turnouts shall have a surfaced area of at least * __ square yards each at the depths shown in Exhibit * __.

Landings shall have a surfaced area of at least * __ square yards each at the depths shown in Exhibit * __.

Load Records. Notify STATE before spreading the rock and maintain a record of all rock delivered for spreading. Make the record available for STATE inspection. A report listing the amount of rock delivered the prior month must be submitted no later than the 15th of each month.

[Sale Name]

(XC7)

[DEPTH MEASUREMENT]

EXHIBIT "** __"

ROCK ACCOUNTABILITY

The rock shall meet the quality and size specifications in Exhibit * __. A sample of the rock must be supplied to STATE for testing and approval prior to rocking. Subgrades must be approved by STATE prior to rocking. Rocking must be done only when weather conditions are acceptable to STATE, and must be suspended when muddy water could enter streams from runoff.

Rock accountability shall be determined by depth measurement. STATE shall be given 24 hours' notice prior to rocking.

Depth Measurement. Rock shall be spread and compacted according to the depths specified in Exhibit * __. Truck measure volumes are given, but shall not limit the amount of rock spread.

Depth shall be determined in the most compacted area of the surface cross section. If additional rock is required because of insufficient depth, it shall be added by truck measure to those areas that were slighted. The conversion from compacted yardage to truck yardage is 1.3 multiplied by the compacted yardage equals truck yardage.

The depth of compacted aggregates shall not vary more than 1 inch from the depth specified in Exhibit * __. The average depth for each road segment shall be the specified depth or greater. Surfacing areas shall be staked by STATE.

Junctions shall have a surfaced area of at least * __ square yards each at the compacted depths specified in Exhibit * __.

Turnouts shall have a surfaced area of at least * __ square yards each at the depths shown in Exhibit * __.

Landings shall have a surfaced area of at least * __ square yards each at the depths shown in Exhibit * __.

Curve Surfacing. Extra surface width shall be required for the inside of all curves as follows: 400 divided by the radius of the curve equals the amount of extra width to be surfaced at the depths shown in Exhibit * __.

[Sale Name]

(XC8)

[ROCK CHECKERS]

EXHIBIT "** __"

ROCK ACCOUNTABILITY

The rock shall meet the quality and size specifications in Exhibit * __. A sample of the rock must be supplied to STATE for testing and approval prior to rocking. Subgrades must be approved by STATE prior to rocking. Rocking must be done only when weather conditions are acceptable to STATE, and must be suspended when muddy water could enter streams from runoff.

Rock accountability shall be determined by rock checking. STATE shall be given 24 hours' notice prior to rocking.

Rock Checking. All rock spreading shall be done only when a STATE representative is present. STATE shall issue a receipt for each load delivered, and rock shall be measured without allowance for shrinkage or shakedown during hauling. Total truck measure volume for each road segment shall be as shown on Exhibit * __. Deliver at least * _____ cubic yards per 8-hour shift, unless otherwise approved by STATE. A penalty of \$* _____ for each 10 cubic yards which are not delivered during a single shift shall be billed, and payment shall be required prior to final acceptance of the project by STATE.

[Sale Name]

(XC9)

EXHIBIT "** __"

ROCK SPREADING, PROCESSING, AND COMPACTION

Pit-Run Rock. Pit-run surfacing rock shall be spread on roads with a crawler tractor and continuously walked-in. Rock spreading shall begin at nearest point from the rock source and progress toward the end of the project, unless otherwise approved in writing by STATE. (*Compaction shall be accomplished by using one or more of the approved equipment options listed below:*) (*Compaction shall be accomplished by using the approved equipment listed below or others approved by STATE:*)

*() Rock shall be compacted and processed during the same project period it is spread, unless otherwise approved in writing by STATE.

*() Rock shall be crowned at 4 to 6 percent unless otherwise specified.

ROAD SEGMENT	COMPACTION EQUIPMENT OPTIONS

Crushed Rock. The rock shall be uniformly mixed and spread in layers on the approved roadbed. Each layer of crushed rock shall be moistened or dried to a uniform moisture content suitable for maximum compaction and compacted in layers not to exceed 6 inches in depth. When more than 1 layer is required, each shall be shaped and compacted before the succeeding layer is placed. Any irregularities or depressions that develop during compaction of the top layer shall be corrected by loosening the material at these places and adding or removing material until the surface is smooth and uniform. A minimum of 3 passes shall be made over the entire width and length of the road. A pass is defined as traveling a road section in one direction and then back over that same section again. (*Compaction shall be accomplished by using one or more of the approved equipment options listed below:*) (*Compaction shall be accomplished by using the approved equipment listed below or others approved by STATE:*)

*() Rock shall be compacted and processed during the same project period it is spread, unless otherwise approved in writing by STATE.

*() Rock shall be crowned at 4 to 6 percent unless otherwise specified.

ROAD SEGMENT	COMPACTION EQUIPMENT OPTIONS

[Sale Name]

(XC10)

[SUBGRADE & FILL]

EXHIBIT "** __"

COMPACTION AND PROCESSING REQUIREMENTS

Subgrade. Subgrade surfaces of the road segments listed below shall be graded and compacted prior to rocking. Compaction shall be accomplished by traveling all surfaces from shoulder to shoulder until visible deformation ceases, or in the case of a sheepsfoot roller, the roller "walks out." A minimum of 3 passes shall be made over the entire width and length of the road. A pass is defined as traveling a road section in one direction and then back over that same section again. (*Compaction shall be accomplished by using one or more of the approved equipment options listed below:) (Compaction shall be accomplished by using the approved equipment listed below or others approved by STATE:)

*() Rock shall be compacted and processed during the same project period it is spread, unless otherwise approved in writing by STATE.

*() Rock shall be crowned at 4 to 6 percent unless otherwise specified.

ROAD SEGMENT	COMPACTION EQUIPMENT OPTIONS

Fills. Embankments and fills shall be placed in (approximately) horizontal layers not more than 8 inches in depth. Each layer shall be separately, and thoroughly, compacted. Compaction equipment shall be operated over the entire width of each layer until visible deformation of the layers ceases or, in the case of a sheepsfoot roller, the roller "walks out." A minimum of 3 passes shall be made over the entire width and length of each layer. A pass is defined as traveling a fill layer in one direction and then back over that same layer again.

Placing individual rocks or boulders with more depth than the allowed layer thickness shall be permitted, provided the embankment will accommodate them. Such rocks and boulders shall be at least 6 inches below the subgrade. They shall be carefully distributed and the voids filled with finer material, forming a dense and compacted mass. (*Compaction shall be accomplished by using one or more of the approved equipment options listed below:) (*Compaction shall be accomplished by using the approved equipment listed below or others approved by STATE:)

*() Rock shall be compacted and processed during the same project period it is spread, unless otherwise approved in writing by STATE.

*() Rock shall be crowned at 4 to 6 percent unless otherwise specified.

ROAD SEGMENT	COMPACTION EQUIPMENT OPTIONS

[Sale Name]

(XC11)

EXHIBIT "*" __"

COMPACTION AND PROCESSING REQUIREMENTS

Pit-Run Rock. Pit-run surfacing rock shall be spread on roads with a crawler tractor and continuously walked-in. Rock spreading shall begin at nearest point from the rock source and progress toward the end of the project, unless otherwise approved in writing by STATE. (*Compaction shall be accomplished by using one or more of the approved equipment options listed below:.) (*Compaction shall be accomplished by using the approved equipment listed below or others approved by STATE:.)

*() Rock shall be compacted and processed during the same project period it is spread, unless otherwise approved in writing by STATE.

*() Rock shall be crowned at 4 to 6 percent unless otherwise specified.

ROAD SEGMENT	COMPACTION EQUIPMENT OPTIONS

Crushed Rock. The rock shall be uniformly mixed and spread in layers on the approved roadbed. Each layer of crushed rock shall be moistened or dried to a uniform moisture content suitable for maximum compaction and compacted in layers not to exceed 6 inches in depth. When more than 1 layer is required, each shall be shaped and compacted before the succeeding layer is placed. Any irregularities or depressions that develop during compaction of the top layer shall be corrected by loosening the material at these places and adding or removing material until the surface is smooth and uniform. Each layer shall be compacted with a minimum of 3 passes over the entire width and length of the road. A pass is defined as traveling a road section in one direction and then back over that same section again. (*Compaction shall be accomplished by using one or more of the approved equipment options listed below:.) (*Compaction shall be accomplished by using the approved equipment listed below or others approved by STATE:.)

*() Rock shall be compacted and processed during the same project period it is spread, unless otherwise approved in writing by STATE.

*() Rock shall be crowned at 4 to 6 percent unless otherwise specified.

ROAD SEGMENT	COMPACTION EQUIPMENT OPTIONS

[Sale Name]

(XC12)
EXHIBIT "*" ____"

COMPACTION EQUIPMENT OPTIONS

- () Smooth-Wheel Power Rollers. Smooth-wheel power rollers shall either be of the 3-wheel type, weighing not less than 10 tons, or of the tandem type, 2-wheel or 3-wheel, weighing not less than 8 tons. Smooth-wheel rollers shall provide compression of 325 pounds per lineal inch of width of rear wheels or drum.
- () Pneumatic-Tired Rollers. Pneumatic-tired rollers shall be of the double-axle type equipped with pneumatic tires of equal size and type. The spacing between the sidewalls of adjacent tires shall not exceed 5 inches; the rear tires shall be staggered with relation to the front tires. The rolling width of the unit shall be not less than 60 inches exclusive of the power unit. The roller shall be so constructed that the contact pressure is uniformly distributed on all of the tires. The tires shall be inflated to maintain the air pressure in the several tires within a total tolerance of 5 pounds per square inch. The roller shall be so constructed that the total weight is between 1,000 and 2,000 pounds per tire. The actual operating weight of the rollers shall be as ordered by STATE.

Each pneumatic-tired roller shall be drawn by equipment having sufficient power and sufficient weight, under normal conditions, to pull the roller at a minimum speed of 5 miles per hour, or may be self-propelled to obtain a minimum speed of 5 miles per hour.
- () Vibratory Rollers. The drum shall have a smooth surface, a diameter not less than 48 inches, a width not less than 58 inches, and a turning radius of 15 feet or less. Vibration frequency shall be regulated in steps to 1400, 1500, and 1600 VPM, corresponding to engine speeds of 1575, 1690, and 1800 RPM. The centrifugal force developed shall be 7 tons at 1600 VPM. It shall be activated by a power unit of not less than 25 horsepower. The vibratory roller shall be self-propelled and operated at speeds ranging from 0.9 miles to 1.8 miles per hour, as directed by STATE.
- () Vibratory Compactors. Vibratory compactors shall consist of multiple or gang type compacting units or pads with a minimum variable width of 2 feet. It shall be self-contained and capable of compacting material as required.
- () Rock Trucks. Rock spreading shall begin at the nearest point to the rock source and progress toward the end of the project. Rock trucks shall be routed over the entire cross section of rock layers.

[Sale Name]

(XC13)

EXHIBIT "** __"

COMPACTION EQUIPMENT OPTIONS

- () Tampingfoot Compactors. Tampingfoot or sheepsfoot compactors shall exert a minimum pressure of 250 pounds per square inch on the ground area in contact with the tamping feet. The compactor shall cover a minimum width of 60 inches per pass and weigh a minimum of 16,000 pounds.
- () Grid Rollers. Pit-run rock shall be processed by grid rolling with a Hyster Grid Roller Model D or equivalent, fully equipped with 32,000 pounds or more of ballast weights. Twenty passes shall be made with a grid roller over the entire length and width of the road, unless STATE requires fewer passes. A grader weighing at least 20,000 pounds shall work the pit-run surface during grid rolling so that all pit-run rock comes in contact with the grid roller. Grid rolling shall be performed when the subgrade is dry and firm. Road surface shall be uniformly shaped and graded prior to and during grid rolling.
- () Vibratory Grid Compactors. The roller shall have a grid surface and have an operating weight of 32,000 pounds or more. The rock shall be worked with a grader weighing at least 20,000 pounds during the grid rolling process.

All rock shall come in contact with the vibratory grid compactor. A minimum of 10 passes shall be made with the grader and vibratory grid compactor over the entire length of the road, unless STATE requires fewer passes.

- () Crawler Tractors. D-7 Caterpillar or equivalent (***or larger**).

[Provide additional or different specifications, if necessary.]

[OPTIONS]

- () Rubber-Tired Skidders. A rubber-tired skidder weighing a minimum of 20,000 pounds shall be operated over the fill layers so that the entire layered surface comes in contact with the tires. Skidders with oversized tires (high flotation) are not acceptable for compaction.

[Sale Name]

(XD)

EXHIBIT "*"__"

ROCK PIT DEVELOPMENT AND USE

- (1) PURCHASER shall conduct the operations relative to the disposal of waste material in such manner that silt, rock, debris, dirt, or clay shall not be washed, conveyed, or otherwise deposited in any stream. All waste shall be deposited at an approved "waste disposal site."
- (2) Where overburden removal limits have not been staked, they shall extend for a distance of at least 20 feet beyond the developed rock source. Overburden and woody debris shall be hauled to a designated waste area. Overburden shall be spread evenly, grass seeded, and compacted at the waste area and woody debris stacked separately. Prior to drilling or rock removal, completion of overburden removal shall be approved (*in writing) by STATE.
- (3) The rock pit floor shall be developed to provide drainage away from the rock pit. Rock pit drainage ditches shall be developed and maintained. Benches shall be constructed at intervals of 40 feet or less in height and shall be a minimum of 20 feet in width. Any gravel or talus slopes shall be left with a working face at an angle of 60 degrees or less. There shall be a minimum of 1 bench with an access road to it. Said bench shall be easily accessible with tractors.
- (4) Blasting shall be accomplished using timing devices, delay charges, low intensity shots, or other suitable means to contain as much material as possible in the rock pit prism.
- (5) Pit face shall be developed in a uniform manner.

[SELECT ONE OF THE 6's]

- (6) Oversized material that is produced shall be piled in a designated area adjacent to the pit. It shall not be wasted.
- (6) Oversized material that is produced or encountered during development shall be broken down and utilized for crushing.
- (7) PURCHASER shall prepare a written development plan for the pit area. The plan shall be submitted to STATE for approval prior to conducting any operation in the pit area.
The plan shall include, but not be limited to:
 - (a) Location of benches and roads to benches.
 - (b) Disposal site for debris and overburden.
- (8) Upon completion of use, the pit site and access roads shall be left in a condition free from overburden and debris. Access roads to the pit, and the pit floor, shall be cleared at the termination of use. Rock pit access roads shall be blocked upon completion of rock pit use as directed by STATE. Rock pit roads shall be waterbar constructed to provide drainage as specified in Exhibit *____ and be blocked as directed by STATE.

[Sale Name]

(XE1)

EXHIBIT "*" ____

CULVERT SPECIFICATIONS

All culvert materials shall be furnished and installed by PURCHASER, unless otherwise specified in the contract. Culverts shall be constructed of corrugated galvanized iron or steel, (*or aluminized steel,) **(*or corrugated aluminum alloy,)** and shall conform to the material and fabricating requirements of Sections 2410 and 2420 of the "Standard Specifications for Highway Construction" prepared by the Highway Division of the Oregon State Department of Transportation. Corrugation types and shapes other than those meeting the above minimum Highway requirements, shall be approved in writing by STATE. Corrugated polyethylene culverts may be used for sizes up to 36 inches in diameter.

The joints between bands and pipe of unlike material shall be coated with an approved bituminous material.

Culverts shall be located according to the alignment and grade as shown on the Plan and Profile, and/or as staked in the field, or as stipulated in special instructions.

(*The STATE Representative shall determine final culvert locations and stake the locations in the field prior to installation.)

(*Culvert grade shall slope away from ditch grade at least 2 percent unless otherwise specified.)

(*Camber shall be incorporated into all culvert trench beds by increasing the lower half of the trench bed slope 1 percent.)

(*Culverts less than 36 inches in diameter shall be installed with the lock seam on the inlet end placed within 45 degrees of the bottom of the trench.)

The foundation and trench walls for all culverts shall be free from logs, stumps, limbs, stones over 3 inches, and other objects which would dent or damage the pipe during installation or use. If tamping is required, the trench shall be excavated wide enough to permit working on each side of pipe. Bedrock shall be excavated as required to provide a uniform foundation for the full length of the culvert.

[OPTION - SELECT ONE OF THE "BEDDING" PARAGRAPHS](*A bedding of granulated material or job-excavated soil shall be placed to provide a wide band of support and to transmit the load from above evenly over the entire length of the pipe.)

(*A bedding of job-excavated granulated soil shall be placed to provide a wide band of support and to transmit the load from above evenly over the entire length of the pipe.)

Transporting of the pipe shall be done carefully. Dragging or allowing free fall from trucks or into trenches shall not be permitted. Damage to bituminous coating shall be repaired before the pipe is covered.

On new installations, joining shall be done with bands of like material and corrugations. Manufacturers' instructions shall be followed for prefabricated pipe assembly.

[OPTION - SELECT ONE OF THE "BACKFILL" PARAGRAPHS

(*Backfill shall consist of granulated material or job-excavated soil free of stumps, limbs, rocks, or other objects which would damage the pipe.)

(*Backfill shall consist of job-excavated granulated soil free of stumps, limbs, rocks, or other objects which would damage the pipe.)

Tamping (when required) shall be done in 8-inch lifts, 1 pipe diameter each side of the pipe to 85 percent density or over, and to the minimum fill height as specified below. Additional fill shall be embankment material.

Fill heights, if not shown on a road plan and profile, shall be in accordance with those shown in Drawing No. 2094, "Fill Height Tables," prepared by the Highway Division of the Oregon State Department of Transportation. Any deviation must be approved by STATE.

Rev. 5/99

[Sale Name]

(XE2)

EXHIBIT "*" __

CULVERT SPECIFICATIONS

Minimum height of cover over top of culvert to subgrade when road is to be rocked shall be as follows: 12" for aluminized steel culverts 18" to 36", 18" for aluminized steel culverts 42" to 96", **(*12" for aluminum culverts 12" to 42", 24" for aluminum culverts 48" to 96",)** and 12" for polyethylene culverts (add 6" for roads which will not be rocked). Minimum vertical cover for other steel **(*or aluminum)** designs shall be as specified by STATE.

Lengths of individual culvert sections shall be not less than 10 feet, unless otherwise provided for in special instructions.

The ends of each culvert shall be free of logs and debris which would restrict the free flow of water. Culverts in Type F streams must allow free passage of fish as provided in the Oregon Forest Practice Rules. The intake end of relief culverts shall be provided with a sediment catching basin 3 feet in diameter at the bottom. The outlet end of any culvert which would allow water to erode embankment soil into waters of the State shall be provided with a downspout or other approved slope protection device.

Following are the minimum standard gauges for pipe and coupling bands. All other designs shall be in accordance with the minimum requirements of the Highway Division (Drawing Nos. 2091-A and B), or as approved by STATE.

____ (") Dia.	Pipe Gauge		Band Gauges		Band Widths (")			Hugger Band Widths	
	Aluminum	Steel	Aluminum	Steel	Annular	Helical	Dimpled	Annular	Helical
12-15	16	16	16	16	7	12	12	13 1/8	10 1/2
18-24	16	16	16	16	12	12	12	13 1/8	10 1/2
30-36	14	16	14	16	12	12	*12	13 1/8	10 1/2
42	12	14	12	16	12	12	NA	13 1/8	10 1/2
48	12	14	12	16	24	24	NA	13 1/8	10 1/2
54	12	14	12	16	24	24	NA	13 1/8	10 1/2
60	10	12	10	16	24	24	NA	13 1/8	10 1/2
66-72	10	12	10	16	24	24	NA	13 1/8	10 1/2
78	10	12	10	16	24	24	NA	13 1/8	10 1/2
84	8	12	8	16	24	24	NA	14 3/4	10 1/2
90-120	8	12	8	16	26	26	NA	NA	NA

(3"x1")

*Up to 33"

Aluminized steel culverts larger than 60" in diameter shall have 3" x 1" corrugations.

Polyethylene culverts between 3" to 10" in diameter shall meet the requirements of AASHTO M-252-851. Polyethylene culverts between 10" to 36" in diameter shall be double walled and meet the requirements of AASHTO M-294-901, Type S.

The STATE Representative shall determine final culvert locations and stake the locations in the field prior to installation.

[Sale Name]

(XE1-a)

EXHIBIT "** __"

CULVERT SPECIFICATIONS

[USED MOSTLY BY ASTORIA]

All culvert materials shall be furnished and installed by PURCHASER, unless otherwise specified in the contract. Culverts shall be constructed of corrugated, double-walled polyethylene, unless use of other culvert materials with an equivalent life expectancy is approved in writing by STATE. Pipe and fittings shall be made of polyethylene compounds which meet or exceed the requirements of Type III, Category 4 or 5, Grade P33 or P34, Class C per ASTM D-1248 with the applicable requirements defined in ASTM D-1248. Double-walled polyethylene pipe shall meet the requirements of AASHTO M-294-901, Type S. Clean, reworked material may be used.

Culverts shall be located according to the alignment and grade as shown on the Plan and Profile, and/or as staked in the field, or as stipulated in special instructions.

(*The STATE Representative shall determine final culvert locations and stake the locations in the field prior to installation.)

The foundation and trench walls for all culverts shall be free from logs, stumps, limbs, stones over 3 inches, and other objects which would dent or damage the pipe during installation or use. If tamping is required, the trench shall be excavated wide enough to permit working on each side of pipe. Bedrock shall be excavated as required to provide a uniform foundation for the full length of the culvert.

A bedding of granulated material or job-excavated soil shall be placed to provide a wide band of support and to transmit the load from above evenly over the entire length of the pipe.

Transporting of the pipe shall be done carefully. Dragging or allowing free fall from trucks or into trenches shall not be permitted. Damage to bituminous coating shall be repaired before the pipe is covered.

Joints shall be made with split couplings, corrugated to engage the pipe corrugations, and shall engage a minimum of 4 corrugations, 2 on each side of the pipe joint.

Backfill shall consist of granulated material or job-excavated soil free of stumps, limbs, rocks, or other objects which would damage the pipe.

Tamping (when required) shall be done in 8-inch lifts, 1 pipe diameter each side of the pipe to 85 percent density or over, and to the minimum fill height as specified below. Additional fill shall be embankment material.

A manufacturer's certification that the product was manufactured, tested, and supplied in accordance with this specification shall be furnished to the Project Engineer upon request.

[Sale Name]

(XE2-b)

EXHIBIT "** __"

CULVERT SPECIFICATIONS

[USED MOSTLY BY ASTORIA]

Minimum height of cover over top of culvert to subgrade when road is to be rocked shall be 12 inches for polyethylene culverts (add 6" for roads which will not be rocked). Minimum vertical cover for other steel or aluminum designs shall be as specified by STATE.

Lengths of individual culvert sections shall be not less than 10 feet, unless otherwise provided for in special instructions.

The ends of each culvert shall be free of logs and debris which would restrict the free flow of water. Culverts in Type F streams must allow free passage of fish as provided in the Oregon Forest Practice Rules. The intake end of relief culverts shall be provided with a sediment catching basin 3 feet in diameter at the bottom. The outlet end of any culvert which would allow water to erode embankment soil into waters of the State shall be provided with a downspout or other approved slope protection device.

This specification applies to high density polyethylene corrugated pipe with an integrally formed smooth interior.

This specification is applicable to nominal sizes 4- to 36-inch diameter. Requirements for test methods, dimensions, and markings are those found in AASHTO Designations M-252 and M-294-901, Type S.

[Sale Name]

(XE3)

EXHIBIT "** __"

CULVERT LIST

CULVERT NO.	DIAMETER (Inches)	LENGTH (Feet)	ROAD SEGMENT POINT TO POINT	STATION

[OPTIONS - PARAGRAPHS]

- () The intake ends of culverts shall be marked by driving or placing steel posts within 6 inches of the downgrade side. Posts shall be painted with a rust-resistant paint and be a minimum of 5 feet long, with the spade driven 2 feet into the ground.
- () Culverts 36 inches in diameter or larger shall have 1:1 beveled inlets.
- () All culverts shall be constructed of **(*corrugated,)** double-walled polyethylene.
- () Tamping is required.
- () All metal culverts scheduled for replacement shall (*become property of PURCHASER and) be removed from State land.
- () Half rounds shall be installed within 72 hours of culvert installation, unless otherwise approved in writing by STATE.

State Timber Sale Contract
No. 341-00-__

Page __ of __

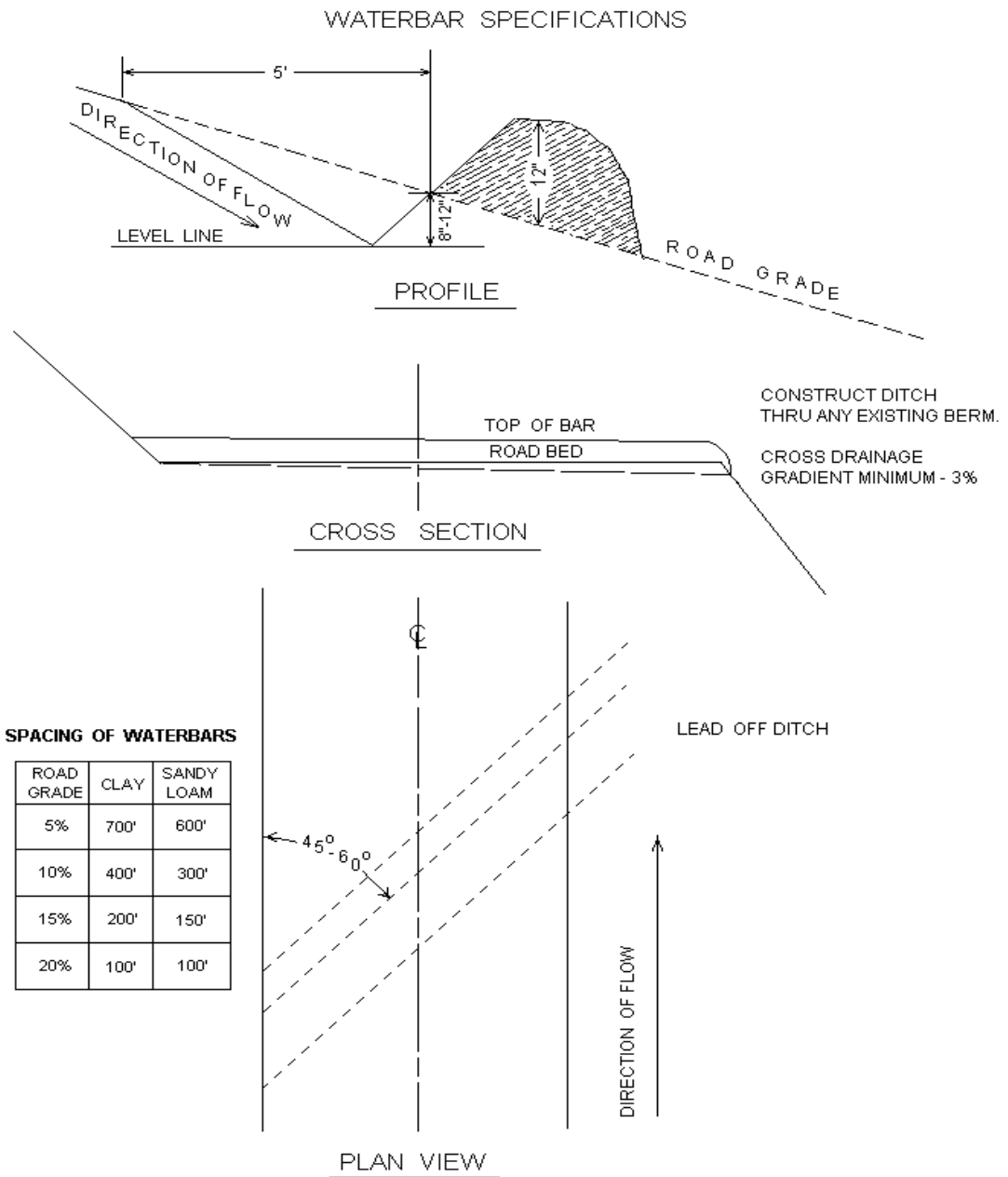
[Sale Name]

EXHIBIT "** __"

[Sale Name]

EXHIBIT "** __"

WATERBAR SPECIFICATIONS



WATERBAR SPECIFICATIONS FOR CROSS DITCHING

State Timber Sale Contract
No. 341-00-__

Page __ of __

[Sale Name]

EXHIBIT "* __"

[Sale Name]

(XX1)

EXHIBIT "** __"

WATERSHED REGULATIONS

PURCHASER shall take precautions necessary to protect the watershed from damage and to prevent pollution to the water supply. Precautions shall include, but not be limited to, the following regulations.

Laws, Rules, and Regulations. Comply with Oregon laws and with the rules and regulations of the Oregon State Board of Health relative to protection of watersheds and sanitation of public water supply.

Debris in Streams. Prevent, insofar as possible, logs, chunks, and other debris, resulting from logging and road building operations, from being deposited in streams. If such material should become deposited in streams, immediately remove the material to restore normal stream flow, using necessary care to prevent unnecessary damage to the stream channel and banks.

General Sanitary Conditions. Do not create any conditions which may permit breeding of flies or mosquitoes. Machinery, equipment, soil, and fuel storage shall not be located near streams. Waste oil shall be removed from the watershed. Camping shall not be permitted.

Privies. Place a clean, sanitary, and usable privy at each landing and other main points of operation and require all personnel to use the privies. Privies shall be placed at locations approved by STATE not closer than 100 feet to any stream. The privies shall be constructed as follows, unless other types are approved by STATE prior to being placed in use:

The housing shall be waterproof and flyproof, and the toilet shall be equipped with a seat and cover. A receptacle shall be provided for all refuse and the privy shall be equipped with a separate urinal draining into the receptacle. The receptacle shall be not less than 45-gallon capacity and the refuse shall be removed from the receptacle and disposed of off the watershed area. The receptacle shall be vented through the roof of the privy housing.

Pit type privies shall not be permitted on the watershed.

Personnel. Persons with a history of typhoid fever, amoebic dysentery, or infectious hepatitis shall not be employed on the watershed. All personnel shall be required to use the privies. PURCHASER shall verbally instruct all personnel employed on the watershed in the required sanitary precautions to be observed and shall give each such person a copy of these regulations.

Overnight Camping Prohibited. No person shall remain on the watershed overnight, unless authorized in writing by STATE.

[Sale Name]

(XX6)

EXHIBIT "** __"

SEEDING (*AND FERTILIZING)

This work shall consist of preparing seedbeds and furnishing and placing required seed **(*and fertilizer)**.

Seeding Seasons. Seeding shall be performed only from March 1 through June 15 and August 15 through October 31. Seeding materials shall not be applied during windy weather or when the ground is excessively wet or frozen. Work shall be performed during each specified seeding season on all completed and previously untreated sections. **(*OPTION: PURCHASER shall notify STATE 24 hours prior to seeding.)**

Soil Preparation. Areas to be seeded that have been damaged by erosion or other causes shall be restored prior to seeding. All areas to be seeded shall be finished and then cultivated to provide a reasonably firm, but friable seedbed. A minimum of 1/2 inch of surface soil shall be in a loose condition.

Application Methods for Seed (*and Fertilizer)

Dry Method. Mechanical seeders, seed drills, landscape seeders, cultipacker seeders, **(*fertilizer spreaders,)** or other approved mechanical seeding equipment shall be used to apply the seed **(*and fertilizer)** in the amounts and mixtures specified. Hand-operated seeding devices may be used when seed **(*and fertilizer) (*is *are)** applied in dry form.

Application Rates for Seed (*and Fertilizer)

Seed listed below shall be applied at the following rates per acre:

<u>Species</u>	<u>Lb./Acre</u>	<u>Mixture</u>	<u>Pure Live Seed</u>	<u>Poison and/or Repellent</u>
Highland Bentgrass	12	40%	98%	0
Annual Ryegrass	9	30%	98%	0
Perennial Ryegrass	9	30%	98%	0

(*Fertilizer: Chemical analysis shall be 16-20-0 and shall be applied at the rate of 300 pounds per acre.)

[NOTE: Delete fertilizer language in () if fertilizer is not being used.]

[Sale Name]

(XX7)

EXHIBIT "** __"

FABRIC SPECIFICATIONS

FABRIC SPECIFICATIONS - shall be woven fabric designed for forest road subgrade surfacing purposes and shall meet or exceed the following requirements, unless otherwise approved in writing by STATE:

- | | | | |
|-----|--------------------------------|----------|------------|
| (1) | Grab Tensile | 300 lbs. | ASTM D1682 |
| (2) | Modulus Load at 10% Elongation | 140 lbs. | ASTM D1682 |
| (3) | Mullen Burst | 600 lbs. | ASTM D751 |
| (4) | Width – 12.5 feet | | |

INSTALLATION REQUIREMENTS - fabric shall be installed according to the following requirements:

- (1) Typical cross section:
- (2) Subgrade surface shall be leveled and smoothed to remove humps and depressions which exceed 6 inches in height and depth. Small pieces of woody debris shall be removed or pushed below subgrade surface. Light vegetation (grass, weeds, leaves, and fine woody debris) may be left in place.
- (3) Fabric shall be installed directly on the prepared surface. Longitudinal and traverse joints shall be overlapped at least 3 feet.
- (4) Surfacing course material shall be placed to the designated thickness in one lift and spread in the direction of fabric overlap. Hauling and spreading equipment shall not be operated on the fabric until the total thickness of surfacing course material is placed.
- (5) Torn, punctured, or separated sections of the fabric shall be repaired by installing a fabric patch over the break prior to placing the surfacing course material. The patch shall be at least 4 feet larger in horizontal dimensions than the break to be repaired.

Fabric failures resulting after rock placement and as evidenced by subgrade pumping or roadbed distortion shall be corrected. Correction measures shall consist of: (1) removing at least three-quarters the depth of surfacing course material in the affected area, (2) placing a fabric patch over the affected area with a minimum 4-foot overlap around the circumference of the area, and (3) replacing enough rock to cover the patch and blend in with the rest of the road.

[Sale Name]

(XX8)

EXHIBIT " __ "

MULCHING

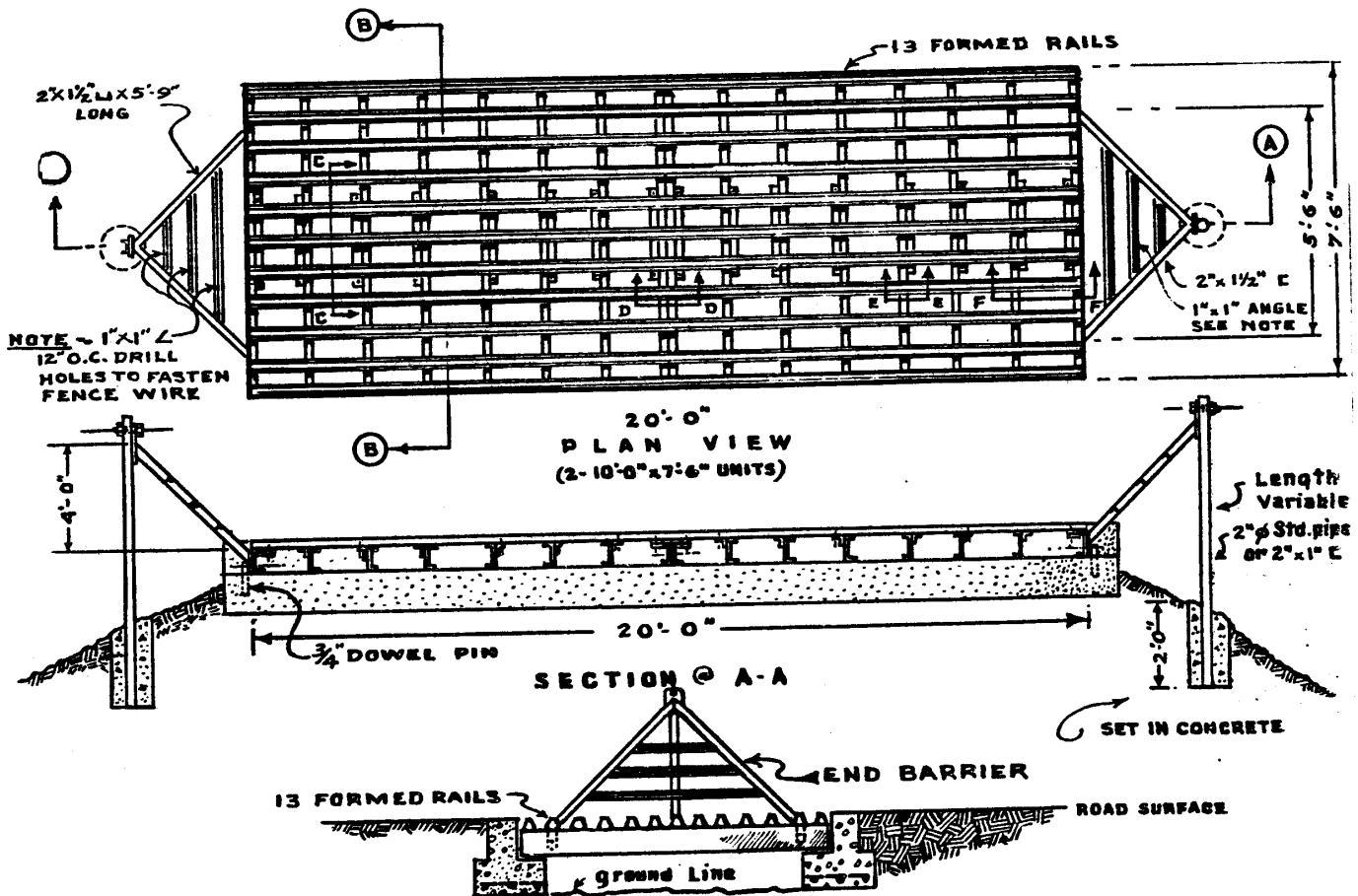
This work shall consist of furnishing and placing required mulch. Mulch shall consist of straw that is free of noxious weeds.

Mulching Period. Straw mulch shall be applied within 24 hours of spreading grass seed and fertilizer.

Application Rates for Mulch

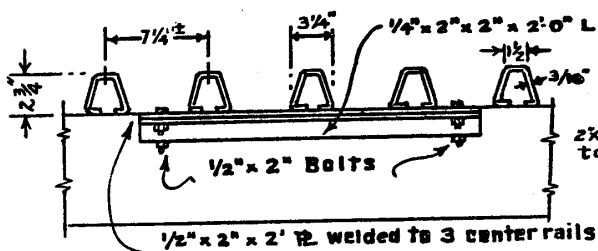
Place straw mulch to a reasonably uniform thickness of 1½ to 2½ inches. This rate requires between 2 and 3 tons of dry mulch per acre.

Added 7/99

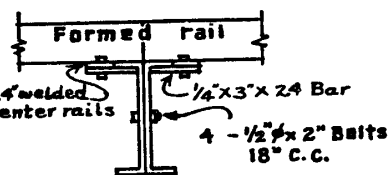


SECTION @ B-B
SCALE 1/4" = 1'-0"

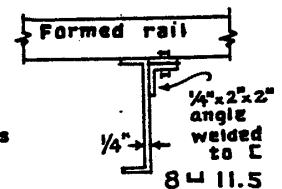
NOTE: TWO COATS OF RUST RESISTANT PAINT, YELLOW CROMITE OR EQUAL.



SECTION C-C



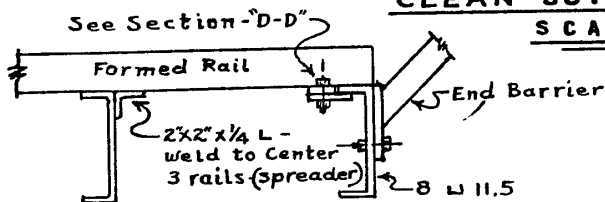
SECTION D-D



SECTION E-E

CLEAN-OUT PANEL DETAILS

SCALE 1" = 1'-0"

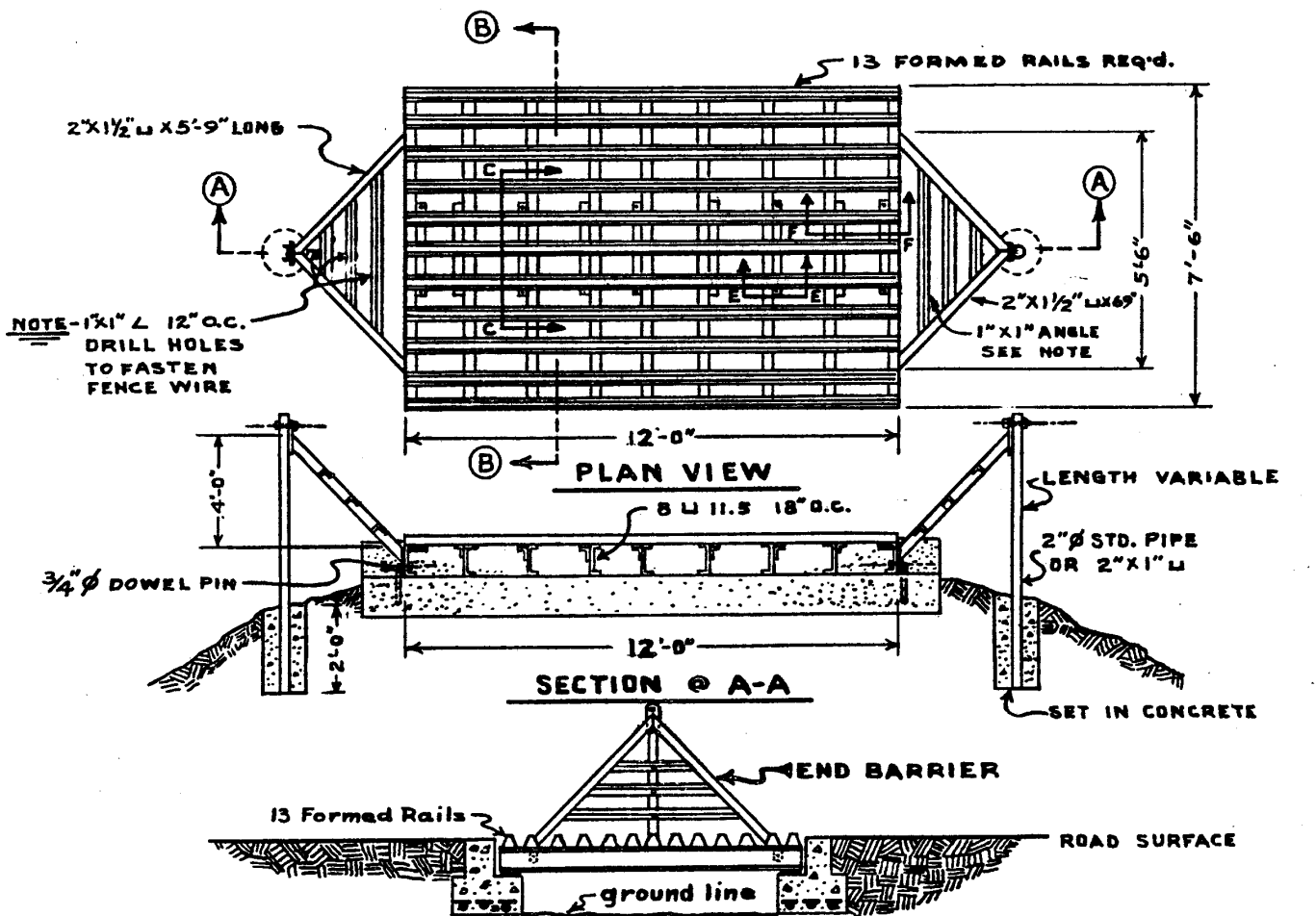


SECTION F-F

OREGON STATE BOARD OF FORESTRY
SALEM, OREGON

METAL CATTLE GUARD

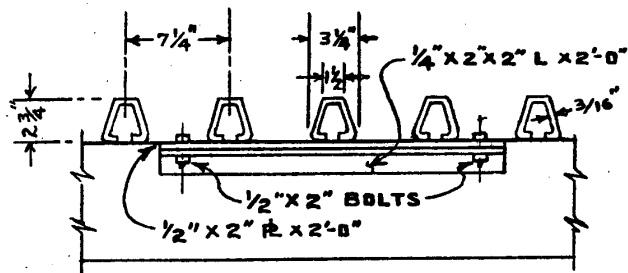
SCALE: AS NOTED



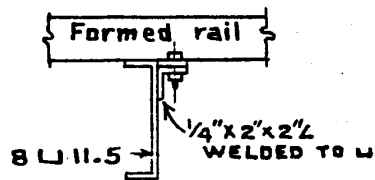
NOTE: (2) TWO COATS RUST RESISTANT PAINT, YELLOW CROMITE, OR EQUAL.

SECTION @ B-B

SCALE 1/4" = 1'-0"



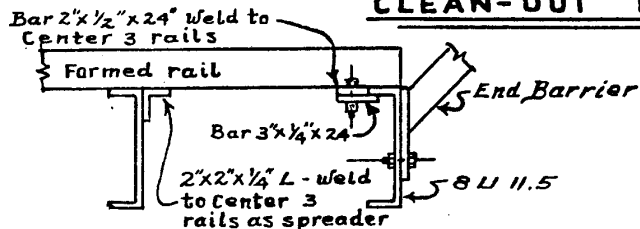
SECTION C-C



SECTION E-E

SCALE 1" = 1'-0"

CLEAN-OUT PANEL DETAILS

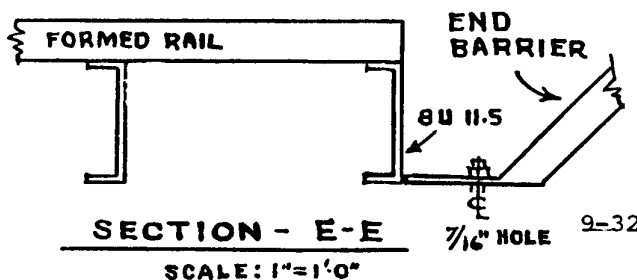
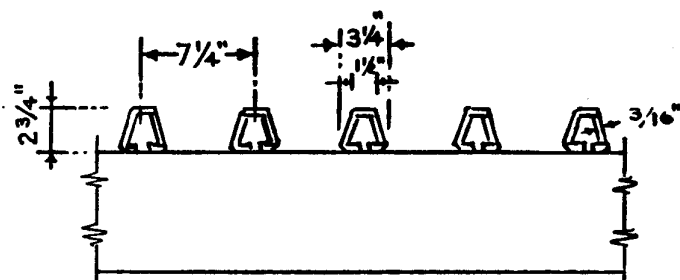
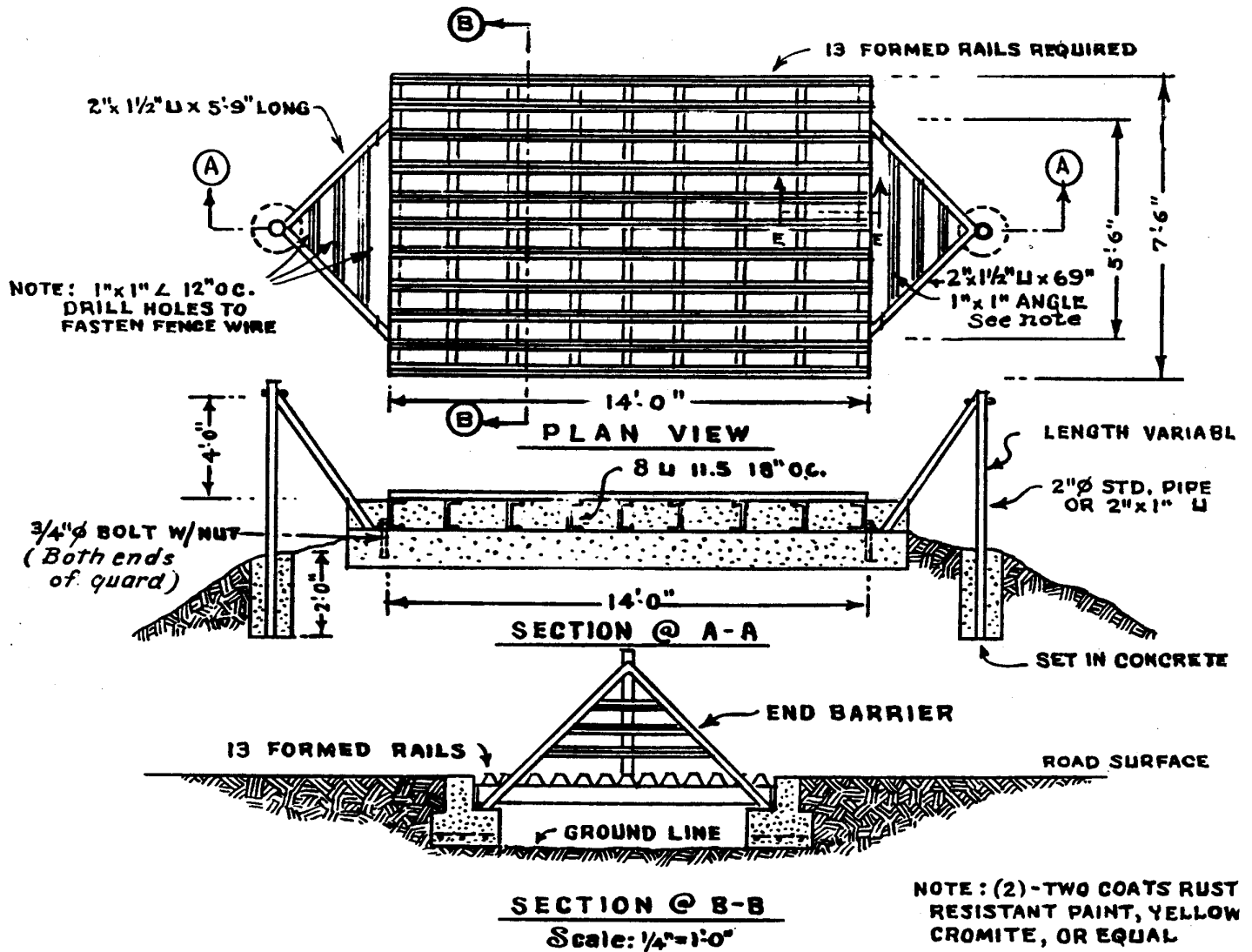


SECTION F-F

OREGON STATE BOARD OF FORESTRY
SALEM, OREGON

METAL CATTLE GUARD

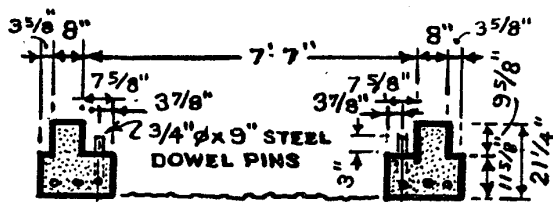
SCALE AS NOTED



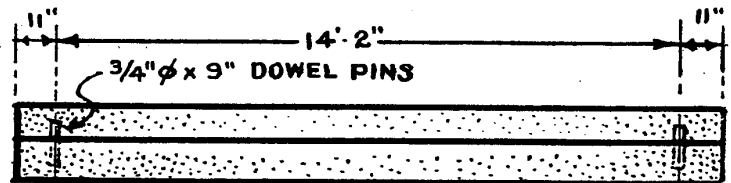
STATE OF OREGON - DEPARTMENT OF FORESTRY
SALEM, OREGON

METAL CATTLE GUARD

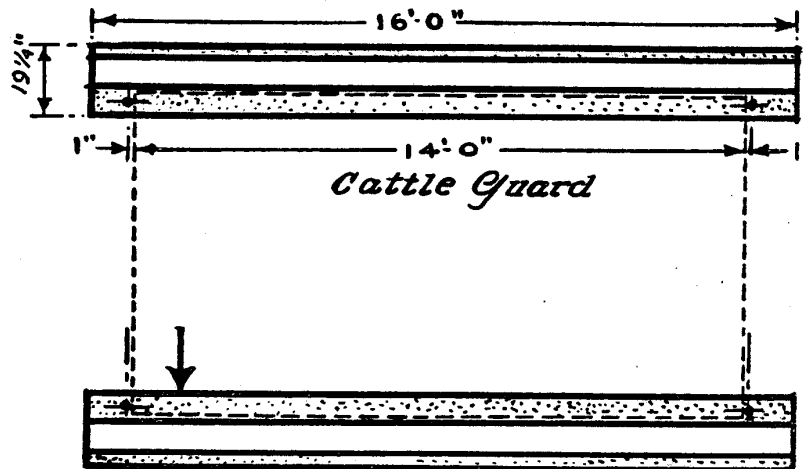
SCALE: AS NOTED



END ELEVATION



ELEVATION

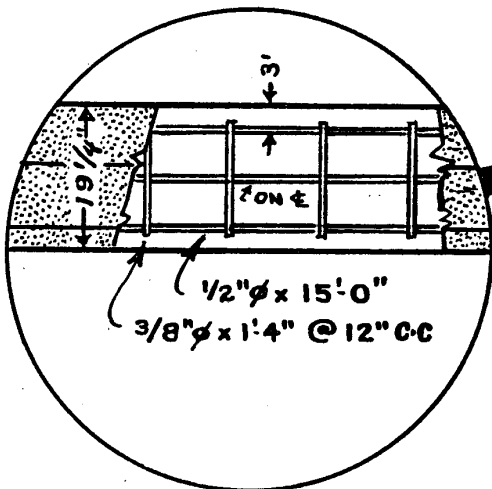


PLAN VIEW

SCALE: 1/4" = 1' 0"

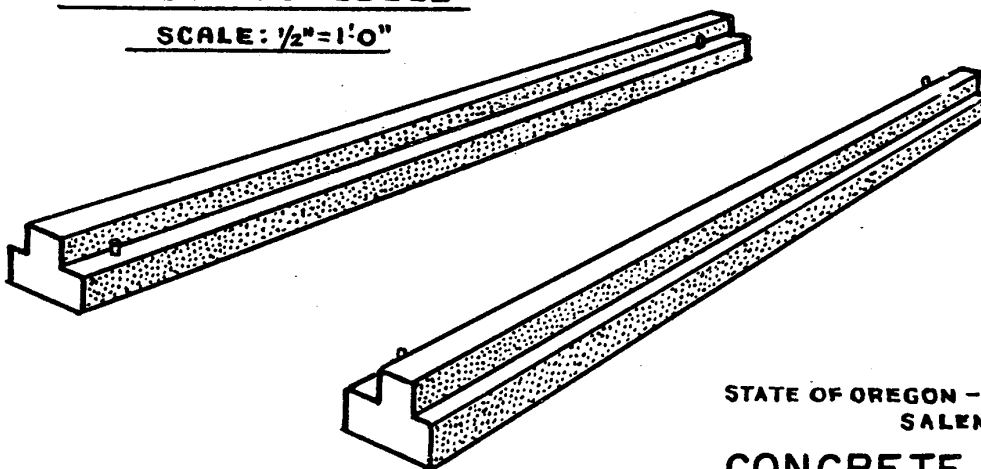
FORM MATERIAL LIST

ESTIMATED CONCRETE 3 CUBIC YARDS		
4 PCS. OF 2" x 12" x 16' 0"	_____	S4S
2 PCS. OF 2" x 12" x 16' 0"	_____	S4S END TIES
4 PCS. OF 2" x 10" x 16' 0"	_____	S4S
2 PCS. OF 2" x 8" x 18' 0"	_____	S4S
2 PCS. OF 2" x 4" x 16' 0"	_____	S4S
6 PCS. OF #4 - 1/2" ϕ RE-BAR	15' 0" LONG	
30 PCS. OF #3 - 3/8" ϕ RE-BAR	1' 4" LONG	
4 PCS. OF 3/4" ϕ x 9" DOWEL PINS (STEEL)		



STEEL SCHEDULE

SCALE: 1/2" = 1' 0"



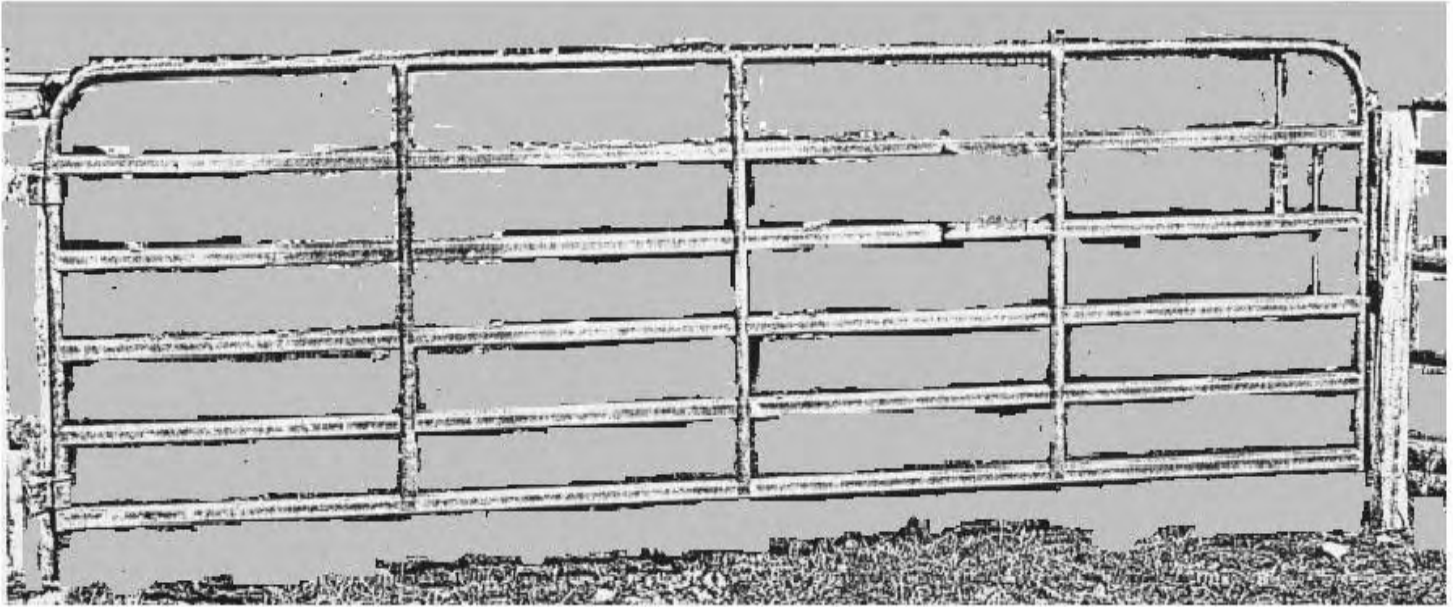
PERSPECTIVE

STATE OF OREGON - DEPARTMENT OF FORESTRY
SALEM, OREGON

CONCRETE FOUNDATION

FOR:

METAL CATTLE GUARD



52-IN. AND 60-IN. CLASSIC GATES

Heavy Duty "Classic" Gates are famous for their strength. Use them with confidence for your toughest corralling job. The heavy duty steel horizontal rails, with their exclusive pentagonal design, will take an amazing amount of abuse from crowding cattle, then spring back to their original shape. The heavy duty 180° swing hinges are the best in the industry, and standard equipment on all gates. They are made of 1/4-in. x 3-in. steel, and are easily adaptable to round and square wooden posts, or welded to steel posts. Two latches are available: a double-pin slide with lever for maximum gate strength, or a 24-in. chain with keeper. Vertical stays are welded to each side of the gate, at each rail, for added strength.

SPECIFICATIONS

- Height — 52 in.
- Frame — 1.66-in. O.D. Tube
- Horizontal Rails — 5 Pentagonal
- Hinges — 1/4-in. x 3-in. - 180° Swing
- Latch — Double-Pin Slide with Lever, or 24-in. Chain with Keeper
- Stays — 1-8 ft. & 10 ft., 2-12 ft. & 14 ft., 3-16 ft., 4-18 ft. & 20 ft.

LEVER LATCH

52" Order No.	LENGTH
32-003	3'
32-004	4'
32-006	6'
32-008	8'
32-010	10'
32-012	12'
32-014	14'
32-016	16'
32-018	18'
32-020	20'

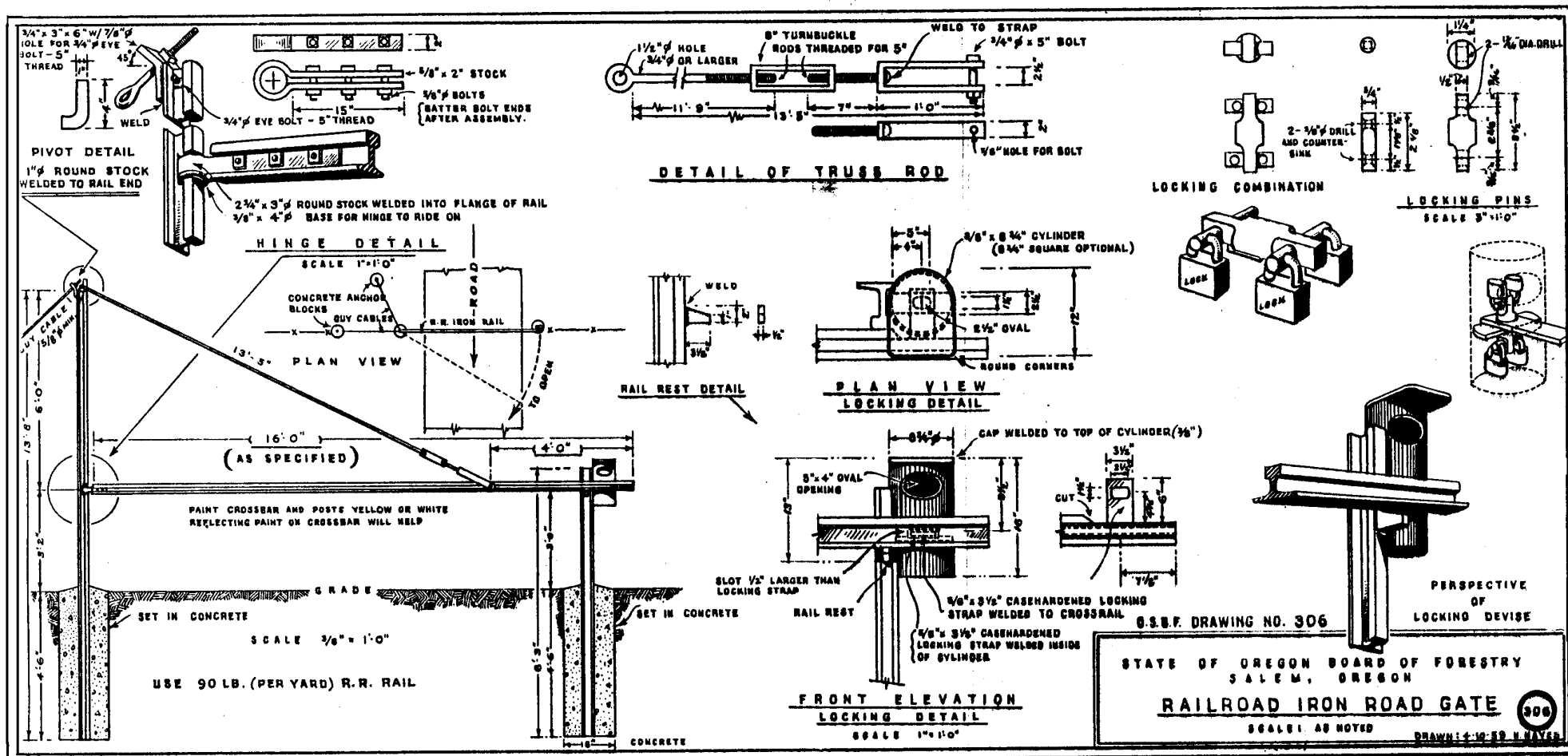
Chain latch price

WEIGHTS

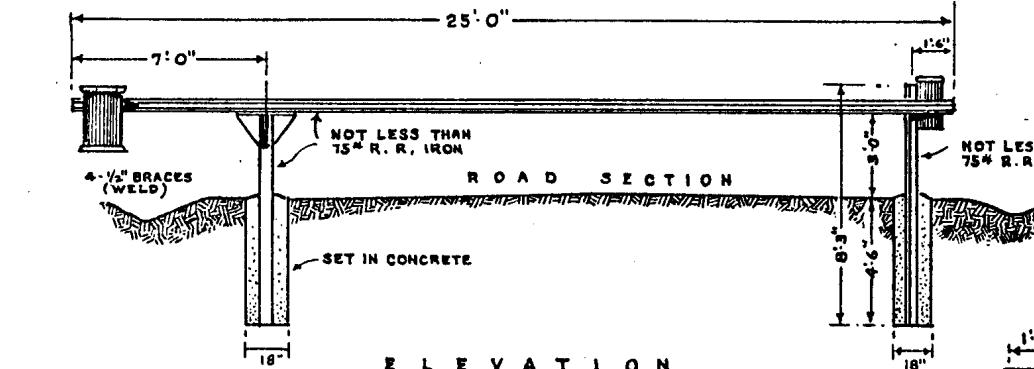
52 in.	60 in.
52 lbs.	-
61	63 lbs.
77	79
101	104
118	121
142	146
158	162
182	187
202	-
220	-

Refer to Price Sheet for order numbers of Chain Latch & 60 in. Gates.

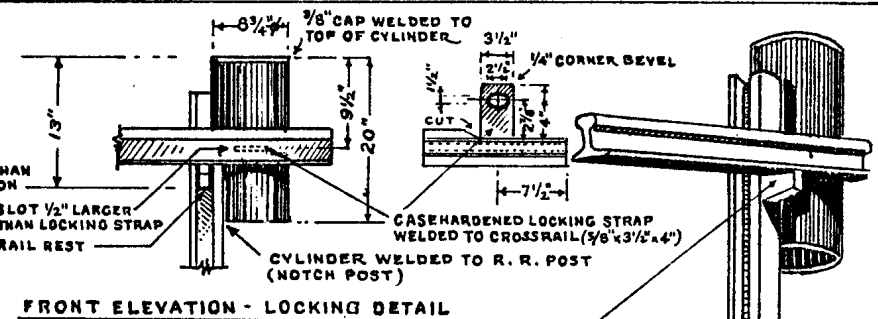
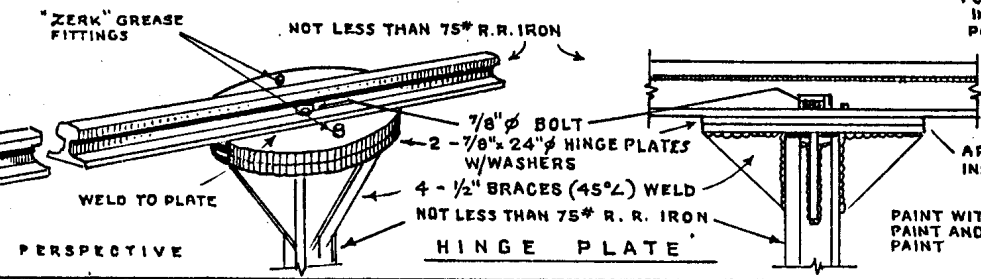
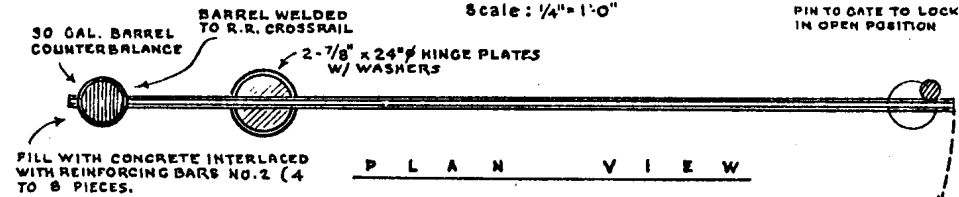
60 IN. CLASSIC GATES



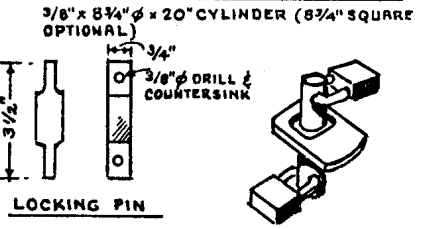
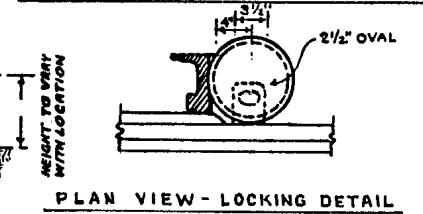
306-B



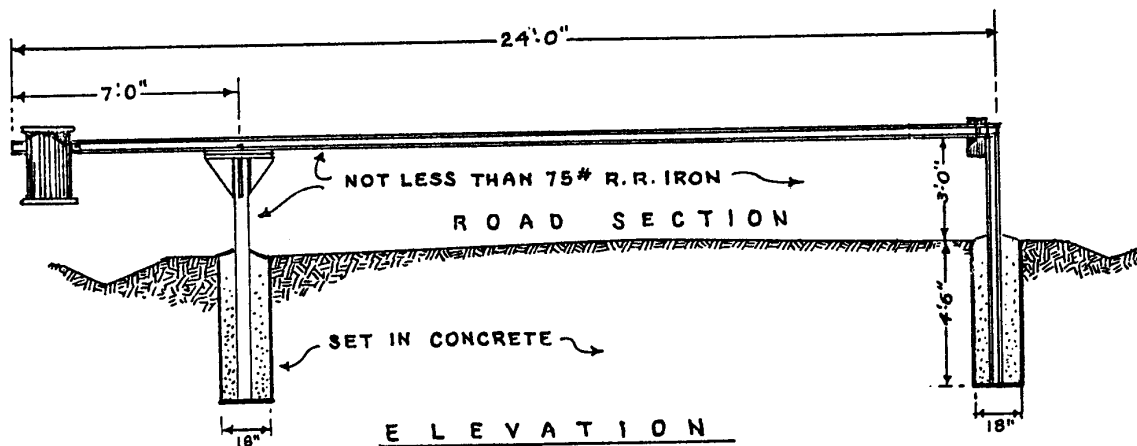
ELEVATION
Scale: 1/4" = 1'-0"



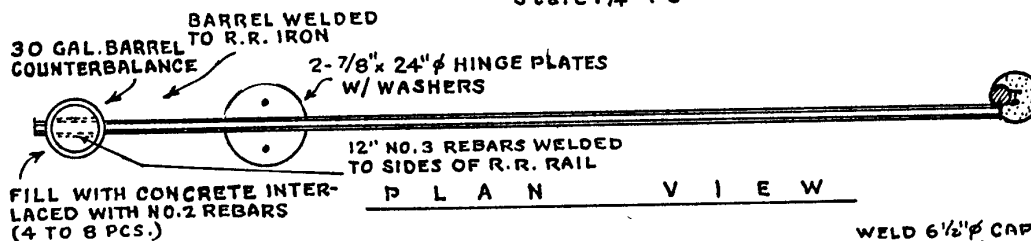
FRONT ELEVATION - LOCKING DETAIL



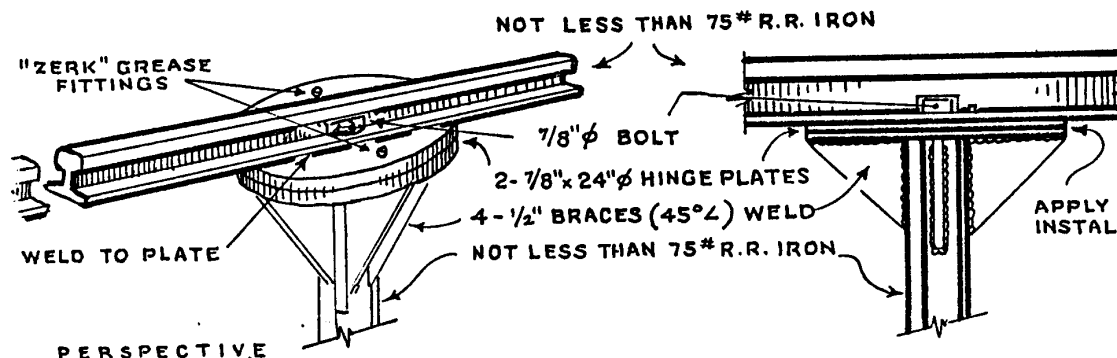
STATE OF OREGON - DEPARTMENT OF FORESTRY
SALEM, OREGON
COUNTERBALANCED RAILROAD IRON ROAD GATE
SCALE: AS NOTED
306-
10-21-75 H.R.



ELEVATION
Scale: 1/4"=1'-0"



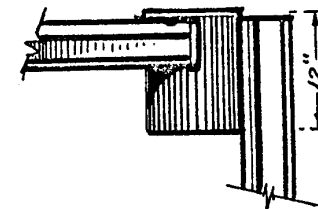
PLAN VIEW



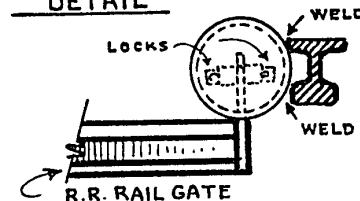
PERSPECTIVE

HINGE PLATE

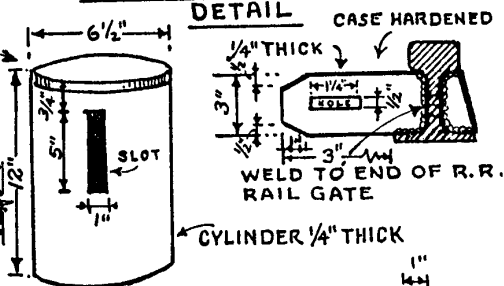
PAINT WITH TWO COATS OF RUST RESISTANT PAINT
AND ONE COAT OF FLUORESCENT RED PAINT.



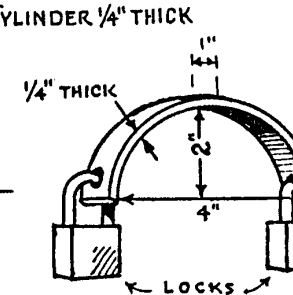
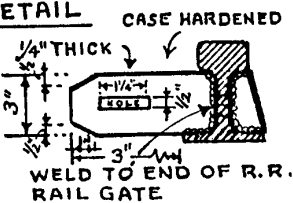
**FRONT ELEV. LOCKING
DETAIL**



**PLAN VIEW - LOCKING
DETAIL**



NO SCALE



STATE OF OREGON - DEPARTMENT OF FORESTRY
SACEM, OREGON
COUNTERBALANCED RAILROAD IRON ROAD GATE
SCALES: AS NOTED
OSBF DRAWING NO. 306-C 10-29-75 H. HAYES

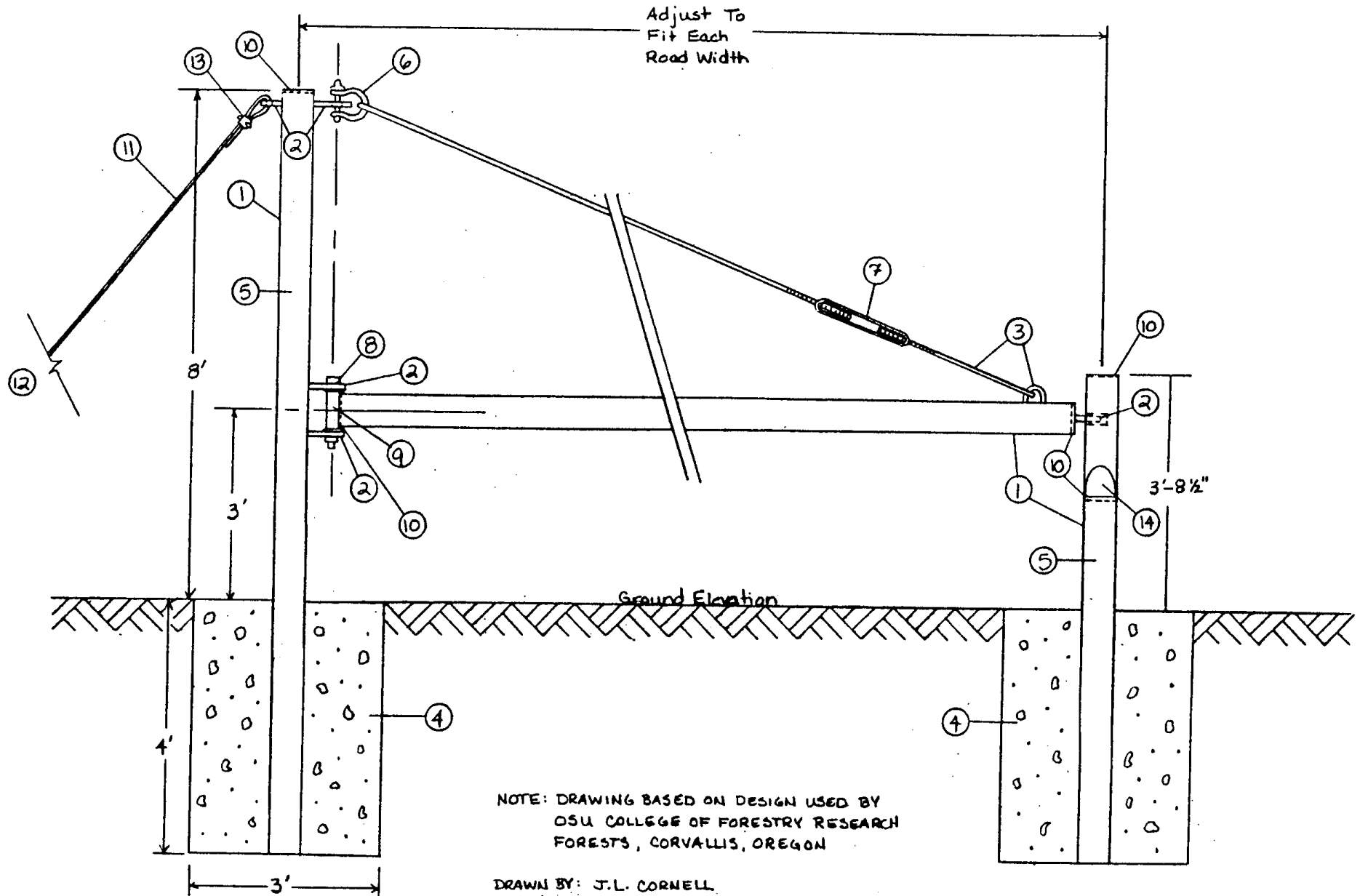
306
C



DRAWING NO.
306-D

STEEL TUBE GATE

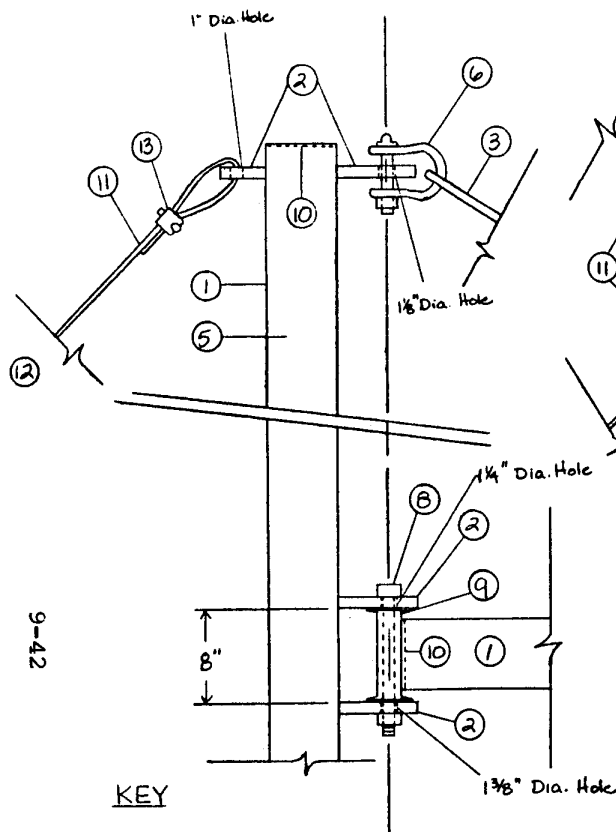
SCALE: AS NOTED DATE: 6-1-89



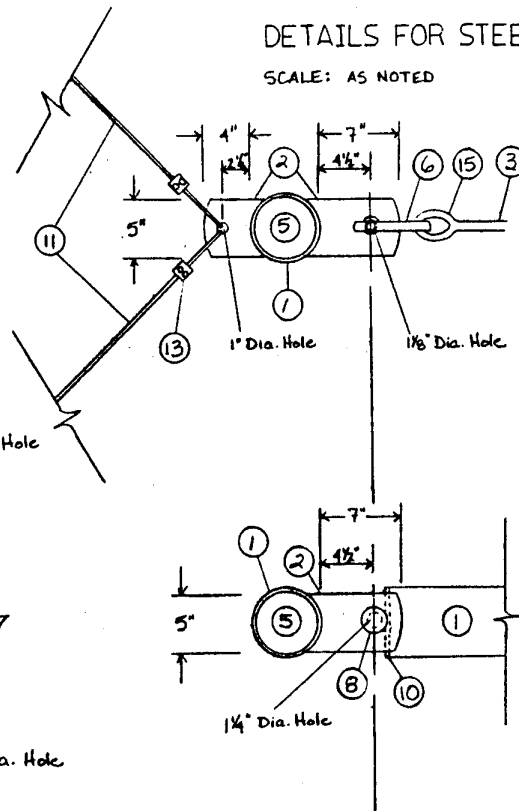
DETAILS FOR STEEL TUBE GATE

SCALE: AS NOTED

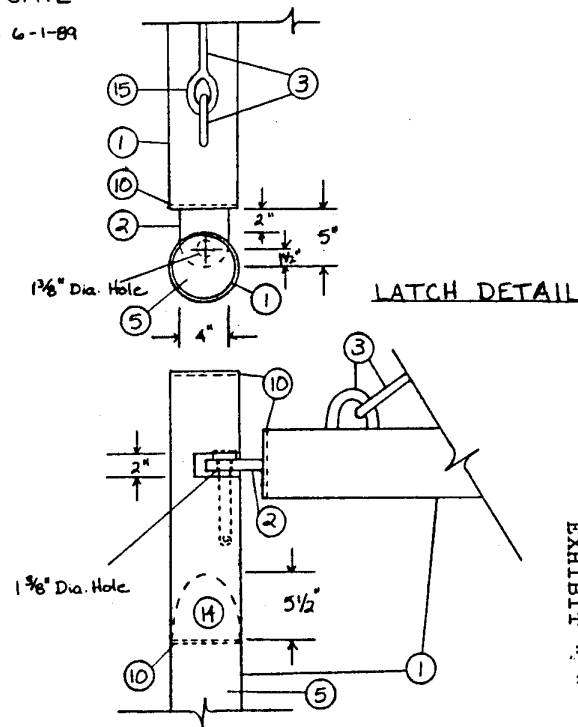
DATE: 6-1-89



KEY

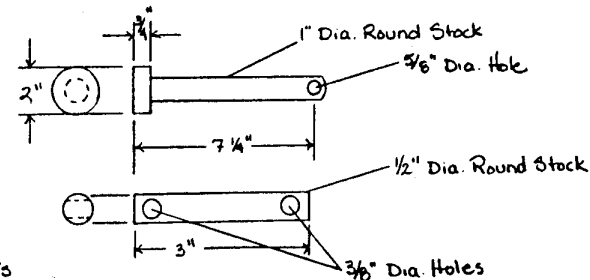


HINGE DETAIL



LATCH DETAIL

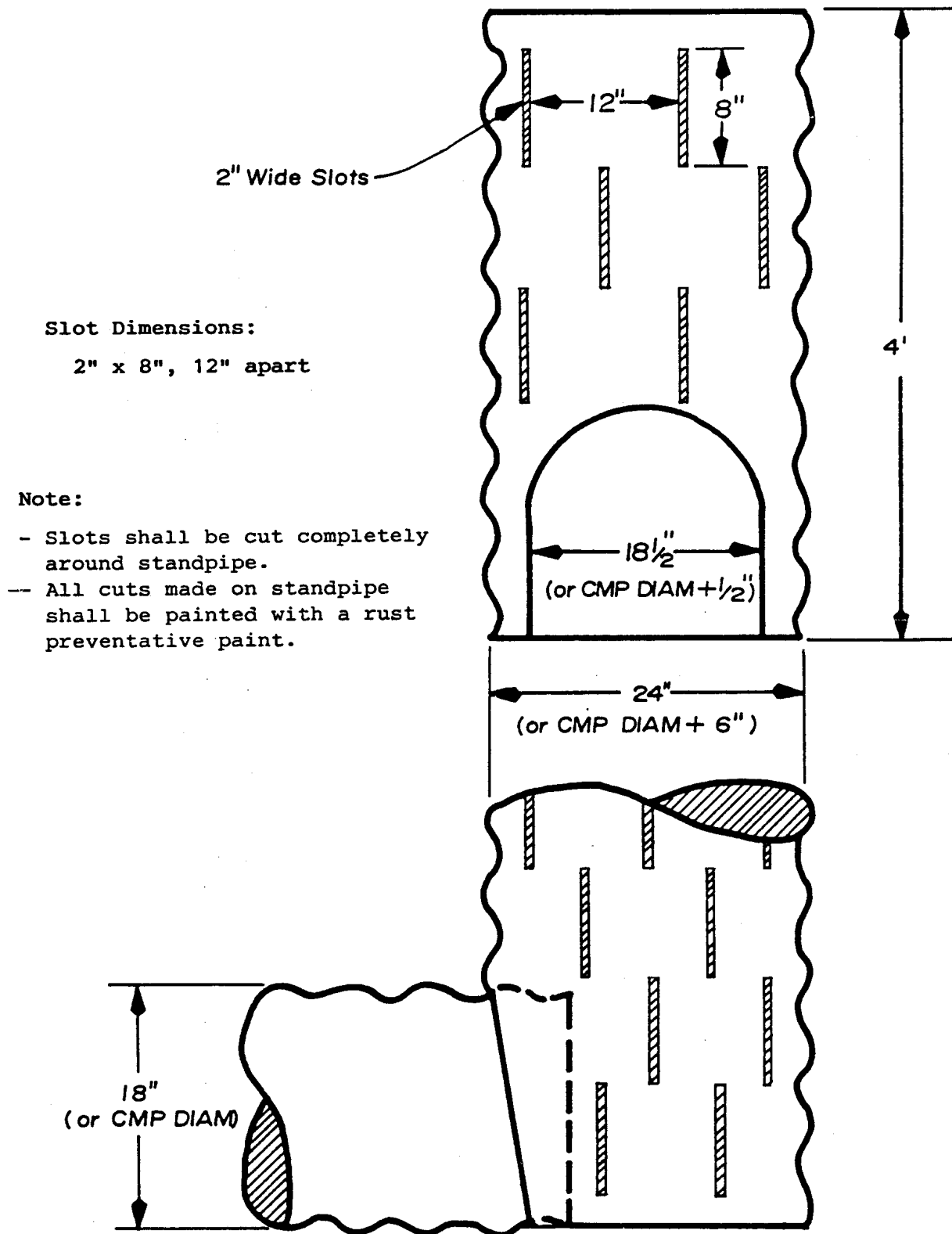
LOCK-PIN WITH CROSS-PIN

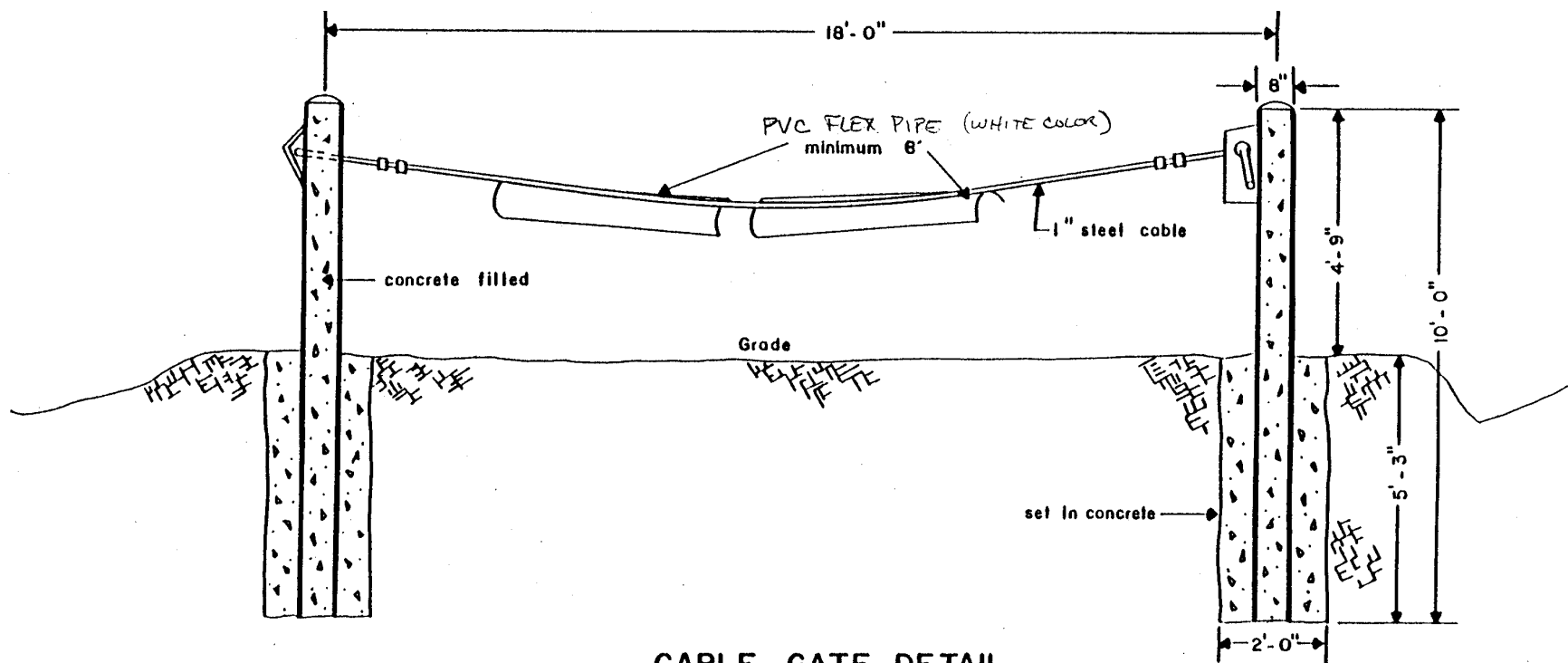


- ① - 6" Dia. Steel Well Casing
- ② - 1" Thick Steel Flat Stock
- ③ - 3/4" Steel Round Stock
- ④ - Concrete Base
- ⑤ - Concrete-Filled Post
- ⑥ - 3/4" Shackle With Welded On Nut/Pin
- ⑦ - Turnbuckle
- ⑧ - 1" Dia. x 13" Steel Bolt With Welded On Nut
- ⑨ - 2" Dia. x 7 1/2" Steel Tube With A 3" Dia. Washer Welded On Each End; The Tube Is Welded On To The End Of The Cross Member
- ⑩ - 1/4" Steel Flat Stock Welded On Ends Of Well Casing As A Cap/Plate
- ⑪ - Guylines: Min. 3/8" Dia. Wire Rope; Ends Secured With Welded On Linc Clamps
- ⑫ - Guyline Anchors: Guylines Are To Be Secured To Something Solid And Permanent; Trees Greater Than 6" In Dia Are Acceptable
- ⑬ - Opening To Access Lock-Pin
- ⑭ - Welded Eye

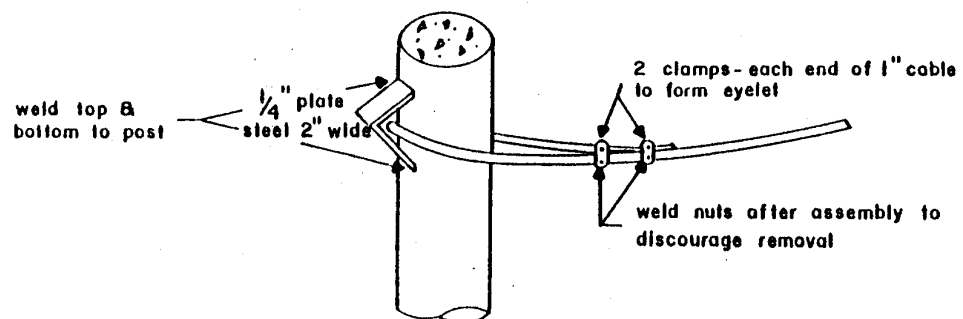
EXHIBIT " "

Typical Culvert Slotted Standpipe Detail

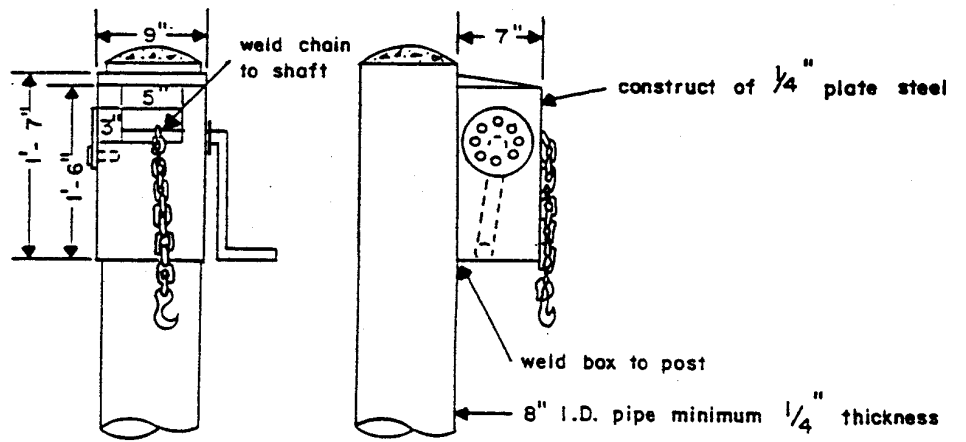




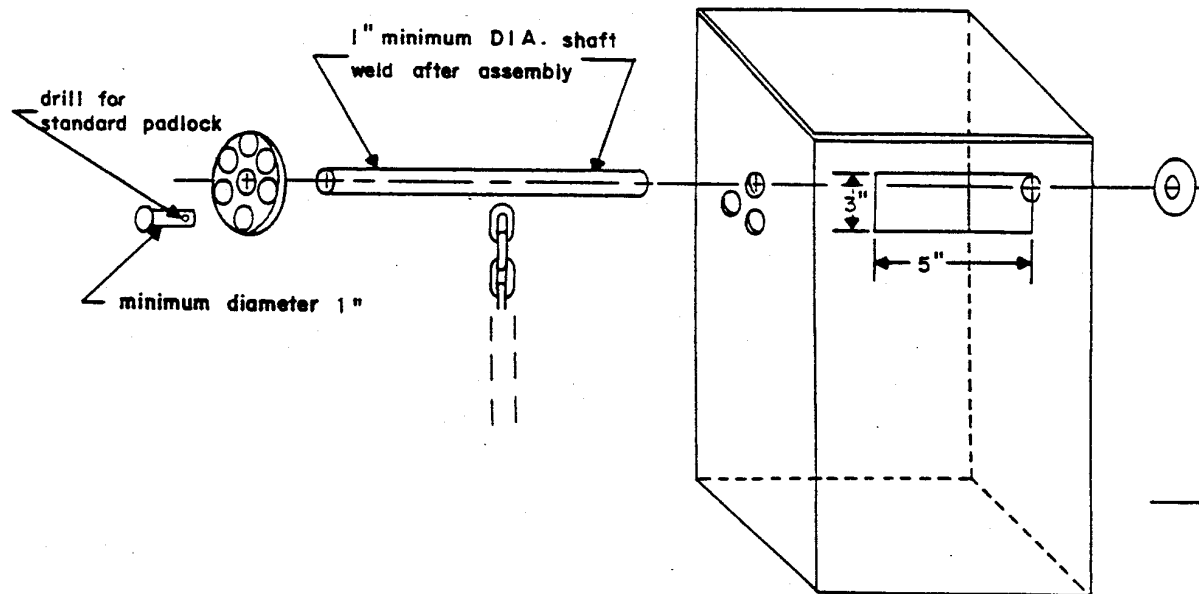
CABLE GATE DETAIL



GATE PLAN



LOCK DETAIL



Appendix 3. Costs Related to Road Construction/Improvement

Appraisal Policy Statement	2
Clear and Grub Costs	3
Excavation Costs	4
Brush Cutting	5
Subgrade Treatments	6
Equipment/Operator Rates	7, 8
Culvert Costs.....(2-2/3 X 1/2 in. corrugations)	9
Move in and set-up Costs.	10, 11
Mileage adjustment factors for move in	12
Railroad Iron, Powder River and steel tube gates	13

APPRAISAL POLICY STATEMENT

The cost appraisal policy in this section shall be concerned only with road construction items.

The appraisals shall be made as fairly and impartially as possible with due consideration for prevailing rates for equipment and labor; size and quantity of equipment available; terrain and material types in which equipment will be working.

Unless otherwise stated, all costs and factors include 17% for profit, risk, overhead, and bonding; and 18% for the labor surcharge.

Cost Establishment Procedure

Direct cost items are provided which are up to date as nearly as practicable. Because of outdating and possible wide variation of conditions from the average, basic rates of time and quantity are supplied which will enable said cost items to be updated or modified with a minimum of effort.

Instructions on the use of tables and cost rate items are included with said tables and rates to facilitate their use.

Where the appraiser needs to know the cost of ownership of equipment or structures he/she should refer to textbooks on computation of Average Annual Investment.

No attempt has been made at this time to break down certain contract items, such as fencing, into detailed unit costs.

For the purposes of estimating costs, the appraiser must assume an operation of average efficiency undertaken by a prudent contractor who operates in the following manner:

1. Understands the project(s) prior to signing the contract.
2. Hires trained, competent persons.
3. Supervises and communicates with his crew closely.
2. Plans seasonal operations to take advantage of weather conditions.
3. Plans to have the road construction equipment and supplies necessary for forest road construction which are of correct size to do the job efficiently, and are maintained properly to minimize time lost for repair.
4. Proceeds with various phases of road construction in a safe and workmanlike manner.
5. Allows sufficient time to do the job.

CLEARING AND GRUBBING COSTS

rev. 12-93

Base Costs/Acre In Dollars For Clearing And Grubbing

<u>Method</u>		<u>Tops & Limbs</u>	<u>Logs</u>	<u>Stumps</u>	<u>Total</u>
1. Side cast	273	30		210	564
2. Scattering	419	48		323	869
3. Piling	465	54		358	965
4. Pile & Burn	671	77		710	1604

Load and Haul to the designated waste area shall be appraised on an individual basis using time and equipment estimates.

$$\frac{\text{Base cost}}{\text{Adjustment factor}} \times \text{X} = \$ \frac{\text{Cost per acre}}{\text{acre}}$$

For explanation of Adjustment factor see "Clear And Grub" section and photos series.

Terrain	<u>Adjustment Constants</u>
Moderate- slopes up to 45%	(1)
Steep- slopes steeper than 45%	(1.1)

Cover types	
Light cover	(.8)
Medium cover	(1)
Heavy cover	(1.3)
(see photo series for guidance)	

Terrain constant__ (X) Cover constant__ = __Adjustment factor

The clearing and grubbing costs shown above represent the total per acre cost for disposal of nonmerchantable material and stumps.

Make sure that you use the correct cost for the type of method that is actually being required in the field. For example sidecast of Clear and Grub debris is one of the most common methods in use on State Forests and should not be confused with Scattering which is sometimes specified but is not actually being done. The appraiser should be familiar with the definitions and differences of these methods.

EXCAVATION COSTS

REV. 12-91

1. Basic Excavation Costs: (basic cost includes haul to 200') (Slopes over 50% may need add on cost for end hauling)

<u>Classification</u>	<u>% Sideslope</u>	<u>Base Cost</u>
A. Common (soil and loose rock 2' in diameter)	0-20	55.49 \$/sta
	0-50	1.09 \$/cy
	over 50	1.41 \$/cy
B. Boulders (rocks greater than 2' in diameter)	0-20	89.63 \$/sta
	0-50	1.73 \$/cy
	over 50	1.84 \$/cy
C. Loose Rock (Talus Material 2' in diameter with minor amounts of soil)	0-20	60.53 \$/sta
	0-50	1.21 \$/cy
	over 50	1.59 \$/cy
D. Rippable Rock	0-20	161.33 \$/sta
	0-50	2.24 \$/cy
	over 50	3.19 \$/cy
E. Solid Rock	0-20	249.48 \$/sta
	0-50	3.84 \$/cy
	over 50	5.66 \$/cy

2. Basic Add-on Costs

a. <u>Embankment Placement Method</u>	Common	Rippable
1. Side casting and end dumping.	0.00	0.00
2. Layer placement.	.15	.15
3. Layer placement (Roller Compaction).	.31	.29

b. End Haul

Cost on a time and equipment basis

2. Loading cost only

a. Excavator (w/dozer excavation)	\$1.46/cy
b. Front end loader	\$.83/cy
(or use the production computation sheets for excavators or loaders)	

3. Truck haul (use "haul cost computation sheet")

- c. Slope Rounding \$.17/L.F. (Consider any additional grubbing requirements)
- d. Subgrade Finishing (\$/Mile)

BRUSH CUTTING

Costs for brush cutters should be based on current estimates from contractors in your local area. Typical mechanical brush cutters have the following characteristics:

a. Specifications - The average reaches for a brush cutter are:

<u>Uphill @ 45°</u>	<	<u>Level</u>	<u>Downhill @ 45°</u>	<	<u>Height</u>
11 ft.		15 ft.	9 ft.		16 ft.

b. Production rates - average 3/4 to 1 mile per day brushing both sides of road.

c. Equipment and manpower

1. Brushcutter and operator
2. Pickup and laborer

d. A tractor mounted flail mower setup should run between \$45 to \$65 per hour for rough estimating.

SUBGRADE TREATMENTS

rev.12-93

Grading (\$/Mile)	<u>Surfaced</u>		<u>Unsurfaced</u>	
	common	rocky	common	rocky
1. Single lane without ditch	422	641	492	693
2. Single lane with ditch	586	731	774	949
3. Double lane with ditch	821	1128	1044	1283
4. Grid roll only	233			
5. Dips				
a. Drain Dips	138.00 \$/ea			
b. Rolling Dips	69.00 \$/ea			
Geotextiles (\$/S.Y.)	Material only		Installed	
1. Woven 500x (stabilization)	1.71		1.86	
2. Nonwoven 140n (separation)	.71		.86	

EQUIPMENT/OPERATOR RATES

rev. 12-91

Division	---- Equipment Rates ---- \$/HR.		
Equipment (Make - Model)	<u>Average</u>	<u>Standby</u>	<u>Operator(s)</u>
<u>BRUSH CHIPPERS</u>			
Brush Mower 8'	89.26		35.90
<u>COMPACTION EQUIPMENT</u>			
Vibratory Roller	36.33	8.60	34.94
Grid Roller	9.00	1.70	
Sheeps Foot	6.12	2.00	
Hand Held Tamper	1.68	.22	34.94
<u>4" DRILL & COMPRESSO</u>	45.0	12.05	(2) 70.36
<u>EXCAVATORS, CRAWLER MOUNTED (BACKHOES)</u>			
1.00 CY (225)	40.54	12.71	36.04
1.50 CY (235)	73.75	23.27	36.04
<u>GRADERS</u>			
12-G	26.26	8.32	35.90
14-G	37.35	11.75	35.90
16-G	53.93	17.0	35.90
<u>LOADERS - FRONT END/BACKHOES</u>			
1.00 CY/24" HOE	13.09	3.56	35.26
1.25 CY/30" HOE	20.06	5.67	35.26
<u>LOADERS - FRONT END</u>			
3.00 CY (950B)	35.77	5.49	35.16
4.00 CY (966D)	48.55	13.56	35.60
5.25 CY (980C)	58.96	15.36	36.68
7.00 CY (988B)	83.28	22.08	37.05
<u>SCRAPERS</u>			
11 CY (613B)	40.74	10.67	35.60
14 - 20 CY (TS14B)	76.21	21.35	35.60
<u>TRACTORS</u>			
D4	19.71	4.72	35.60
D6	35.14	8.35	35.60
D7 WINCH	59.78	15.59	35.60
D8 WINCH	91.44	25.73	35.60
D8 RIPPER	94.71	26.71	35.60

Division Equipment (Make - Model)	---Equipment Rates		\$/HR. Operator(s)
	<u>Average</u>	<u>Standby</u>	
<u>TRUCKS</u>			
Distributor Truck	45.43		33.21
Dump: 10 CY	15.32	3.59	33.21
: 12 CY	24.46	5.23	33.21
: 20 CY (Belly)	40.11	9.48	33.51
Water: 2000 Gal.	14.77	3.48	33.29
: 3000 Gal.	23.95	5.14	33.29
Lowboy	38.33	8.92	33.29
1/2 Ton P.U.	5.80	.92	33.07
3/4 Ton P.U. (Crew Cab)	6.70	1.19	33.07
1 Ton Stake	14.89	2.04	33.07
<u>CRUSHING EQUIPMENT</u> (typical 3 stage equipment)			
Jaw 22" X 36"	29.98		35.60
Cone 45" Standard	42.03		
Rolls 30" X 18" standard	21.79		
Belt 24" X 60'	12.03		
Screen 5' X 12' Triple Deck	10.34		
Apron 48" X 14' - Heavy Duty	17.39		
Grizzly 52" X 27' Vibrating feeder	21.13		
Typical cost for entire setup includes feeding equipment			
1 stage	\$312.31/hr		
2 stage	\$422.05/hr		
3 stage	\$466.21/hr		
<u>MISCELLANEOUS</u>			
CHAIN SAW: BRUSH CUTTERS	3.14		27.65
: FALL AND BUCK	3.14		28.07
ELECTRIC MOTOR 200 HP	14.66		
GENERATOR: 250 KW	21.84	2.78	35.47
: 355 KW	31.34	4.44	35.47
HYDRO-MULCHER	42.75	(2)	70.94
LOG SKIDDER - CAT 518	41.06		35.60
<u>WATER PUMPS</u>			
4" - 600 GPM	2.69	.22	34.64
- 1100 GPM	13.12	1.00	34.64
Welder, 200 AMP	8.50	.49	35.60

CULVERT COSTS PER FOOT

rev. 12-91

The following costs were derived from the USFS Cost Estimating Guide. For large projects where a full load of culverts (truck and trailer) will be ordered these costs may be reduced 20%. For small projects where only a few culverts will be needed these costs may be increased by 20%.

The cost shown is an average cost and can be used for culvert estimating without regard for culvert order size and should be within a reasonable range of the true cost.

Costs include bands and delivery				Coated corrugations	
2-2/3" X 1/2 "	Material	Material+		Material	Material+
<u>Thickness</u>	<u>Diameter(in)</u>	<u>Price</u>	<u>installation</u>	<u>Price</u>	<u>installation</u>
16 Gage	18	7.59	13.48	8.85	14.74
	21	8.86	14.75	10.33	16.22
	24	10.12	16.01	11.80	17.69
	30	12.65	19.13	14.75	21.23
	36	15.18	26.90	17.70	29.42
	42	17.71	31.61	20.65	34.55
	48	20.25	37.50	23.61	40.86

corrugations					
2-2/3" X 1/2"	Material	Material+		Material	Material+
<u>Thickness</u>	<u>Diameter(in)</u>	<u>Price</u>	<u>installation</u>	<u>Price</u>	<u>installation</u>
14 Gage	18	9.45	15.34	10.71	16.63
	21	11.02	16.91	12.49	18.38
	24	12.60	18.49	14.28	20.17
	30	15.75	22.23	17.85	24.33
	36	18.90	30.62	21.42	33.14
	42	22.05	35.95	24.99	38.89
	48	25.20	42.45	28.56	45.81
	54	38.35	48.44	32.13	52.22
	60	31.50	53.94	35.70	58.14

corrugations					
3" X 1"	Material	Material+		Material	Material+
<u>Thickness</u>	<u>Diameter(in)</u>	<u>Price</u>	<u>installation</u>	<u>Price</u>	<u>installation</u>
14 Gage	48	28.19	46.30	31.55	49.66
	54	31.72	52.81	35.50	56.59
	60	35.24	58.80	39.44	63.00
	66	38.77	65.40	43.39	70.02
	72	42.29	71.41	47.33	76.45
	78	45.81	78.52	51.27	83.98

CORRUGATED POLYETHYLENE PIPE

18	7.02	11.93
24	8.77	14.98

For pipe arches - find the cost for equivalent round pipe & add 10%

MOVE IN AND SET-UP COSTS

rev. 12-91

Equipment Allowances

Equipment Description within (\$/mile)	Move-in	Project area _____	Move (dollars)
Fire Equipment	120	N/A	
Powder House			241
N/A			
Drill and Compressor			241
N/A Cranes - 20 tons			241
N/A			
- 60 tons			533
N/A			
Graders - all sizes			241
7.05			
Loader - 1 1/2 - 2 1/2 cy			241
6.83			
- 3 cy and over			387
8.15			
Roller and Compactors			241
13.73			
Scrapers - 11 cy and under			241
4.91			
- over 11 cy			533
7.21			
Excavators, large backhoes, etc.			533
21.42			
Backhoes 24/30" Bucket (rubber tired)			241
3.52			
Tractors - D5 -7			387
18.47			
- D8			533
25.53			
Dump trucks : under 10 cy			121
2.30			
: over 10 cy			144
2.76			
Water Truck			158
3.03			
Rock Crusher (setup not included)			
1 stage			1066
2 stage			1597
3 stage			2489
Screening Plant			387

Crusher <u>setup</u>	1 stage	733	COSTS are
	2 stage	1598	complete per
	3 stage	2520	stage, don't
cost to change gradation:		207	add together
Screening Plant:		395	

THE COST TO MOVE THE EQUIPMENT TO THE PROJECT AREA WITH OR WITHOUT A LOWBOY, AS APPLICABLE, IS BASED UPON 50 MILES (ONE WAY). ADJUST COSTS, AS SHOWN ON EXHIBIT 15.

COST TO MOVE THE EQUIPMENT WITHIN THE PROJECT ARE WITHOUT THE USE OF A LOWBOY. IF THE USE OF A LOWBOY IS NECESSARY WITHIN THE PROJECT AREA, USE THE COSTS FROM THE MOVE IN COLUMN.

EXHIBIT 15
MILEAGE FACTORS
(ONE WAY MILES)

Apply to \$ / each costs obtained from move in chart

<u>DISTANCE</u>	<u>FACTOR</u>
0 - 25	0.58
30	0.66
35	0.74
40	0.82
45	0.91
50	1.00
55	1.07
60	1.15
65	1.23
70	1.31
75	1.40
80	1.48
85	1.56
90	1.64
95	1.72
100	1.80
110	1.97
120	2.13
130	2.29
140	2.46
150	2.62
160	2.78
170	2.95
180	3.11
190	3.27
200	3.44
210	3.60
220	3.76
230	3.93
240	4.09
250	4.25

GATES

Railroad Iron Gates

These gates are extensively used in many areas and many designs are available.

Four designs are shown, the rock filled barrel counterweight being very popular.

The cost is \$450-650, the 95-125 lb. rails being more expensive.

Add \$200 for installation.

Because of short sight distances on mountain roads, gates must be placed so as to allow sufficient stopping distance for traffic. If this is impossible, warning signs must be placed alongside the road 500 to 1000 feet away on one or both approaches. In addition, gates must be painted a light or fluorescent color that is highly visible. Do not use white where snow is encountered.

Quite often an information sign hung from the center of the gate can also serve to make the gate more easily detected.

<u>Powder River Gates</u>		<u>dollars</u>	
	52" X 12'	139.00	add 11% for delivery
heavy duty with	52" X 14'	153.00	
chain latch,	52" X 16'	176.00	
no installation	52" X 18'	212.00	

Steel tube Gate (see exhibit)

These are custom made gates, the approximate cost is \$1000

(see exhibit section for picture)

Cable gates will not be used on State land.

Appendix 4. Work Forms

Excavator Endhaul Production Computation - CAT 235

Cycle Time Estimating Chart

Hauling Cost Computation Sheet

Hauling Costs Instructions

Loading Cost Computation Sheet

Loading Costs Instructions

Pusher Production Sheet (For Assisting Scraper)

Pusher Production Sheet Instructions

Scraper End Haul Production Sheet

Scraper End Haul Production Instructions

Scraper Travel Time Table

Rock Pit Development And Crushing Cost Summary

Rocking Cost Computation Sheet

Summary Of All Project Codes

Summary Of Construction Cost

Volume Computation Sheet

EXCAVATOR ENDHAUL PRODUCTION COMPUTATION - CAT 235

Sale Name _____ Date _____

Road Name _____

BUCKET PAYLOAD COMPUTATION

Average Bucket Payload = (heaped bucket capacity) x (bucket fill factor)

Heaped bucket capacity for a 48" cutting width = 1.5 cy. for rock and

1.88 cy for soil (1) _____

Bucket Fill Factor:

Material	<u>Fill Factor Range</u>	
Moist Loam or Sandy Clay	1 to 1.1	
Sand and Gravel	.95 to 1	
Hard, tough clay	.80 to .9	
Rock-Well Blasted	.60 to .7	
Rock-Poorly Blasted	.40 to .50	(2) _____
Average Bucket Payload = Line (1) x Line (2)		(3) _____

CYCLE TIME COMPUTATION

Cycle time Estimate from Chart	(4) _____ sec.
LINE (4) / 60 = CYCLE TIME (100% EFFICIENCY)	(5) _____ MIN.
Operator Efficiency Correction = Line (5)/ _____	(6) _____ MIN.
Job Efficiency Correction = Line (6)/ _____	(7) _____ MIN.
Swell Factor = Line 7/.80 (if bank yards are used)	(8) _____ MIN.
Time (min.) per cubic yard = Line (8)/Line (3)	(9) _____ MIN.

COST PER CUBIC YARD COMPUTATION

Cost of Excavator and Operator per Hr./60	(10) _____ \$/MIN.
Cost per cu. yd. = Line (9) x line (10)	(11) _____ \$/cy.

CYCLE TIME ESTIMATING CHART

CYCLE TIME ESTIMATING CHART					
CYCLE TIME	MACHINE SIZE CLASS				CYCLE TIME
	215 & 215 SA	225	235	245	
10 SEC.					10 SEC.
15					15
20 SEC.					20 SEC.
25					25
30 SEC.					30 SEC.
35					35
40 SEC.					40 SEC.
45					45
50 SEC.					50 SEC.
55					55
60 SEC.					60 SEC.

Fastest Possible

Fastest Practical

Typical Range

Slow

Excellent

Above Average

Average

Below

Severe

CYCLE TIME vs

JOB CONDITION DESCRIPTION

- Easy digging (unpacked earth, sand gravel, ditch cleaning, etc.). Digging to less than 40% of machine's maximum depth capability. Swing angle less than 30°. Dump onto spoil pile or truck in excavation. No obstructions. Good operator.
- Medium digging (packed earth, tough dry clay, soil with less than 25% rock content). Depth to 50% of machine's maximum capability. Swing angle to 60°. Large dump target. Few obstructions.
- Medium to hard digging (hard packed soil with up to 50% rock content). Depth to 70% of machine's maximum capability. Swing angle to 90°. Loading trucks with truck spotted close to excavator.
- Hard digging (shot rock or tough soil with up to 75% rock content). Depth to 90% of machine's maximum capability. Swing angle to 120°. Shored trench. Small dump target. Working over pipe crew.
- Toughest digging (sandstone, caliche, shale, certain limestones, hard frost). Over 90% of machine's maximum depth capability. Swing over 120°. Loading bucket in man box. Dump into small target requiring maximum excavator reach. People and obstructions in the work area.

HAULING COST COMPUTATION SHEET

Sale Name _____ Date _____

Road Name _____

Time Computation

Basic haul cycle time per RT* for this job =

2.4 min. X _____ MRT (1) _____ minutes

Road speed time factors:

- | | | | |
|----|----------------------------|-----------------|---------|
| 1. | 40 MPH (-0.90 X _____ MRT) | (2) _____ | minutes |
| 2. | 35 MPH (-0.69 X _____ MRT) | (3) _____ | minutes |
| 3. | 25 MPH | (4) <u>0.00</u> | minutes |
| 4. | 17 MPH (+1.13 X _____ MRT) | (5) _____ | minutes |
| 5. | 10 MPH (+3.60 X _____ MRT) | (6) _____ | minutes |
| 6. | 5 MPH (+9.60 X _____ MRT) | (7) _____ | minutes |

Dump or spread time per RT (8) _____ minutes

Total hauling cycle time for this setting
100% efficiency

(9) _____ minutes

Operator efficiency correction = line 9/ _____

(10) _____ minutes

Job efficiency correction = line 10/ _____

(11) _____ minutes

TIME per cubic yard:

Hauling only, per cubic yard = line 11/ _____
cubic yard capacity of truck)

(12) _____ minutes

Delay time/cy for loading, line 10 from
loading comp. form

(13) _____ minutes

TOTAL TIME per cu. yd. = line 12 + 13

(14) _____ minutes

Cost per cu. yd. Computation

Cost of truck & operator per minute
(cost/hour divided by 60) cost /hr. _____

(15) _____ \$/minute

Total cost per cy. yd. = line 15 X line 14
\$/cy

(16) _____

RT* = round trip

MRT = MILES PER ROUND TRIP

HAULING COSTS

The following figures assume a basic haul cycle time with 100% efficiency. They must be modified to conform to the variables on any particular project.

The basic time cycle in minutes required for a dump truck travelling at an average 25 MPH to make a round trip of 2 miles is 4.8 minutes or 2.4 minutes per mile.

The variables listed below show the time factors in minutes by which the basic cycle is to be increased or decreased. Numbers in parentheses coincide with those on the work sheet.

TIME Computations

(1)	Haul distance on this setting or project multiplied by the basic time cycle of 2.4 minutes per mile from above. <u>Road speed time factors</u> (2-7)	<u>Time (minutes)</u>
(2)	<u>Highway (State or Federal)</u> paved, up to 4%, good alignment, up to 50 MPH., Av. 40 MPH.	-0.90
(3)	<u>Highway (County)</u> paved with steep grades, poor alignment, up to 45 MPH., Av. 40 MPH.	-0.69
(4)	<u>Rocked State Forest mainline or Co. road</u> , grades up to 8%, fair alignment, up to 35 MPH. Av. 25 MPH.	0.00
(5)	<u>State Forest</u> , new or rough surface up to	+1.13
(6)	10%, 17 MPH AND 10 MPH respectively	+3.6
(7)	a. <u>State Forest road spur</u> , with some grades over 10%, up to 10 MPH. Av. 5 MPH.	+9.6
	b. <u>Backing</u> (usually end hauling) Av. 5 MPH	+9.6
(8)	Dump or spread time can vary from 0.2 to 0.5 minutes. Use least time for pile dumping, or spreading of rock, and the greater time where excessive maneuvering is needed to dump end haul material over a bank.	
(9)	Add above figures algebraically to obtain 100% efficiency total haul time.	
(10-11)	Corrections to obtain true haul time: Operator efficiency - average .75 Job efficiency - average .75 to .83	

LOADING COST COMPUTATION SHEET

Sale Name _____ Date _____

Road Name _____

TIME Computation

Basic loading cycle time	(1) _____ min.
Materials time factor (plus or minus)	(2) _____ min.
Pile type time factor	(3) _____ min.
Miscellaneous items time factor	(4) _____ min.
Travel distance time factor	(5) _____ min.
<u>Total</u> loading cycle time for this setting (100% efficiency)	(6) _____ min.
Operator efficiency correction = line 6 ÷ .75	(7) _____ min.
Job efficiency correction = line 7 ÷ .75	(8) _____ min.
TIME (minutes) per cubic yard = line 8 ÷ ____ (CY capacity of loader)	(9) _____ min.

COST PER CU. YD. Computation

Cost of loader and operator per hour	(10) _____ /hr.
Operating cost per minute = line 10 ÷ 60	(11) _____ /min.
Cost per cu. yd. = line 9 X line 11	(12) \$ _____ /cy

LOADING COSTS

The following instructions are compiled from information in a publication by Caterpillar Tractor Co. entitled Caterpillar Performance Handbook, Edition 3. These figures assume 100% efficiency and must be modified to conform to the variables on any particular project.

A basic loading time cycle in minutes is the time it takes for a loader to load, dump, go through four reversals of direction, a minimum cycle travel distance of loading and dumping within its turning area, and the complete hydraulics needed to accomplish the cycle. Numbers in parentheses coincide with those on the work sheet.

TIME Computations

- (1) Basic cycles are 0.40 minutes (24 seconds) for a wheel loader and 0.33 minutes (20 seconds) for a track type or an articulating type loader

Variables and the time factors in minutes by which the basic cycle is to be increased or decreased are listed below.
- (2)

<u>Material type</u>	<u>Time (decimal of a minute)</u>
Mixed	+ 0.02
- (3)

<u>Pile type</u>	
Piled 10' and up	0.00
Piled 10' or less	+ 0.01
Dumped by truck	+ 0.02
- (4)

<u>Miscellaneous</u>	
Restricted maneuvering area	+ 0.00 to 0.04
Small Target (small hopper or truck)	+ 0.00 to 0.04
Fragile target (loading large stone)	+ 0.00 to 0.05
Normal or average digging	+ 0.06
Retaining material on road width or retrieving	+ 0.02
- (5)

<u>Loader travel distance in addition to basic cycle travel distance</u>	<u>Wheel Loader</u>	<u>Track Loader</u>
0 - 25 ft. + 0.10	+ 0.15	
25 - 75 ft. + 0.25	+ 0.28	
50 - 100 ft.+ 0.45	+ 0.33	
75 - 100 ft.+ 0.55	+ 0.45	
100 - 125 ft.+ 0.75	+ 0.53	
125 - 150 ft.+ 0.80	+ 0.70	
- (6) Add above figures algebraically to obtain 100% efficiency total loading time.
- (7-8) Corrections to obtain true loading time (self explanatory)
- (9) Time per cu. yd. to be used below in (12).

COST PER CU. YD. Computation

- (10) See equipment & labor rates
- (11-12) Self explanatory.

PUSHER PRODUCTION SHEET (For Assisting Scraper)

Sale Name _____ Date _____

Road Name _____

Equipment _____

TIME COMPUTATION

Basic pusher cycle time* (1) 1.09 min.

Operator efficiency correction = line 1 _____ (2) _____ min.

Job efficiency correction = line 2 _____ (3) _____ min.

Time (minutes) per cubic yard =
line 3 ÷ 16 (CY capacity of scraper) (4) _____ min.

COST PER CU. YD. COMPUTATION

Cost of tractor per hour \$ _____

Cost of operator per hour \$ _____

Total operating cost per hour (5) \$ _____ hr.

Operating cost per minute = line 5 ÷ 60 (6) \$ _____ min.

Cost per cu. yd. = line 4 X line 6 (7) \$ _____ cy.

*Pusher cycle time = 140% of basic load time from line 1 Scraper Endhaul
Production Sheet + 0.25 minute.

INSTRUCTIONS FOR PUSHER PRODUCTION SHEET

The following figures assume a basic pusher cycle time with 100% efficiency. They must be modified to conform to the variables on any particular project

The basic pusher cycle time consists of load, boost, return and maneuver time. Numbers in parentheses coincide with those on the work sheet.

TIME COMPUTATION

- (1) Basic pusher cycle time = 140% of basic load time + 0.25 minute.
- (2-3) Corrections to obtain true loading time (.75 = the average operator efficiency and the job efficiency range is .75 to .83).
- (4) Time per cu. yd. to be used below in line (7).

COST PER CU. YD. COMPUTATION

- (5) See equipment and labor rates section.
- (6-7) Self-explanatory.

SCRAPER END HAUL PRODUCTION SHEET

Sale Name _____

Date _____

Road Name _____

Equipment cu. yd. _____

TIME COMPUTATION

Basic load cycle time	(1) _____ .06	min.
Materials time factor	(2) _____	min.
Miscellaneous items time factor	(3) _____	min.
Basic haul cycle time per *RT	(4) _____	min.
Dump or spread time	(5) _____ .07	min.
<u>Total</u> loading and hauling cycle time for this setting (100% efficiency)	(6) _____	min.
Operator efficiency = line 6 ÷ .75	(7) _____	min.
Job efficiency correction = line 7 ÷ .75	(8) _____	min.
Load factor (swell) = line 8 ÷ _____	(9) _____	min.
Time (minutes) per cubic yard = line 9 ÷ _____ (cy capacity of scraper)	(10) _____	min./cy

COST PER CU. YD. Computation

Cost of scraper and operator / hour	(11) \$ _____	hour
Operating cost per minute = line 11 ÷ 60	(12) \$ _____	min.
Cost per cu. yd. = line 10 x line 12	(13) \$ _____	/cy

Total cost per cu. yd. for end haul project
line 13 from above + line 7 (from Pusher
Production Sheet)

(14) \$ _____ /cy

*RT - Round Trip

INSTRUCTIONS FOR SCRAPER END HAUL PRODUCTION

The following instructions are compiled from information in a publication by Caterpillar Tractor Co. entitled Caterpillar Performance Handbook, Edition 5. These figures assume 100% efficiency and Bank Cubic Yards. They must be modified to conform to the variables on any particular project.

A basic cycle time in minutes is the time it takes for a scraper to load, haul, maneuver and spread or maneuver and dump, and return. Numbers in parentheses coincide with those on the work sheet.

TIME COMPUTATION

- (1) Basic load cycle is 0.60 minutes (36 seconds) for a 621B scraper.

Variables and the time factors in minutes by which the basic cycle is to be increased are listed below.

- | | | |
|-----|----------------------|-----------------------------------|
| (2) | <u>Material type</u> | <u>Time (decimal of a minute)</u> |
| | Bank or broken | +0.04 and up (.10 normal or |
| | average | for Elliott State Forest) |

- | | | |
|-----|-----------------------------|---------------|
| (3) | <u>Miscellaneous</u> | |
| | Restricted maneuvering area | +0.00 to 0.04 |
| | Normal or average digging | +0.06 |

- (4) Basic haul cycle time per round trip is obtained from the scraper travel time table in this section.

- (5) Dump or spread time is 0.7 minutes (42 seconds) for a 621B scraper.

- (6) Add above figures algebraically to obtain 100% efficiency total cycle time.

- (7-8) Corrections to obtain true loading time.

- (9) Load factor considers material which has been disturbed and has swelled as a result of loading.

- (10) Time per cu. yd. to be used below in (13).

SCRAPER TRAVEL TIME IN MINUTES

#621B-16 CY

Haul distances Round trip in feet	2%	4%	Scraper Grade 6%	8%	10%
500	.49	.55	.60	.67	.73
1000	.69	.76	.86	.98	1.14
2000	.83	1.11	1.21	1.44	1.64
3000	1.54	1.82	2.22	2.78	3.30
4000	1.91	2.32	2.91	3.67	4.34
5000	2.26	2.75	3.55	4.49	5.37
6000	2.59	3.20	4.18	5.35	6.42
7000	2.94	3.66	4.80	6.21	7.47
8000	3.29	4.12	5.45	7.07	8.49
9000	3.66	4.56	6.06	7.91	9.49
10,000	3.98	5.01	6.89	8.25	10.66
12,000	4.67	5.90	8.00	10.56	12.80

The Caterpillar performance handbook may also be used for different sizes of scrapers and steeper grades than those listed above.

ROCK PIT DEVELOPMENT AND CRUSHING COST SUMMARY

Pit: _____ Location: _____ County: _____

Type and Size Rock: _____ Cubic Yards: _____

Scalp and Clear Overburden.....

Drill and Shoot \$_____/CU.YD. X _____ CU.YDS. = _____

Strip Rock Loose \$_____/CU.YD. X _____ CU.YDS. = _____

Load Crusher \$_____/CU.YD. X _____ CU.YDS. = _____

Crushing \$_____/CU.YD. X _____ CU.YDS. = _____

Load Dump Truck \$_____/CU.YD. X _____ CU.YDS. = _____

Msc. (haul, spread, \$_____/CU.YD. X _____ CU.YDS. = _____
 process, stockpile)

_____ \$_____/CU.YD. X _____ CU.YDS. = _____

Move in and Setup Crusher

Sub Total

Sub total ÷ Cu. Yd. = _____ Base Cost/Cu.Yd.

<u>Rd. Segment</u>	<u>Haul Cost</u> <u>Rock Cost</u>	+	<u>Processing Cost</u>	+	<u>Base Cost</u>	=	<u>Cost/Yd.</u>	<u>No. Yds.</u>
_____	\$_____/YD. \$_____		\$_____/YD.		\$_____/YD.		\$_____/YD	____YDS
_____	\$_____/YD. \$_____		\$_____/YD.		\$_____/YD.		\$_____/YD	____YDS
_____	\$_____/YD. \$_____		\$_____/YD.		\$_____/YD.		\$_____/YD	____YDS
_____	\$_____/YD. \$_____		\$_____/YD.		\$_____/YD.		\$_____/YD	____YDS
_____	\$_____/YD. \$_____		\$_____/YD.		\$_____/YD.		\$_____/YD	____YDS
_____	\$_____/YD. \$_____		\$_____/YD.		\$_____/YD.		\$_____/YD	____YDS

ROCKING COST COMPUTATION SHEET

Sale Name _____ Date _____

Road Name _____

HAULING TIME COMPUTATION

1. 50 MPH (1.20 x _____ MRT)* _____
Minutes

2. 40 MPH (1.50 x _____ MRT) _____
Minutes

3. 35 MPH (1.71 x _____ MRT) _____
Minutes

4. 30 MPH (2.00 x _____ MRT) _____
Minutes

5. 25 MPH (2.40 x _____ MRT) _____
Minutes

6. 20 MPH (3.00 x _____ MRT) _____
Minutes

7. 15 MPH (4.00 x _____ MRT) _____
Minutes

8. 10 MPH (6.00 x _____ MRT) _____
Minutes

9. 5 MPH (12.00 x _____ MRT) _____
Minutes

Dump or spread time per RT _____
Minutes

Total hauling cycle time for this setting _____
Minutes

(100% efficiency)

Operator efficiency correction = line 11 ÷ .75 _____
Minutes

Job efficiency correction = line 12 ÷ .75 _____
Minutes

Time per Cubic Yard:

Hauling only - per cubic yard = line 13 ÷ 12 _____
Minutes /cy

(CY capacity of truck)
Delay time (while loading = loading time per cubic yard) _____
Minutes /cy

Total Time per Cubic Yard = line 14 + line 15 _____
Minutes /cy

HAULING COST PER CUBIC YARD COMPUTATION

Cost of truck per hour (A) \$ _____/Hr.

Cost of Operator per hour (B) \$_____/Hr.

Total Operating Cost per hour = A + B

\$_____ Hour

Operating Cost per minute = line 17 ÷ 60
Minute

\$_____

Cost per cubic yard = line 16 x line 18

\$_____ cy

LOADING COST PER CUBIC YARD

\$_____ cy

SPREADING COST PER CUBIC YARD

Cost of Grader or Cat per hour \$_____/Hr.

Cost of Operator per hour \$_____/Hr.

Total Operating Cost per hour \$_____/Hr.

Cost per cubic yard = Cost per hour - 150 CY/Hr.

\$_____/cy

ROCK COST (From Summary of Rock Crushing Costs, or quote)

\$_____/cy

Total Rock Cost = lines 19 + 20 + 21 + 22

\$_____/cy

_____ * MRT = Mile per Round Trip

SUMMARY OF ALL PROJECT CODES

Sale Name _____

Date _____

New Construction <u>Road Segment</u>	<u>Length</u>	<u>Cost</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
TOTAL	_____	_____
S	_____	_____

Improvements <u>Road Segment</u>	<u>Length</u>	<u>Cost</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
TOTAL	_____	_____
S	_____	_____

Special Projects

TOTAL

Move In

TOTAL

Compiled By _____ Date _____

GRAND TOTAL _____

SUMMARY OF CONSTRUCTION COST

SALE _____ LENGTH const _____ sta _____ miles
ROAD _____ impr _____ sta _____ miles

CLEARING AND GRUBBING

_____ acres @ \$ _____ /acre = \$ _____
_____ acres @ \$ _____ /acre = \$ _____
_____ acres @ \$ _____ /acre = \$ _____

TOTAL CLEARING AND GRUBBING \$ _____

EXCAVATION

Unclassified _____ cy @ \$ _____ /cy = \$ _____
Other: _____ cy @ \$ _____ /cy = \$ _____
_____ cy @ \$ _____ /cy = \$ _____
_____ hrs @ \$ _____ /hr = \$ _____
_____ sta @ \$ _____ /sta = \$ _____
_____ @ \$ _____ /cy = \$ _____

TOTAL EXCAVATION \$ _____

CULVERT MATERIALS AND INSTALLATION Bands

Culverts	Size	No.	
_____ LF of _____ " @ \$ _____ /LF = \$ _____	_____	_____	@ \$ _____ /bnd = \$ _____
_____ LF of _____ " @ \$ _____ /LF = \$ _____	_____	_____	@ \$ _____ /bnd = \$ _____
_____ LF of _____ " @ \$ _____ /LF = \$ _____	_____	_____	@ \$ _____ /bnd = \$ _____
_____ LF of _____ " @ \$ _____ /LF = \$ _____	_____	_____	@ \$ _____ /bnd = \$ _____
_____ LF of _____ " @ \$ _____ /LF = \$ _____	_____	_____	@ \$ _____ /bnd = \$ _____
_____ LF of _____ " @ \$ _____ /LF = \$ _____	_____	_____	@ \$ _____ /bnd = \$ _____

Culvert Stakes

Base cost/stake \$ _____ + Install \$ _____ = \$ _____ installed cost/stake

No. of stakes _____ @ \$ _____ /STK = \$ _____

TOTAL CULVERT MATERIAL AND INSTALLATION \$ _____

SURFACING

	Size	
Subgrade _____ cy of _____	@ _____	/cy = \$ _____
_____ cy of _____	@ _____	/cy = \$ _____
Turnouts _____ cy of _____	@ _____	/cy = \$ _____
_____ cy of _____	@ _____	/cy = \$ _____
Landings & other _____ cy of _____	@ _____	/cy = \$ _____
_____ cy of _____	@ _____	/cy = \$ _____

TOTAL ROCK COST \$ _____

SPECIAL PROJECTS, Miscellaneous Material, Installation (not move in)

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

TOTAL SPECIAL PROJECTS \$ _____

GRAND TOTAL

\$ _____

Compiled By _____ Date _____

PROJECT _____

NOTES OR CALCULATIONS
 SHRINK / SWELL FACTOR _____ TOTAL UNCLASS _____
 TOTAL ROCK _____

Appendix 5. List of Useful References

1. **Oregon Forest Practices Rules and Statutes.** Oregon Department of Forestry, Forest Practices Program. January 2000 (or later version if available).

This is a complete listing of the forest practices rules and statutes that apply to state owned forestland. It provides the regulatory requirements for all forest operations including regulation for road construction, road improvement, road maintenance, and the vacating of forest roads. These regulatory requirements are the minimum standard for forest roads on state-owned forestland.

2. **Forest Practices Field Guide.** Oregon Department of Forestry. 1999

This notebook provides guidance on complying with the regulatory requirements of the Oregon Forest Practices Rules and Statutes. It is a useful field reference.

3. **Forest Road Management Guidebook.** Oregon Department of Forestry, Forest Practices Program. January 2000

This guidebook provides helpful checklists, ideas and suggestions, related to road improvement, road maintenance, and vacation of forest roads. It is useful reference when planning the repair and maintenance of forest roads.

4. **Oregon Road/Stream Crossing Restoration Guide:** Advanced Fish Passage Training Version. Oregon Department of Forestry, Spring 1999 (or later version if available)

The primary purpose of this document is to provide guidelines to managers that are assessing, planning, designing, or installing repairs or replacements for road/stream crossings that will provide for optimum fish passage. It provides useful information on the biological elements of fish passage, fish passage hydrology and hydraulics, steps in restoring fish passage, and background on culvert/bridge sizing methods. This is an important reference when repairing or replacing stream crossing that are partially or totally blocking fish passage or when installing stream crossings on new road construction.

5. **Handbook of Steel Drainage & Highway Construction Products:** Prepared under direction of the HIGHWAY TASK FORCE for Committee of Galvanized Sheet Producers Committee of Hot Rolled and Cold Rolled Sheet and Strip Producers.

This reference book provides design information on steel culverts and other drainage products as well as some other construction products. There is useful information on fill heights, pipe gages, arch pipes, structural plate culverts, coupling bands, and hydraulic formulas.

6. **Standard Specifications for Highway Construction:** ODOT State Highway Division 1996 or newer.

This reference contains useful specifications for various types of crushed rock, rip rap, drain rock, rock tests, Bridge specifications, various drainage structures, concrete specification, geotextiles and slope protection. Be careful in the use of highway specifications used for forest roads, many of these need to be altered slightly to fit forest road uses.

7. **AASHTO/ASTM testing methods:** Available from Oregon State Highway Division testing lab.

Test methods are described for various crushed rock products to test for durability, unit weight, and specific gravity, sieve analysis of fine and coarse aggregates and many other tests. These may be useful in analyzing rock sources and rock products to produce from quarries.

8. **Road Design Handbook:** A handbook prepared principally for the design of secondary roads. This 1971 book was sponsored by federal agencies such as the USFS and BLM.

This book provides instruction on some of the road design procedures and calculations. Although the book is several decades old it still contains good information on the basics of designing a forest road. Many of the hand calculations can now be done by computer, but by knowing how the hand calculations are done the reader will get a better appreciation for what goes on inside the computer program.

9. A Road Design Process for Low Volume Recreation and Resource Development Roads:
Written by Brian Kramer an Oregon State University Forest Engineering Instructor.
Available from the OSU book store.

This is much like the 1971 **Road Design Handbook** only much newer material is presented.

APPENDIX 6. ROAD TERMINOLOGY

This document includes basic road definitions needed for State Forest management. There are five different categories (classification, status, model need, surfacing, and use), as defined and categorized below, with a few additional definitions at the end of the document. These terms are used in the Roads Manual, and will also be used in the Road Information Management System currently under development. All planning and design documents should now use these terms consistently.

Classification: Existing ODF roads are classified as **mainlines, collectors, spurs** and **administrative roads**. These are the ODF roads that should be shown on road system maps. **Vacated roads and abandoned roads may be included in classification.** If planned and vacated/abandoned roads are shown on maps they must be distinguished from actual roads on all data layers and maps produced from those data layers. A long road may change classification along its length, although the vast majority of roads should have only one classification.

No fee - A public road not owned by ODF and open for highway-legal traffic. The road may be a county road or state highway.

Mainline

- Principal haul route for at least 5,000 acres (typically more) and includes all roads accessing over 20,000 (40,000 Klamath) acres (combined ODF and other landowners)
- Outlets onto a state or county public road (may pass through other landowner)
- Is surfaced with durable aggregate
- The desired running surface = 18 feet (1.5 lanes), the minimum width is 14 feet and if width is under 18 feet road must have intervisible turnouts
- The maximum grade is 18%, target under 10%
- Minimum horizontal curve radius is 70 feet with widening

Collector

- Principal haul route for at least 500 acres, over 1,000 acres in Klamath and Southwest
- Maximum of 20,000 acres accessed (over 20,000 must be a mainline)
- Maximum loads per day = 50 (can occasionally exceed this amount)
- Is surfaced with aggregate, except an option for Klamath and Southwest
- The desired running surface = 12–14 feet with turnouts at 750 feet maximum spacing
- The maximum grade is 20%, target under 13%
- Minimum horizontal curve radius is 60 feet with widening

Spur

- Maximum length of 2.5 miles until collector, mainline or off State Forests
- Access to no more than 1,000 acres
- Maximum loads per day = 40 (infrequently)
- Surfaced if expected to increase in timber sale value by more than surfacing cost, or to allow hauling that is restricted due to proximity of certain bird species.
- Target running surface is 12 feet with occasional turnouts

- Target maximum grade is 20% however grades **up to 35% are acceptable for end spur with no other alternative access (assists required, status is constrained use)**
- Minimum horizontal curve radius is 50 feet with widening

Administrative

This classification includes all other existing roads that are not essential for timber haul, those not classified as mainline, collector or spur. Examples include power-line roads, campground roads, and old fire roads that cannot be upgraded for haul. This classification **does not include vacated or abandoned roads.**

Abandoned road

A linear feature that used to be a road, but has not been used for forest management after 1973 and is currently not useable due to tree growth and/or old washouts or failures. Some trees on road surface are over 6 inches diameter. Maintenance is not required. **These roads may or may not be kept on the GIS layer at the districts' discretion, but should not be shown on maps or exhibits as roads.**

Vacated road

A linear feature that used to be a road, but has been permanently obliterated and meets forest practices vacated road standards. It needs no maintenance and should only be inspected if there is evidence of erosion in streams below the road, or a change in long term plans requiring reopening of the road. Vacating requires removal of all stream crossing fills to re-establish the original channel grade and active channel width, frequent cross ditching, and removal of fill with landslide risk. Depending on area in non-forested condition, some parts of the road should be ripped and reforested (at minimum, cross ditched locations). **Vacated roads may or may not be kept on the GIS layer at the Districts discretion, but should not be shown on maps or exhibits as roads.**

Status: Current overall road condition as it affects vehicular access

Open - A road that can now be used safely by trucks and maintenance equipment.

Constrained - Roads that are too steep or with too sharp curves, or too narrow in many locations for safe log truck use. These roads can be negotiated by pick up, at least after maintenance. Some reconstruction is needed to allow efficient log transport (contain extreme grades or extreme switchbacks) and often significant road relocation.

Blocked - Is a closed road that cannot be driven by a pick-up because of a tank trap, boulders or debris on the road, or by vegetation growing on the road. These roads should be routinely inspected if they include any stream crossings or steep fills/sidecast. They may be used as trails. Construction equipment is required to remove the blockage.

Dormant - Is blocked to motorized vehicles and stabilized in self draining condition. It contains extra waterbars and has dips near or fords at stream crossings to handle high flow events. It can be re-opened for fires or other emergencies. Dormant roads do not need routine inspections

unless there is evidence of a problem or use by vehicles. ***In the roads manual this has been labeled "partial vacation" that will no longer be used. Vacated roads should not be classified as dormant, as they should have no future use.***

Unknown - Nothing is known about status as there have been no recent inspections.

Designed - Is a planned road that has been designed for construction as project work in a timber sale or for construction by other funds. *Roads in this status, and the two that follow, should be kept as linework for transportation planning, but should not be used for publishing road maps. They may be used for exhibits, but must be labeled accordingly.*

Verified - Are planned roads that have been ground verified that a road meeting grade requirements and avoiding the most critical locations can be constructed. This includes flagging a preliminary location on-site. These are changed to a specific classification upon construction.

Unverified - A planned road that has been planned as part of the Harvest & Habitat (H & H) Model or through the district planning process for transportation planning. The road has not been field verified and there is a possibility that the road cannot be built at the location shown. Planned new roads may be relocated at any time, and are deleted as soon as a road is designed on the ground.

Model need: Is the road used in the H & H model, there are only 2 choices.

Yes - The road is used in the H & H model.

No - The road is not used in the H & H model. It may be an in unit spur or an administrative road.

Surfacing: Is the material directly supporting traffic

Dirt - A road with native soil surface that cannot be used in rainy periods by pick-ups.

Rock - A road with an aggregate surface that allows use during wet weather.

Paved - Any road with an asphalt, concrete, or chip-seal surface.

Unknown - Nothing is known about the road surfacing.

Not applicable - Applies to planned roads.

Use: When and how the road can be used

All-season - A road surfaced with durable aggregate (normally crushed rock) of sufficient depth and quality to allow use during most of the wet season without causing visible turbidity in Type F or D streams, or a paved road.

Intermediate - An aggregate surfaced road that allows wet weather use by pick-ups or occasional use by log trucks

Dry-season - Default dirt surfaced road with open or constrained status

Trail - Blocked, dormant or abandoned road that is being used as a recreational trail

None - Planned and vacated roads, or abandoned roads that are not being used as official trails.

Unknown - There is insufficient information to make a use determination.

Road Work Activities: All road work should fall into one and only one of the three categories below. This is not a road classification.

Construction - Includes both new construction, building a road in a location that did not previously have a road, and reconstruction. Reconstruction includes relocation of a pre-existing road for a distance of greater than 1,000 feet, and re-opening any abandoned road (with trees greater than 6 inches on the surface).

Improvement - Is road work necessary to bring an existing (not abandoned), older road up to current use standards. Specific improvement activities include widening; minor relocation of the road away from streams or slide areas; replacing stream crossings to current standards; adding cross drains or fill protection where needed to disconnect streams or prevent on-going erosion of the road prism, and rocking un-rocked or lightly rocked roads. Note that improvement requires filling out a notification for Forest Practices and standard filing of this document.

Replacing surfacing lost by wear is not improvement, it is maintenance.

Maintenance - includes grading, brushing, ditch and culvert cleaning, removing recent bank slough, replacing existing cross drainage culverts, and replacing aggregate lost to wear. Maintenance requires no forest practices paperwork.

Road Definitions: (may fit into one, two or all three categories)

A **forest road** is used principally for forest management activities includes any road used by truck or pick-up since 1972 and that has not been formally vacated. It does not include abandoned roads, vacated roads, planned roads, or designed roads that have not yet been constructed. Vacated roads, abandoned, planned roads and designed roads may be kept in the roads database, but shall only be displayed as needed and clearly described as vacated, abandoned, planned or designed.

A **public road** has a rock or paved surface and is open to the public, except during essential maintenance or severe weather. It is not closed by yarding or to prevent wildlife disturbance, nor is it blocked or gated. It must be passable by a 2-wheel drive sedan.

State forest roads include all roads on state forest lands except those requiring ODF to get a permit from another landowner for haul. State forest roads include roads on another ownership if the district has an easement for use with ODF primary maintenance responsibility. These two conditions describe the roads that should be summarized in any reports and used for determining state forest road mileage. Roads on ODF lands where an exclusive agreement for the roads has been given to another party, where that party is meets their responsible for maintenance are not considered state forests roads.

APPENDIX 7. ANNUAL REPORTING

These are sorted by annual reporting needs, and by longer term internal needs for determining road performance and spending efficiency. Annual reports are needed for reporting to the counties, the Land Board, and to meet Government Accounting standards (GASB34). Thus the reason to track rock and dirt roads separately, as only rock roads are reported as assets. These needs all met with the same information.

Annual Roads Report by District and County (needed by accounting, counties, DSL)

BOF Lands - Every Fiscal year (completed between July 1 and June 30)

Road Construction aggregate/paved - miles and cost

Road Construction dirt - miles and cost

Road Improvement (rock only) - miles and cost

Roads Vacated - miles and cost

New bridges built - number and cost

Bridges replaced - number and cost

Bridges removed- number

CSL Lands - Every Fiscal year (completed between July 1 and June 30)

Road Construction aggregate/paved - miles and cost

Road Construction dirt - miles and cost

Road Improvement (rock only) - miles and cost

Roads Vacated - miles and cost

New bridges built - number and cost

Bridges replaced - number and cost

Bridges removed- number

Reporting Table

FY **State Forests Road Accomplishments** District County
Land Type BOF or CSL submit two tables if road work on both land types

	<u>Aggregate/Paved Surface</u>		<u>Dirt Surface</u>		
Constructed	mi.	\$	mi.	\$	
Improved	mi.	\$			
Vacated	mi.	\$	mi.	\$	
		<u>New</u>		<u>Replaced</u>	<u>Removed</u>
Bridges	#	\$	#	\$	#

APPENDIX 8. ROCKING STATE FOREST ROADS

Issue: Road surfacing is often the most expensive item associated with road management (over half of all project costs on many Districts). Surfacing is a non-renewable resource. Current formal engineering procedures for road surfacing types and depths are impractical to use for low-volume roads, thus the need for guidance consistent with state forests plans and objectives.

Objective: To present an empirical system for management of low-volume road gravel road surfacing that integrates planning, design, construction, production, maintenance and repair.

Northwest Oregon State Forests Forest Management Plan Direction (January 2001):

ACCESS—Main access roads are surfaced with rock to provide for all-weather use and to minimize impacts from rainfall and runoff. Secondary spur roads are built to the same maintenance standards but may have lesser specifications for width and surfacing. FMP p. 2–58

ENERGY AND MINERALS—Survey, evaluate, and identify aggregate rock sources important for the long-term management needs of northwest Oregon state forests. FMP p. 4–94

LAND BASE—Minimize the amount of forest land used for roads, road corridor clearings, landings, and mineral extractions by ensuring that construction and development specifications are designed to efficiently meet management activity objectives. FMP p. 4–96

Forest Practices Rules—OAR 629-625-0700

Wet Weather Road Use

1. *The purpose of this rule is to reduce delivery of fine sediment to streams caused by the use of forest roads during wet periods that may adversely affect downstream water quality in Type F or Type D streams.*
2. *Operators shall use durable surfacing or other effective measures that resist deep rutting or development of a layer of mud on top of the road surface on road segments that drain directly to streams on active roads that will be used for log hauling during wet periods.*
3. *Operators shall cease active road use where the surface is deeply rutted or covered by a layer of mud and where runoff from that road segment is causing a visible increase in the turbidity of Type F or Type D streams as measured above and below the effects of the road.*

SUMMARY PROCEDURES: This guidance includes information on design, construction, aggregate production and maintenance and repair. Guidance is summarized on the following two pages, with the rest of the guidance providing more detail. Since aggregate is so expensive and there is also high aquatic risk from inadequate surfacing near streams, review of aggregate design work by the Engineering Supervisor and/or Unit Forester is essential.

A. Aggregate Surfacing Design

- 1) Determine road classification and/or near term use
- 2) Segment road and classify subgrade material and any existing aggregate
- 3) Categorize in-place subgrade material strength(s) using Table 1 (*pg. 4*)
- 4) Identify drainage conditions and drainage effectiveness, rated 0, 1 or 2 (*pg. 4-5*)
- 5) Determine construction period and compaction level, also rated 0, 1 or 2 (*pg. 5*)
- 6) Start with initial strength value, and add drainage or compaction effectiveness factors (each 0, 1, or 2) to get constructed subgrade strength (as constructed) from Table 2

- 7) Consider available aggregate surfacing materials (hardness, durability, gradation)
- 8) Determine aggregate depth for spur roads.
- 9) Consider use of sub-base and base reinforcement.
- 10) Consider use of geosynthetics for separation, drainage and/or reinforcement.
- 11) Add depth (to base course) for collector and mainline road classifications.
- 12) Use two-layer road rocking (base plus surface) new collector and mainline roads.
- 13) Add a 5 to 20 percent aggregate reserve to stockpiles for unexpected conditions.

B. Aggregate properties and production

- 1) Determine available quarries or rock sources.
- 2) Use the Unified Rock Classification System (URCS) to classify rock source materials and where necessary evaluate testing information.
- 3) For ODF quarries, prepare a quarry management plan and track reserve stockpiles.
- 4) Use gradation specifications based on aggregate durability and surfacing type.
- 5) Monitor rock production by visual observations. Routinely test gradation with sieve analysis, and where necessary conduct other aggregate tests.

C. Construction Practices

- 1) Verify subgrade materials used for surfacing design and identify any changed conditions after initial excavation begins and make local adjustments for aggregate depth.
- 2) Monitor moisture conditions. Avoid working when too wet or dry to effectively compact.
- 3) Grade, shape, drain and compact subgrade for maximum strength
- 4) Modify surfacing requirements when actual subgrade materials or construction practices are different from the design.
- 5) Use appropriate compaction equipment and methods for subgrade and road surfacing.
- 6) Apply aggregate in uniform depths and widths.
- 7) Process (uniformly mix and compact) aggregate in lifts not exceeding 6 inches in depth at time of placement. Avoid separation of materials.
- 8) Monitor aggregate processing and compaction. Make any corrections by loosening and processing until visual deformities cease.
- 9) Apply water during extended drying periods where necessary (most commonly used for surfacing courses and for rock products produced during dry periods and hauled directly to construction sites).
- 10) Consider use of aggregate stabilizing agents for dust abatement or improved surface course performance.

D. Maintenance and Repair

- 1) Inspect roads during heavy use and commercial operations (more frequently during wet-season periods). Maintain and inspect highest use roads more frequently.
- 2) Use reserve aggregate for corrective maintenance during initial heavy uses.
- 3) Perform maintenance only as needed – frequent grading wears out rock and may release fines.
- 4) Rutting is normal for gravel roads, so grade only when needed to protect water and the road. Remove ruts over 1½” deep and provide a safe running surface.
- 5) Plan to add rock by use (for logging **plus** rock hauling)

- 6) Use correct materials for road maintenance and repair (original aggregate or open graded repair aggregate).
- 7) High impact areas (landings, severe pumping) may require removal of deteriorated materials and replacement.
- 8) Perform highest level work for high traffic roads or where needed for resource protection.
- 9) Limit use of dirt roads to appropriate moisture conditions, and stop use prior to wet season.
- 10) Cease heavy-hauling during rapid thawing cycles, significant snowmelt, flooding and/or conditions when soils are saturated (uncommon on well drained roads).
- 11) Preserve unused reserve aggregate for uses on other roads.

Determining roads to rock by road functional use/classification

A) Mainlines should be surfaced for all-season weather use, and should be resurfaced in part based on actual traffic and resource protection.

B) Collectors should normally be surfaced for all weather use unless there is a compelling reason for not surfacing, and should be resurfaced in part based on actual traffic.

C) Spurs should be surfaced where surfacing is likely to increase timber sale value by more than the cost of the rock, as necessary for planned future forest management activity, or for timing restrictions. In addition, purchasers should also have this option (at their discretion). Spurs should be surfaced with the minimum rock necessary for the immediate use. Very steep spurs (sustained grades over 18%) have marginal traction when rocked, if rocking is essential use a 3/4 inch minus traction lift for these roads.

D) Administrative roads should be lightly surfaced or unsurfaced.

AGGREGATE SURFACING DESIGN: Surfacing depth is based on: 1) road strength, 2) traffic types and road use, and 3) current condition of existing roads. This design method considers effective road drainage (and compaction) as the primary factors affecting road strength. **For new roads, the design starts with initial soil strength, then adjusted for drainage and compaction effectiveness to determine the surfacing depth for spur roads. Design for summer (dry) building conditions unless there is a sound resource management reason for not doing so.** The aggregate depth is increased for higher use based on road classification (collectors or mainlines) and based on actual traffic if possible.

Properties of the roadbed: The properties that effect performance of the road subgrade include soil strength and drainage (moisture content), and on existing roads, the thickness and quality of the existing aggregate. These properties often vary along the road. Important properties and how they vary along the road should be evaluated during layout or design work. Break roads into segments based on significant differences in either subgrade material or drainage conditions. Short spurs often have a single segment. Longer roads typically have segments that vary between 200 and 2000 feet. Remember, two compacted inches of rock saved per station is about 12 yards. For a one mile road, this is a savings of \$5,000 to \$15,000. Also, surfacing designs are based upon the worst-case conditions that are anticipated during active road use. High traffic continual use roads require more design information than roads planned for seasonal-controlled use only.

Subgrade Material is most simply characterized by Unified Soil Classification System (USCS) and Unified Rock Classification System (URCS), at least for engineering properties. Existing

soil surveys are a source of information that may be used for initial planning. The final soil evaluation should be made in the field during design processes. Examine exposed soils in nearby road cuts and by local landforms and recognize how they change over the length of the road by landscape position. Also, it is important to use local knowledge of past performance.

Landforms with typically higher strength materials include ridgetops, and full-bench road sections. Old roads that have been modified by previous uses may also have higher strength values. Weaker soils are often found on benches and flats next to streams, with the weakest materials in wetlands. During field layout, identify seeps, wetlands, saturated soils and other wet areas. Soil strength evaluation is performed for the bearing surface only (upper 12" depth). Initial material strength is summarized in Table 1.

TABLE 1. Initial Subgrade Soil Strength (wet season in place)

Unconfined Compressive Strength (t/ft²)	Strength Category	Description	Unified Soil Classification
4	Strong	full bench in rock well graded gravels	GW, GM
3	High	other gravels	GP, GC
2	Average	well graded sands and typical forest soils	SW, SM
1	Low	poorly graded sands, normal clays	SP, SC, CL*
0.5	Weak (pumping)	silts and soft clays	CH*, ML, MH*
0.25	Very Weak	organic, wetland soils	OL*, OH*

* Effective drainage and compaction difficult, use 0 or 1 for condition ratings

Drainage effectiveness is categorized by three categories and is determined by drainage of the road as it will be constructed. When evaluating drainage, also identify stream crossings and segments that will drain to streams versus draining onto the forest floor. Some conditions can be well drained, others cannot. These are noted during segmenting of the road as described below:

Well drained (+2) Used for roads that are effectively drained. This means that there can be no seeps, springs or wetlands in the segment. In addition, positive road drainage is accomplished by:

- A. Road grades, ditch lines (ditch bottom at least 2 feet below road surface), cross drainage relief and/or cross slopes of at least 4%.
- B. Subgrades are well shaped and compacted. Cross slopes are uniform with ruts removed and concentrations of organic materials are removed.

Intermediate drainage (+1) applies to roads with drainage and cross slopes of at least 2%, and for roads that must be constructed during wet weather (not the ODF design standard). Ground water concentrations are drained and/or geotextiles membranes are used for wicking, separation and reinforcement.

Poorly drained (0) is used where drainage is ineffective or impossible, often for old roads with grades under 2%.

Compaction is accomplished with construction equipment and 3 ratings are also used, based on the likely relative subgrade density as the road is constructed. Moisture content and use of specialized compaction equipment are critical to achieve high relative density.

Well compacted (+2) means that specialized compaction equipment must be used during periods when soils are near optimum moisture content (***fine grained soils must be dry to moist, this normally occurs in summer and early fall***). This is the design standard for new mainlines and collector roads. For fine-grained soils (silts and clays) a tamping compactor and 6 inch lifts must be used. For coarse grained soils without many fines, vibratory equipment is required to obtain the well compacted condition, and moisture content is not as critical. Compaction should continue until there is no visual deflection. During compaction, it is essential that the road cross section be reestablished, with cross slopes $\geq 4\%$, (crowned, insloped or outsloped). A rating of +2 requires control of construction activity and moisture content. In western Oregon, controlled conditions for soils are limited to drier construction season periods only. **For silts and clays, a lab test must be used to monitor moisture content during compactive efforts if designed with a rating of 2.**

Mid level compaction (+1) includes roads where loaded trucks or tracked equipment are used for compaction. This also includes when work is performed during conditions when soils are moderately wet or dry. Trucks and tracked equipment must be routed over the entire road cross section. Mixing dried ravel material from cut slopes and ditches can be used to improve and dry out wet soils. Note that roads constructed during wet periods or in the winter are not well compacted (the category that follows). Again as with the well compacted condition, it is necessary to insure the road cross slopes are re-established during compaction. This is the design standard for spur roads.

Not well compacted (0) includes all roads in fine grained materials that are constructed during the wet season or wet periods. This also includes any organic (wetland type) soil during any time of the year.

Determining depth of surfacing for spur roads: Spurs should be rocked using the depth indicated in Table 2. **The depth should be just sufficient to allow completion of heavy equipment operations without loss of traction or production of significant turbidity.** Begin with the Soil strength Number (0.25 to 4), and add drainage and compaction factors if appropriate. The drainage and compaction factors are 0, 1, or 2, and for typical conditions are a given a 1. The final strength rating varies from 0.25 to 8, and if less than a whole number round down. This relative strength is related to the unconfined compressive strength. Numbers in this table may be changed as additional field evaluations are conducted. Spurs should be surfaced with a single (base-type) course, though for steep roads (over 12%) should include a traction lift (2 to 3 inches of well graded 3/4 inch minus aggregate).

Determining aggregate depth for mainlines and collectors: Mainline and collector roads require increased base course depths primarily due to heavy traffic. In addition, these roads also require a stable running surface due to the increased loading and higher vehicle speed. Therefore, it is recommended that 2 layer aggregate systems are used for mainline roads and for higher traffic level collector roads. The 2 layer system consists of a base course plus a surface (wearing) course. The surfacing course is typically constructed from finer, well-graded aggregate (Table 5). The surface course provides stability by sealing the road surface. Aggregate depth for mainline roads is increased by at least 4 inches (above spur depth) and is increased by 2 inches (above spur depth) for collector roads.

Table 2. Minimum Aggregate Depth for Low Traffic Road Based on Modified Strength

As-modified Strength	Depth without geotextile	Depth with Geotextile
≥ 7	0	X
6	4	X
5	6	X
4	8	X
3	10	8
2	14	10
$\leq 1^*$	**	***

- X - not applicable
- * - indicates likely wetland crossing, evaluate relocation options
- ** - must use on site rock or geotextile for reinforcement
- *** - consult with geotechnical specialist or state forests engineer

AGGREGATE PROPERTIES AND PRODUCTION: There is a range of useable aggregate specifications based on what the quarry is capable of producing. Ideal aggregate has hard, dense angular fragments with at least 3 sharp edges. It is well graded with a compact (not elongated/arrow) shape. Well-graded aggregate is superior because it can be compacted to a higher density than other materials and keeps water away from the subgrade, both resulting in a higher strength road surface. Single course aggregates should be well-graded and meet the specifications shown in Table 3, unless they are of marginal durability where the open graded (few fines) specifications shown in Table 4 are appropriate. Marginal, lower durability aggregate should not be used as a surface course on segments that drain to streams, but is usually acceptable as a base course, or for spurs that are not draining to streams. Use larger aggregate if the durability is marginal, as it is longer lasting. For this design method, **durable aggregate** is defined by strength bearing particles (large and intermediate sizes) with an unconfined compressive strength $\geq 9,000$ psi. **Marginal durability aggregate** is defined by strength bearing

particles with and an unconfined compressive strength ranging from 4,500 to 9,000 psi. These may be estimated by the URCS, as there is no perfect laboratory test to determine these values now. **Durable aggregate road surfacing** must be used for active use roads segments draining into streams. If non-durable aggregate is used on spurs or on other roads with light winter use, traffic must be controlled and the road periodically evaluated for FPA wet weather rule compliance (visible turbidity in Type F or D streams).

Table 3. Standard gradation specifications for a single course well-graded aggregate

Sieve size	Percent Passing			
	4 inch*	3 inch	2 inch	1.5 inch**
4	95-100	100		
3		95-100	100	
2	70-90		95-100	100
1.5		70-90		95-100
1	50-80		70-90	
3/4		50-80		70-90
1/4 or #4	30-50	35-60	50-80	40-60
#10	20-40	25-50	25-50	30-50
#40	5-15	5-15	5-20	10-20

* Standard for spur if quarry can produce it

** Standard for l-layer surfacing on higher use roads

Table 4. Standard gradation specifications for marginal durability base or single course aggregate (fewer fines)

Sieve size	Percent Passing		
	4 inch*	3 inch	2 inch
4	95-100	100	
3		95-100	100
2	70-90		95-100
1.5		70-90	
1	50-70		70-90
3/4		50-70	
1/4 or #4	15-50		20-60
#10	0-30	0-30	0-30
#40	0-10	0-10	0-10

* Standard for spur if quarry can produce it

For the surface course of a higher use road (Table 5), aggregate should contain 8-16 percent plastic fines (not just rock flour) if possible as estimated by examining the percent passing the #40 sieve (should be sticky). Without plastic fines, a surface stabilizer may be needed to prevent loss of fines during heavy summer use. Steep spurs ($\geq 12\%$ adverse grades) should receive a thin

veneer of aggregate (Table 5 specs.) to increase traction. Finer graded aggregates (1-inch and 3/4-inch minus) are better at sealing the surface and allow higher speeds and easier grading. However, they will break down under traffic more quickly than the coarser materials, so they must be durable quality and obtained from the better rock sources.

Table 5. Standard gradation specifications for durable surface course aggregate

Sieve size	Percent Passing		
	1.5 inch	1 inch	3/4 inch*
2	100		
1.5	95-100	100	
1	80-95	95-100	100
3/4	70-90	75-95	90-100
1/4 or #4	40-60	50-75	50-75
#10	25-40	25-50	30-55
#40	8-16***	8-16***	8-16***

*** Use the higher very fine percentage for road grades over 15 percent

Table 6. Gradation specifications for repair aggregate (excess fines in existing aggregate)

Sieve size	Percent Passing		
	1.5 inch	1 inch	3/4 inch*
2	100		
1.5	95-100	100	
1	80-95	95-100	100
3/4	60-80	80-95	90-100
1/4 or 4	20-50	20-40	30-60
#10	10-30	10-30	10-30
#40	0-10	0-10	0-10

Aggregate production: There are many ways to produce aggregate and rock products for road construction and maintenance activities. In some cases, rock of sufficient quality can be obtained by excavation into a road cut or other exposure. This can be placed on the road as is, or improved through processes such as blasting, ripping, screening, crushing, sorting and/or mixing. Aggregate production normally requires crushing and screening to produce consistent (reliable products) for road surfacing uses. Procedures for management of major quarries include:

1. Thorough field investigation of the rock source.
2. Classify source materials using the Unified Rock Classification System (URCS) to determine best potential products and uses.
3. Perform topographic surveys of the rock source development area(s).
4. Prepare a geologic model that displays materials distribution, plan and profiles, cross sections and initial volume calculations.
5. Verification of the geologic model by sub-surface testing (excavation, drilling)

6. Develop a quarry management plan, including aggregate/rock specifications and any special development requirements.
7. Test aggregate/rock during production, including visual and sieve analyses.
8. Monitor aggregate performance during uses.

Testing: All tests other than gradation and the URCS have limitations and can be expensive. These other laboratory tests are appropriate only where you have a specific question about the aggregate and feel a specific test can answer your question, or to determine compliance. Other tests are more appropriate for purchased rock, as we do not have control over the quarry. The two most valuable tests are the Oregon Air Degrade (TM-208) and the LA Abrasion (AASHTO T-96). Durable material should have a value under 30 percent for either of these tests. Consult the State Forests Engineer or Area Geotechnical Specialists for advice when needed.

CONSTRUCTION PRACTICES: Aggregate requires compaction after placement on the road. The standard conversion from loose in-truck rock to in place compacted inches by road width is shown in crushed rock Table 7 (compaction factor 1.3)

Table 7. In-truck aggregate required for compacted depth.

		Finished Surface Width (feet)					
Rock Depth	inches	10	12	14	16	18	20
		5	5	6	7	8	9
		9	11	12	14	16	17
		14	16	19	21	23	26
		18	22	25	28	31	35
		23	27	31	35	39	43
		28	33	37	42	47	52
		32	38	44	49	55	60
		37	43	50	56	63	69
		42	49	56	63	70	78
		46	54	62	70	78	86
		51	60	68	77	86	95
		55	65	75	84	94	104
		60	70	81	91	102	112
		65	76	87	98	110	121
		69	81	93	105	117	129
		74	87	100	112	125	138
		78	92	106	119	133	147
		83	98	112	126	141	155
		88	103	118	133	149	164
		92	108	124	140	156	173

This volume change during aggregate placement and compaction is due to air space caused by fluffing when loaded and subsequent air space removal due to compaction. The conversion from pit-run rock compacted yardage to truck yardage is 1.3 to 1.4 based on conditions of the particular pit-run source.

It is essential to reevaluate the subgrade and drainage conditions prior to rocking. In addition to the practices described on page 2, ensure that the surface (wearing) course depth for higher use roads is between 4 to 6 inches. The surface course wears out over time and depth should be based upon expected loadings over 3 to 10 year time intervals. Use staged construction methods, applying 2-4 inches lifts in the locations with the highest traffic or that show the most wear first, and then completing the project in later years to get surfacing depths over time when funds are limited. Where minimum surfacing depths are used, it's important to monitor road performance during the initial heavy road use. Aggregate must be held in reserve (stockpiled) and used to correct any problems occurring during road use by adding reserve rock to these soft spots. As a general rule, reserve aggregate should be at least 5% for spur roads and as much as 20% for mainline and collector roads. Reserve rock for mainlines and collectors should be surface course aggregate, for spurs it should be the aggregate used on that road

Geotextiles: Use geotextiles for separation where effective drainage is not possible, including where aggregate is placed on organic soils, in wetlands, flat grades (which we should not have on new roads). Geotextiles should also be used for silts and clays than cannot be effectively compacted. For spurs, use a geotextile if the final strength rating from Table 2 is no greater than 2. Even when well-compacted, silts under mainlines and collectors may pump under wet weather use, so geotextiles should be considered. Another geotextile use is to help recycle aggregate from temporary or unneeded roads. In addition, consider geotextiles when roads must be constructed or repaired outside of normal construction periods (wet periods). Specifications for separation geotextiles are shown in Table 7.

Table 7. Standard Specifications for Separation Geotextiles

High Strength Option - 6 oz/yd² – Woven Fabric

Grab Tensile Strength	300 lbs.	ASTM D4632
Puncture Strength	110 lbs.	ASTM D4833
Mullen Burst	600 psi	ASTM D3786
Width	12.5 or 16 ft.	

Mid Strength Option - 4½ oz./yd² – Woven Fabric

Grab Tensile Strength	200 lbs.	ASTM D4632
Puncture Strength	90 lbs.	ASTM D4833
Mullen Burst	400 psi	ASTM D3786
Width	12.5 or 16 ft	

Some geotextiles can improve drainage. In areas with seeps and springs, a drainage geotextile should be used. These are normally non-woven, and have a specification called permittivity. For seeps and small springs, permittivity should also be specified, normally as greater than 0.2 sec⁻¹. A higher value is appropriate for larger springs or seeps. Except for wetlands, use of a drainage geotextile will change the drainage class from 0 to +1. Other geosynthetic products (such as geogrids and drainage fabrics) may be used for specific reinforcement or drainage applications.

Changed conditions: Determine if subgrade materials used for design are those observed during initial construction. Identify any changed conditions after initial excavation begins and make local adjustments for aggregate depth. This may be a decrease or increase in required aggregate depth, and should be added to or subtracted from the aggregate reserve. Changes due to purchaser action or inaction, including if the purchaser had a dry period in which to construct the road, but instead built it during a wet period are the purchaser's responsibility. The design depth should be recalculated and the purchaser is responsible for any increased aggregate required due to this condition. On the other hand, if the purchaser constructs the road during a dry period and encounters different subgrade conditions, seeps or springs, the increased aggregate required is an ODF responsibility and taken from the design reserve. Purchasers can choose to rock spurs designed for dirt surface at their cost. These spurs must be rocked and used to FPA standards (durable surfacing on those segments connected streams)

Application: Aggregate used for road surfacing must be applied in a uniform depth and width. The maximum depth lift that can be processed is 6 inches, 8 inches when applied over geotextiles. This often requires staking the road prior to rock spreading. Aggregate must be uniformly mixed and often requires application of water for processing and compaction. This is especially true for aggregate produced and applied during dry periods. Stockpiled rock retains water and will normally require less applied water for optimum moisture content.

Resurfacing roads: Over time, the road surface weakens while the subgrade increases in strength. Evidence of need for new rock includes 1) excess fines on the surface, *especially fines the color of the subgrade, not just rock flour*; 2) frequent grading required to correct ruts and imperfections; and 3) loss of traction (loss of stability when driven by field rig when surface is wet). Gradation tests can confirm worn surfacing. If over 25 percent of the sample passes the number 40 sieve then additional replacement aggregate is probably needed. Another indicator is the loss of rock to rock contact when observing the aggregate (just below the surface). **If surface runoff discolors Type F or D streams, hauling must cease until the situation is corrected.**

Only roads with active use planned for the current or next year should be resurfaced. Since new surfacing lowers traction during dry periods, resurfacing is best done in the fall after some rain but before the subgrade reaches mid winter moisture levels. Before a major re-rocking project it is essential to estimate the existing useful depth of aggregate. This is best accomplished by digging through the existing rock surfacing (use of road graders or excavators is recommended) and determining the effective rock depth (to aggregate/subgrade contact). Effective rock depth can be zero where the entire road surface has been punched into the subgrade. Use the same subgrade strength and drainage ratings as new roads, and use a compaction rating of +1 unless the subgrade is unusually dense. Existing roads should be resurfaced with surface course material so that the total aggregate depth equals the design depth in Table 2.

When treating a surfacing with too many or too few fines, use gradation as in Table 6. In very limited cases, re-rock segments that have failed (very deep ruts, wet) by removing and replacing contaminated surfacing. Cut out defects and add leveling and reinforcement rock for uniform depth. This requires waiting until it is dry enough to drain and re-compact. If this is not possible,

use a geotextile. Do not dump crushed rock into a very soft area (only purchasers can have this option with rock they buy).

Aggregate wear rates: Heavy traffic wears out aggregate. For this design method, wear rates can be used to plan for rock replacement for mainline and collector roads. Traffic using mainlines and collectors should be tracked or estimated based on either volume or truck counts. This method is directly related to 18,000 pound equivalent single vehicle axle loads (ESAL).

This includes use by rock trucks. Each 10 c.y. rock **truck is equivalent to approximately 3 MMBF**. Based on past experience, highest quality durable aggregate wears at a rate of 1 compacted inch per 10 MMBF and marginal durability rock wears at a rate of 1 inch per 3.5 MMBF. For each mainline or collector road, rate the durability of the aggregate based on URCS investigations, laboratory tests for durability and/or past experience. For high traffic roads, plan to replace surfacing course materials after 2 to 3 inches of rock wear occurs. Past experiences indicate that surfacing course replacement typically occurs on 1 to 7 year cycles, dependent upon axle loading (heavy traffic).

Tire Pressure: Many studies have shown that aggregate wear is greatly increased by higher tire pressures. This also reduces overall road surface performance. **Tire pressure for trucks using State forests roads should be limited to 75 psi.** This is a safe pressure for operating on paved roads. For rock trucks working only on ODF roads, consider limiting tire pressures to 50 psi (but only if they do not drive on paved roads during the work period).

Aggregate recycling is a technique that Astoria District has used with success. This makes sense for roads with no current wet season uses, and roads that are being vacated, **but only if durable rock was used on that road being closed.** Astoria has found aggregate recovery rates ranging from 75 to 92 percent. Also, recovery and quality of recovered rock was improved when geotextiles were used for subgrade/aggregate separation.

MAINTENANCE AND REPAIR: Work is needed periodically to protect the road investment and minimize environmental impacts. Maintain roads before they are deeply rutted (ruts that keep water from flowing off the road). **The purchaser is also responsible to bring a mainline or collector used for logging back to original condition if logging activity has damaged the surface.** Consider the following items when monitoring and planning for road maintenance operations:

1. Grade only when necessary. Frequent grading wears out aggregate and releases fines.
2. Rutting is a normal occurrence for gravel roads. Ruts and roughness are indicators of maintenance need. If ruts exceed 1½" in depth or direct water down the road, or, surface roughness affects the ability to travel the road it's time to perform surface maintenance.
3. Re-establish positive road drainage (ditch lines, cross drainage, cross slopes, water-bars).
4. Avoid contamination of aggregate (logging debris, grass and grouser tracks).
5. Cut to depth to correct problems. Most surfacing failures are due to poor quality materials that may require removal or reprocessing to correct.
6. Add patch rock to soft and locally rutted locations.
7. Restrict heavy equipment to staging and landing areas.

8. Avoid working when too wet or too dry. Aggregate must be moist to grade to obtain uniform mix and to process rock. Aggregate processing often requires application of water for optimum moisture content.
9. For mainlines and collectors, compact aggregate for maximum density. Use specialized compaction equipment, such as vibratory rollers where necessary to restore running surfaces.

Winter weather: Snow removal by plowing should be allowed by permission only. Avoid disturbance of road surfacing by leaving a 1 inch layer of snow on the road surface. Provide drainage, avoid berms that direct water down the road surface. Avoid filling in ditch lines, culvert inlets and/or outlets. As a general rule, use of motor graders for snow removal is preferred as opposed to tracked equipment, such as a dozer.

Heavy hauling should be suspended during rapid thawing cycles, significant snowmelt or flooding. *Ceasing road use* is essential for all traffic (excluding that necessary to prevent more serious emergencies) during deep thawing period after the aggregate surface has frozen down to the subgrade. Traffic must also be controlled on all roads with marginal durability surfacing that have drainage to streams. This requires careful inspections by contract administrators during periods of moderate rainfall in order to comply with FMP water quality standards and Forest Practices wet season road use rules. All heavy uses must cease except for public safety or more serious resource damage emergencies.

Dry season stabilization: During dry weather, loss of fines as dust will destabilize the surface, affect driving safety, and affect air quality for persons living or recreating near the road. Water, magnesium chloride and lignin sulfate are most commonly used. Where available, water is cheapest in the short term and has the least environmental effects. Use of road water from a stream requires a road watering permit from the Water Resources Department. Magnesium chloride is generally considered to have minimal environmental effects if rainfall does not occur shortly after application. Lignin sulfate needs to be applied during dry periods.

Unstable Slopes Riparian Strategy

Introduction

Identification of potentially unstable slopes is an important activity in forest management. Proposed forest road alignments need to be located through terrain that is stable both from a road maintenance perspective and for long-term protection of water resources. Canopy removal from potentially unstable slopes can increase the likelihood of slope failure in some locations and can reduce the availability of large wood recruitment to the aquatic system.

This appendix discusses Oregon Department of Forestry (ODF) slope stability buffering and assessment strategies. The goal of these strategies is to manage and minimize slope instability and potential effects on aquatic resources. Potentially unstable slope classification and identification, as well as mitigation measures, are discussed.

Slope Classification and Management Practices

During timber sale planning and marketing, foresters from the local district offices, planners from the Salem planning unit, and the geotechnical specialist¹ assess the proposed harvest with respect to the slope-related strategies. Aquatic resources are protected by standard stream buffers that relate the width of the adjacent buffer to stream size, flow duration (perennial versus seasonal), and fish presence. In the case of identified slope instability features, these will often add additional buffer width or buffer length, or establish harvest modifications upland not directly adjacent to a Riparian Conservation Area (RCA). There are four types of these additional protections for aquatic resources that are slope stability related: aquatic adjacent unstable slopes, inner gorges, and upland potentially unstable slopes and their associated debris flow tracks (Table I-1 and Figure I-1).

Table I-1. Slope Buffers for Protection of Fish-Bearing Streams

Slope Classification	Characteristics	Management Practices	Buffer Above Fish Bearing When:
Inner gorge (Figure I-2)	Obvious slope breaks of >20% from moderate to steeper slopes of $\geq 70\%$ and ≥ 15 feet in height. Not to exceed widths of 170 feet from the edge of the aquatic zone.	No harvest. Leave trees within one canopy width ^a above the slope break, unless at least one conifer of the dominant cohort ^b already occupies the inner gorge, in which case leave trees only within the gorge.	Adjacent to: Type F; Perennial Type N; Seasonal High Energy ^c ; Potential Debris Flow Track ^d
Aquatic adjacent unstable slope	Unstable slope immediately adjacent to a channel, where the toe of the unstable slope interacts directly with erosive forces of a stream. Not to exceed widths of 170 feet from the edge of the aquatic zone.	No harvest. Retain trees within one canopy width above the unstable slope, unless at least one conifer of the dominant cohort already occupies the unstable slope, in which case leave trees only on the unstable portion of the slope.	Adjacent to: Type F; Perennial Type N; Seasonal High Energy; Potential Debris Flow Track

¹ The geotechnical specialist, or *geotech*, is either a professional engineer or a certified engineering geologist, licensed in the state of Oregon. See Oregon Revised Statute Chapter 672, *Professional Engineers; Land Surveyors; Photogrammetrists; Geologists*.

Slope Classification	Characteristics	Management Practices	Buffer Above Fish Bearing When:
Upland potentially unstable slopes and debris flow tracks ^e	High Hazard upland slopes: do have relatively high likelihood of slide initiation.	Retain trees within one canopy width above potential slide initiation sites, unless at least one conifer of the dominant cohort already occupies the site in which case retain trees only on the unstable portion of the slope. Apply 35-foot RCA buffer protections to entire debris flow path including underlying debris flow track.	Deliverable to Type F stream Debris-flow path may traverse other high-energy seasonal and perennial Type N segments between the potential unstable upland site and Type F stream. Applies when large woody material could become trapped within downstream segments for a time before remobilizing to potentially deliver to fish.
	Medium Hazard upland slopes: <i>may</i> have relatively high likelihood of slide initiation.	Apply 35-foot RCA buffer to underlying debris flow track.	
	Low Hazard upland slopes: do not have a relatively high likelihood of slide initiation.	No harvest modifications required on potential initiation site, debris flow track, or underlying seasonal stream. Apply ERZs on seasonal non-fish stream reaches.	N/A

^a Canopy width is the width of the canopy of an average dominant tree within the stand.

^b Dominant cohort is a surrogate. It does not imply that only one conifer of this size is needed to be delivered in case of slope failure, but rather, if a conifer of this size is present it is highly likely that there will be plenty of other species and conifer on the site to provide adequate large wood to the aquatic system.

^c High Energy Reach is a stream segment on a seasonal non-fish stream with any likelihood of large wood and gravel delivery to fish-bearing during large flow event. These are independent of potential up-channel initiation sites.

^d Debris Flow Track is a reach on a seasonal non-fish stream with any likelihood of large wood delivery via channelized debris flow to a fish-bearing stream. Remobilization by subsequent debris flow and deposition is also considered delivery. Deposition which remains in a non-fish stream is not considered.

^e See Slope Hazard and Delivery Assessment Process section below.

RCA = riparian conservation area; ERZ = equipment restriction zone; N/A = not applicable

* "Dominant cohort" is a surrogate. It does not imply that only one conifer of this size is needed to be delivered in case of slope failure, but rather, if a conifer of this size is present it is highly likely that there will be plenty of other species and conifer on the site to provide adequate large wood to the aquatic system.

**High Energy Reach is a stream segment on a seasonal non-fish stream with any likelihood of large wood and gravel delivery to fish-bearing during large flow event. These are independent of potential up-channel initiation sites.

***Debris Flow Track is a reach on a seasonal non-fish stream with any likelihood of large wood delivery via channelized debris flow to a fish-bearing stream. Remobilization by subsequent debris flow and deposition is also considered delivery. Deposition which remains in a non-fish stream is not considered.

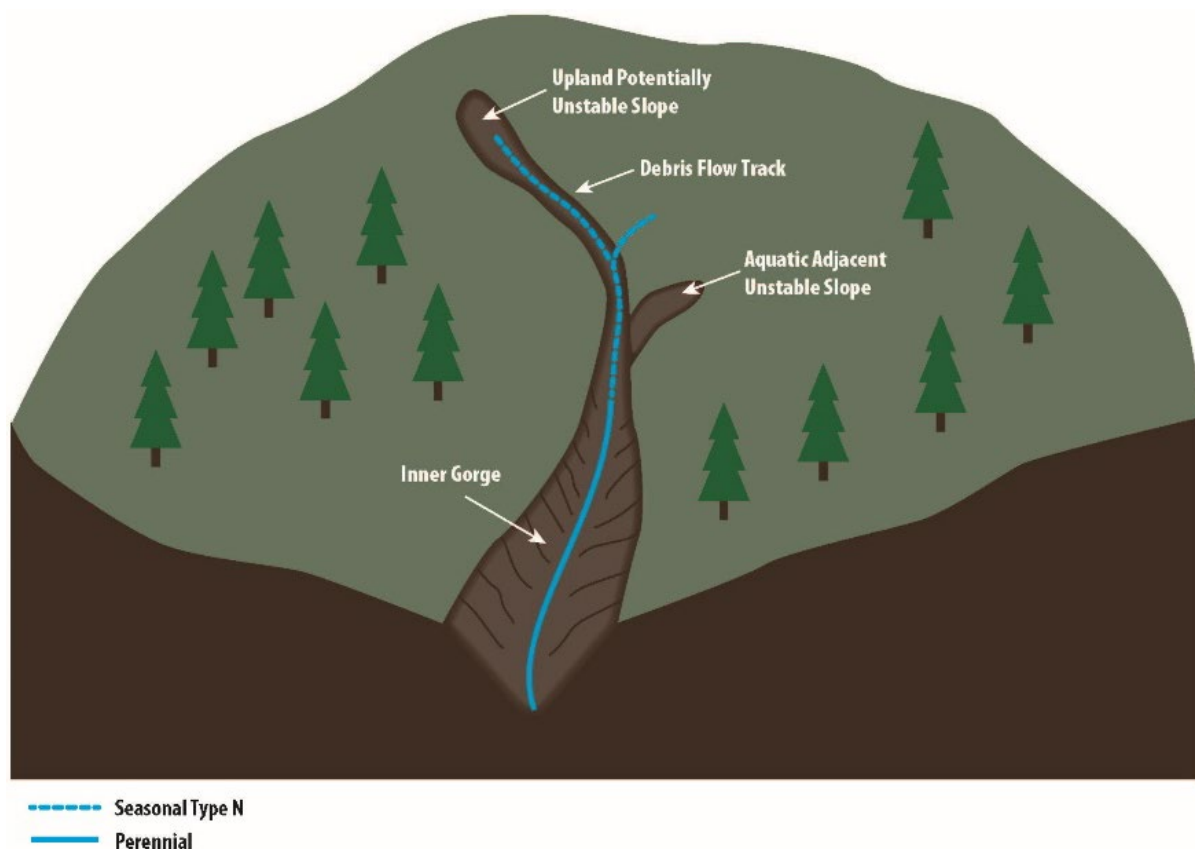
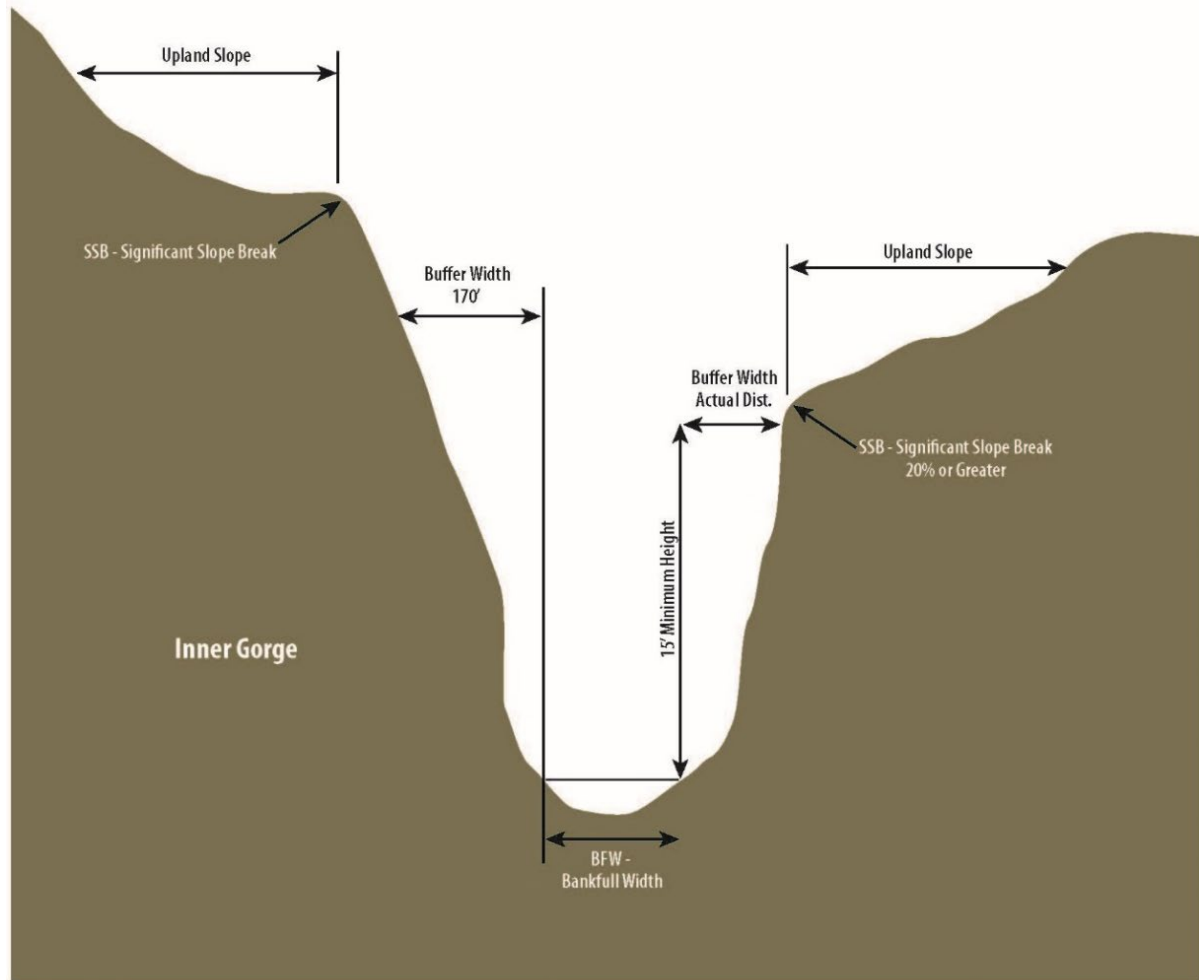


Figure I-1. Slope Features

Inner Gorge

An inner gorge is an area next to a stream where the adjacent slope is significantly steeper than the gradient of the surrounding hillsides. It is the result of downcutting of the stream into the surrounding landscape, and the resulting slope is over steepened and reacting to the erosive work of streamflow at its base. When these are identified, they are added to the adjacent stream's RCA (Figure I-2).



Limiting Distances to SSB			
Channel Adjacent Slope	Slope Distance	Max. Vertical Distance	Max. Buffer Width Horizontal
70%	207'	119'	170'
80%	219'	138'	170'
90%	229'	153'	170'
100%	240'	170'	170'

Figure I-2. Identifying Components of the Inner Gorge

Topographic Expression

This feature is defined as being at least 15 feet deep from stream bottom to top of the slope break (vertical measurement taken perpendicular to the channel bottom). The channel adjacent slope is at least 35 degrees (70%). A well-defined slope break of 20% or greater is present (e.g., if the channel adjacent slope is 70%, the next slope segment as measured at the slope break would be 50%). They are often quite large, extending quite some distance from the aquatic environment, and so are

defined at their maximum as extending not more than 170 feet from water's edge (horizontal measurement).

The slope break will be the last significant break prior to reaching the stream. The top of the steep slope defines the top of the inner gorge, and the toe of the slope where it intersects the channel bottom defines the bottom of the inner gorge. This is due to the process of its formation (discussed in *Geo-fluvial Processes*). In cases where the inner gorge takes on a more complex expression, the first significant slope break separating the gorge from the upland is also present, but below that there is often a series of very steep slopes/cliffs and small, less steep benches or talus slope sequences. In either case, soils and woody debris fall or migrate down slope in a fairly direct path and will either immediately, or eventually, interact with the stream at its base. Topography located between steep slopes and streams, such as significant benches or steep dry swales that will catch debris or halt their migration toward water, will be an indicator that the steep slopes above do not classify as an inner gorge.

Geo-fluvial Processes

The inner gorge is a slope that is reacting to the erosive work of streamflow at its base. Small slope failures and raveling soils are common in the inner gorge. The slope is steep enough—for the given site soils—that any loose material is not stable on the slope surface and is actively creeping into the active channel, or fails catastrophically to be carried away by the active channel adjacent to the slope base. If soil sluffs off the inner gorge slope, it deposits directly into the active channel, which usually moves most of the soil debris downstream within the first season.

Stream power is not always great enough and water not deep enough, however, to move woody debris downstream in many small and/or seasonal streams adjacent to inner gorges. In those cases, only the passing of a debris flow will entrain woody debris, and this is only possible along streams of steeper gradients with steep uplands that can fail to the stream-course. Sometimes slide debris from a channel adjacent slope failure will remain for a time because water tunnels through woody debris and flows beneath the debris pile, leaving the above material untouched by its erosive power.

Because of these mobile soils, forest characteristics of inner gorges are often different from the adjacent upland stand, due to the more transient nature of the soils. Often the upland stand will transition to hardwoods and underbrush as the inner gorge is encountered.

If the geologic formation is relatively consistent along the stream, the inner gorge can take on a parallel or roughly parallel expression along one or both sides of the stream (Figure I-1). In such a case the landscape is reacting to a relatively recent (geologically speaking) adjustment of either a drop in sea-level, tectonic uplift of the area, a change to a wetter climate, or large deep-seated landslide movement. These processes increase the power of the stream, enabling it to notch itself into the pre-existing landscape. This stream-side erosive notching causes the slope break at the top of the inner gorge to progressively move up slope, naturally laying back the slope until a more stable angle is obtained. Given enough time the adjacent slope would reach a stable angle appropriate for the stream power and site soils and geology.

In its more complex form, the inner gorge is controlled by varying hardness of the underlying geologic formation(s). As regional topography is uplifted, harder materials are gradually exposed or uncovered through the erosive force of local hydrology. These harder underlying materials will naturally form streamside cliffs and steep slope sequences. Often, ancient volcanic terrain is

exhumed by hydrology, eroding away less resistant marine formations, forming rugged complex terrain like in the Tillamook State Forest.

If forest occupying the flat of an old flood plain at the base of a steep slope is the same age as surrounding forest, it is unlikely that the active channel is influencing the base of the slope and, in this situation, the slope does not meet the definition of an inner gorge. If it is unlikely that the stream will be able to interact with accumulated debris or the base of the slope during the timeframe of the next harvest rotation, then harvest of the steep slope is unlikely to have a significant effect on sediment routing or wood recruitment to the aquatic system.

Steep slopes that fail (or might fail) and deposit debris on topography above the active stream do not make up part of the inner gorge if this material cannot make its way to an active channel. In the case of a flood plain that is wide in comparison to the stream under consideration, soils that could fail from the above slope should be deposited within the width of the normally active floodplain for the slope to be considered part of an inner gorge.

Aquatic Adjacent Unstable Slopes

Aquatic adjacent unstable slopes are, or have recently been, in a state of active shallow landslide failure. Movement may be creeping or catastrophic. They may have a dish or scalloped-shaped curvilinear expression outlining the upper extent of the failure surface, and vertical or horizontal ground surface offsets along the margins of the failure. The ground surface within the boundaries of the unstable slope may be irregular or hummocky. These are slopes where the toe of the unstable portion interacts directly with erosive forces of a stream. This interaction has influence on the stability of the slope. These are sometimes found within an inner gorge delineation and do not require additional protection measures. Aquatic adjacent unstable slopes tend to be small, discontinuous, and more isolated features. When these are identified on the landscape, they are added to the nearby stream's RCA. Trees on topography representative of ancient deep-seated movement would not be considered candidates for buffering. Large, active, deep-seated, slides whose toes are delineated by a stream can be considered for buffering if the timber in those stream-side locations could deliver within the timeframe of the next rotation.

Upland Potentially Unstable Slopes and Their Associated Debris Flow Tracks

These slopes are potential landslide initiation sites that are above and often not adjacent to a stream. Examples include channel headwalls (otherwise known as "zero-order basins" and "bedrock hollows"). These slopes may also include the over-steepened toes of large deep-seated landslides, or legacy sidecast along old roads. After failure, steep, confined channels below these slopes act as conduits for delivery of large wood, and coarse and fine-grained material to streams below (See Figure 1-3 through Figure I-6). The ability of the site to deliver large wood to a fish-bearing stream via a channel is considered necessary for buffering to occur (see *Determining Delivery*). If a potential landslide initiation site with a medium or high risk of failure has the ability to deliver, leaving trees and buffering are considered.



Figure I-3. Road Construction Through Headwall Depicts Deeper Soil Contained Within “U”-Shaped Bedrock



Figure I-4. Failed Headwall



Figure I-5. Channelized Debris Flow Track



Figure I-6. Large Wood, Boulders, and Coarse and Fine Grained Sediment Deposited at Confluence of Channelized Debris Flow Track and Fish-Bearing Stream

A hazard-based approach (see *Slope Hazard*) is taken in determining buffers for upland potentially unstable slopes. When evaluating this feature, the geotechnical specialist makes a determination of high, medium, or low potential for slide initiation. A high hazard site is a location that has characteristics indicating a relatively high probability of failing. A medium hazard site may have a relatively high probability of failing. Characteristics of low hazard sites indicate a lack of potential slope instability. While various data sources, models, and other analytic products (e.g., the modeled stream network developed for this Habitat Conservation Plan by Terrainworks²) are used in this assessment, the final determination of hazard is based on professional experience and field observation.

The determination to retain trees on potential initiation sites and/or apply 35-foot RCA buffers is based on the likelihood of failure and likelihood of delivering large-wood-containing debris to a fish-bearing stream. This delivery can be direct at the time of the slide initiation, or delayed as when the initial slide debris becomes lodged at a tributary junction, but then becomes remobilized by a passing debris flow in the receiving tributary some time later, and subsequently delivered to a fish-bearing stream. The process of gradual decomposition of debris flow-delivered woody debris lodged in a stream, which then routes incrementally by streamflow to a fish-bearing stream, is not considered “delivery” in this context. If a potential initiation site is deemed “high hazard” and there is any likelihood of delivery to a fish-bearing stream, then harvest modifications are required. These modifications include retaining trees on the high hazard potential initiation site, the portion of the debris flow path occupying any non-stream-featured swale above surface water flow, and establishing a 35-foot RCA buffer along both sides of the potential channelized debris flow track where there are indications of surface water flow, where an RCA is not already designated.

In the case of “medium hazard” initiation sites, harvest modification is required that establishes a 35-foot RCA buffer along both sides of the potential channelized debris flow which traverses any indications of surface water flow. Retaining trees on the potential initiation site or below the initiation site and above the upper extent of surface water flow are not required.

In the case of a “low hazard” initiation site, no harvest modification or establishment of an RCA buffer is required below the potential slide initiation site. However, the low hazard stream buffers will retain an ERZ.

Slope Hazard and Delivery Assessment Process

The assessment of slope hazard and potential delivery involve both geographic information system (GIS) analysis and field visits, which help in understanding the various factors that could be present at a particular site that contribute to slope stability hazard. Because, to have risk, there must be both a hazard (unstable slope) and a resource at risk (fish-bearing stream), the geotechnical specialist examines the landscape and considers multiple contributing factors and makes a judgment as to the *hazard* (i.e., risk of slope failure) and the *delivery* (i.e., risk of debris flow reaching fish-bearing water) for the site.

All planned clearcut harvest units will undergo GIS screening during the development of operations plans, which normally take place 1 to 3 years in advance of harvest activities. Across much of the

² Terrainworks. 2020. *NetMap and Wood Recruitment Modeling for the Western Oregon State Forest Habitat Conservation Plan*.

permit area, there is a low chance of encountering potential sites that require further analysis; however, some areas of generally steeper terrain will require additional analysis and field work to accurately assess specific sites and designate protections. In addition to areas found during screening, field staff may become aware of additional potential slope issues during harvest unit preparation activities such as road design, stream classification and designation, boundary posting, and timber cruising. Any potential slope issues discovered at any point during the planning process or preparation of the harvest unit for auction will be brought to the geotechnical specialist for further review.

A GIS review is conducted on all proposed clearcut harvests and new road alignments using ODF's GIS. Data reviewed include proposed harvest and buffer locations provided from harvest planners, orthophotographs, stream data (location, size, seasonality, fish presence), underlying geology, and digital elevation models (and associated products) derived from lidar. Paramount in the GIS review is the use of lidar topographic data, which exists for all lands west of the Cascades. Various renderings of the data are used to evaluate the steepness, shape, and texture of the ground surface, including: analysis of fine-scaled contours at; multi-directional hillshade models; slope steepness categories (as percent slope); ODF's HLHL model³; and slopeshade (a continuous representation of slope steepness, as percent slope). The modeled stream network, developed for this Habitat Conservation Plan, showing landslide initiation and delivery risk GIS products, will be also be used during this review. The desktop review often identifies locations of the four landforms described above and associated slope buffers. For upland potentially unstable slope features, delivery to fish-bearing streams can sometimes be determined during this stage of review as well. This review often identifies former landslides and areas of higher hazard that could be affected by harvest activities or that may fail in the future.

The GIS review may necessitate a field review to ground-truth a given site. Various indicators of slope hazard are not fully discernable by the desktop review and can be more fully understood in the field.

After determinations are made from either the GIS review and/or field visit, the landform is identified, and the appropriate vegetative buffer is applied to the harvest area. In the case of road alignments, recommendations often involve special best management practices or complete avoidance of an identified location.

Determining Slope Hazard

For activities such as roadbuilding and canopy removal, it is important to understand the slope hazard of the affected landscape. With such understanding, application of additional buffers and leave areas, or adjusting road location, can reduce impacts on the aquatic environment. Each of the characteristics of the landscape used to make a determination of hazard of slide initiation has a range of effect on the hazard from high to low. Table I-2 shows the relative effect of the types of landscape characteristics that can contribute to slope stability. They can be used collectively to determine stability, or if a particular site seems predominantly influenced by just a few characteristics, then the geotechnical specialist can weigh those as more important to inform the decision. In most cases, relative hazard is determined by a smaller set of features that are

³ High Landslide Hazard Location GIS model. Created from Lidar DEM. Slopes longer than 30 feet and $\geq 80\%$ or $\geq 70\%$ for convergent topography. In forests underlain by the Tyee Formation slope thresholds are 5% less. Thresholds determined from recommendations from ODF's 1996 storm report and issue paper.

themselves the net result of multiple factors shown in Table I-2, namely slope steepness, topographic and timber indications of instability, and slope shape. Regardless of which factors predominate in any given analysis, the result is a judgment on the potential hazard associated with the potentially unstable slope.

Table I-2. Hazard Evaluation Landscape Characteristics Used to Evaluate a Potential Unstable Slope for the Initiation of a Shallow Rapidly Moving Landslide

Factors Determining Hazard ^a	Less Hazard 					More Hazard	
Overlying Soil	Gravelly						Fine-grained
Soil Thickness	Thin						Thick
Underlying Geology	Intrusive	Lava flows	Layered volcanics	Sedimentary Beds		Steep outslope-dipping Sedimentary Beds	
Slope Steepness	<70% (volcanic terrain) <60% (sedimentary terrain)			>80% (volcanic terrain) >70% (sedimentary terrain)			
Topographic Indicators of Soil Instability	No slide indicators	Ancient deep-seated movement apparent	Ancient shallow failure but in-place old growth stumps	Recent shallow slide		Open tension cracks	
Timber Indicators of Soil Instability	Present conifer stand has straight trunks	Bent trunks near slope surface	Swept trunks	Jack-strawed trees		Former recent failure has removed conifer; bare soil, alder, or salmonberry are dominant	
Slope Shape	Ridge top (convex slope)		Open straight slope			Headwall (concave)	
Site Drainage	Well-drained soils		Wet soil			Spring/Stream	
Headwall Drainage Area (above top of seasonality)		Small area <0.5 acre		Large area >3 acres			
Harvest Prescription	No harvest	Partial cut				Clear Cut	
Site Preparation for Reforestation		No herbicide use planned		Herbicide planned to control understory		Broadcast burning	

Factors Determining Hazard ^a	Less Hazard increasing to More Hazard				
					
Unused Legacy Grade/Trail	Not present	Present without sidecast	Present with sidecast and cutslope	Sidecast has experienced movement	Sidecast has experienced movement and poorly drained grade

^a Descriptions within rows are related (comparable) to each other but descriptions within columns are not. For example, a “ridge top” location may have more weight in determining if a slope is stable than “well-drained” soil, even though they lie in the same column.

Determining Delivery

Delivery relates to the likelihood that landslide debris will be transported to a fish-bearing stream. In cases where a slope fails directly into a fish-bearing stream (such as an aquatic adjacent unstable slope), the analysis is straightforward. In other instances, where a slope failure may be distal to the fish-bearing stream, the mobilized debris will have to traverse the stream network by moving around corners, past tributary junctions (requiring tight turns), and traverse downstream along varying gradients. If the debris lodges in the network above fish habitat, it may be moved later by a debris flow from a different tributary. It is in these cases that more analysis is needed to make a delivery determination. A landslide will be determined to deliver if there is any likelihood of large wood debris entering a fish-bearing stream. The possibility of remobilization of debris deposited above fish-use by a subsequent debris flow from a connecting tributary will be considered delivery. As in the hazard evaluation, determining delivery is also informed by various data and observations. Usually the evaluation of delivery is very straightforward in the steeper terrain of northwest Oregon because the water resource is commonly close to the potentially unstable slope, and flow paths are steep and fairly straight to a fish-bearing stream—often existing at the bottom of the proposed harvest unit.

In more subdued topography, or for stream sections with questionable geomorphology, determining delivery can be more challenging. The geotechnical specialist starts the evaluation using various GIS products and information as described above. This information provides a good understanding of the geomorphology of the stream network below the slope in question. Junction angles, stream and slope gradient, and travel distances for stream segments can be discerned easily from lidar data. Once the basic geomorphology is understood the following sources can further inform decisions of the likelihood of delivery:

- ODF guidance on debris flow deposition and transport.⁴

⁴ The *Transport* and *Deposition* sections in Forest Practices Technical Note #6 are helpful in identifying landscape characteristics that have an effect on the likelihood of an unstable slope’s ability to deliver to an aquatic resource. The note was prepared to help geotechnical specialists evaluate slopes in the context of *public safety*; however, the principals in these two sections are useful for water resources. See <https://www.oregon.gov/odf/Documents/workingforests/LandslideImpactRatingTechNote6.pdf>.

- Deliverability guidance stating the likelihood that a debris flow will stop when one of the following is met.^{5,6,7}
 - The presence of a channel junction that is 70 degrees or more, provided the channel downstream of the junction is <35% gradient, or
 - The presence of a stream reach which is <6% gradient for at least 300 feet, or
 - The average slope from the initiation site along the potential landslide path to the first stream that is <20%.
- Comparison of the stream network with landslide data from other northwest locations (unpublished debris flow track data collected from two 1996 storms⁸).
- Field visit to examine existing debris flow deposits in the stream network.

⁵ Benda, Lee. 1990. The Influence of Debris Flows on Channels and Valley Floors in the Oregon Coast Range, U.S.A. *Earth Surface Processes and Landforms* 15:457–466.

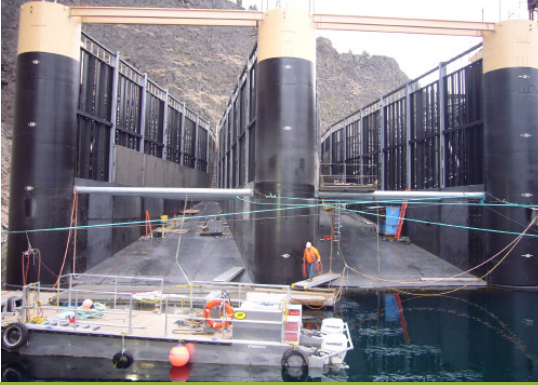
⁶ Oregon Department of Forestry. 2010. *Northwest Oregon State Forests Management Plan*. Revised April 2010. 581 pp.

⁷ Guthrie, R. H., A. Hockin, L. Colquhoun, T. Nagy, S. G. Evans, and C. Ayles. 2010. An Examination of Controls on Debris Flow Mobility: Evidence from Coastal British Columbia. *Geomorphology* 114(4):601–613. <https://doi.org/10.1016/j.geomorph.2009.09.021>.

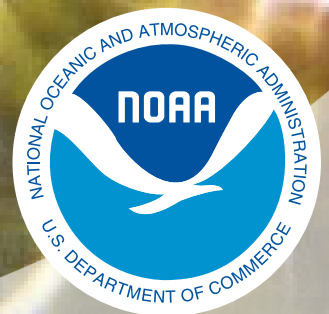
⁸ Robison, E.G., K.A. Mills, J. Paul, L. Dent, and A. Skaugset. 1999. *Oregon Department of Forestry Storm Impacts and Landslides of 1996: Final Report Oregon Department of Forestry Forest Practices Monitoring Program*. Salem, OR.

Appendix J

Fish Passage Design Criteria



NOAA Fisheries WCR Anadromous Salmonid Design Manual



NOAA
FISHERIES

NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual

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West Coast Region
Environmental Service Branches

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The year(s) in the title of this document was removed from the title page and the flow chart in Figure 1.

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Acronyms and Abbreviations

Symbol or Acronym	Term or Title
°C	degrees Celsius
°F	degrees Fahrenheit
ASP	Alaska steep pass
AWS	auxiliary water system or auxiliary water supply system
BOR	U.S. Bureau of Reclamation
ft ³ /s	cubic feet per second
EDF	energy dissipation factor
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FERL	Fisheries-Engineering Research Laboratory
FPA	Federal Power Act
ft ²	square foot
ft ³	cubic foot
ft/s	foot per second
ft-lb/ft ³ /s	foot pounds per cubic foot of flow per second
GCF	grade control fishway
gpm	gallon per minute
HDM	Hydraulic Design Method
HGMP	Hatchery and Genetic Management Plan
lb	pound
LSSS	Low Slope Stream Simulation
MSA	Magnuson-Stevens Fishery Conservation and Management Act
mm	millimeter
NMFS	National Marine Fisheries Service

Symbol or Acronym	Term or Title
NOAA	National Oceanic and Atmospheric Administration
O&M	operations and maintenance
PIT	passive integrated transponder
R/D	ratio of radius of curvature to pipe diameter
SSD	Stream Simulation Design
USACE	U.S. Army Corps of Engineers
VFD	variable frequency drive
WCR	West Coast Region

1 Introduction

The Environmental Service Branches provide technical and engineering assistance to National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) West Coast Region (WCR) fisheries biologists. NMFS also plays a supportive and advisory role in the management of living marine resources in the areas under state jurisdiction. This document is intended to assist with improving conditions for salmonids that must migrate past barriers to complete their life cycle. Effective fish passage requires the integration of numerous scientific and engineering disciplines including, but not limited to, fish behavior, ichthyomechanics, hydraulics, hydrology, fluvial geomorphology and engineering. Installing a fish passage structure does not constitute providing satisfactory fish passage unless all of the above components are adequately factored into the design.

This document is intended to: provide internal assistance to NMFS biologists in designing effective fish passage; encourage consistency across the WCR region; while supporting the implementation of NMFS's statutory authorities related to the conservation and protection of marine resources; and provide technical assistance to project proponents.

The efficacy of any fish passage structure, device, facility, operation, or measure is highly dependent on local hydrology, target species and life stage, obstacle orientation relative to the stream, facility operation, and many other site-specific considerations. While the information provided herein will apply to many structures, it should be regarded as general guidance for the design, operation, and maintenance of fishways throughout the WCR. The criteria described in this document are not universally applicable and should not replace site-specific recommendations.

This document provides general guidance and is not intended as an alternative to active consultation with NMFS biologists and engineers. Application of these criteria in the absence of consultation does not imply approval by NMFS. This document provides criteria and additional guidelines for the design and operation of facilities at barriers to fish migration and water intakes in California, Washington, Oregon, and Idaho. The facilities are designed to create safe passage routes for adult and juvenile salmonids in rivers and streams and through reservoirs, restore habitat connectivity within watersheds, and enhance salmonid population productivity. NMFS's manual for fish passage facility design is meant to help NMFS staff advise project applicants on the engineering design of future fish passage projects and modifications to existing projects. The criteria are based on decades of experience developing, testing, operating fish passage systems and relies on the best available scientific information.

The WCR has developed a flow chart for how to use their various fish passage guidance documents (Figure 1). Prior to designing a fish passage facility, NMFS recommends the project proponent familiarize themselves with the "NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change" (Improving Resilience) guidance

document. The Improving Resilience document outlines how to incorporate projected future flows the facility may experience over the life of the project and should be the starting point for the design process.

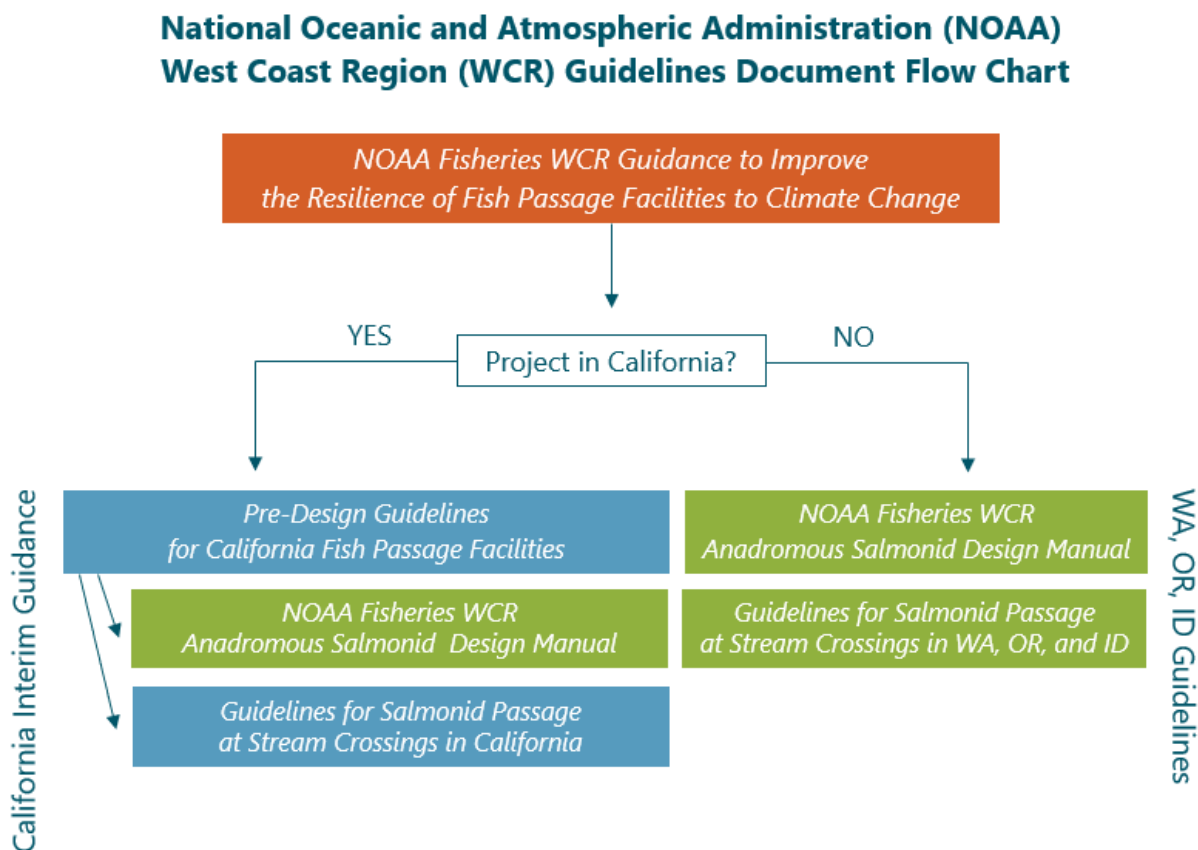


Figure 1-1. West Coast Region Fish Passage Guideline Flow Chart

In 2013, the Northwest and Southwest regions of the National Oceanic and Atmospheric Administration's (NOAA) NMFS were merged to form the WCR. This document is the first step in integrating fish passage design criteria and guidelines of the two former regions. This document, *NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Guidelines* supersedes the following documents:

- Northwest Region's *Anadromous Salmonid Passage Facility Design*, dated July 2011
- Southwest Region's *Fish Screening Criteria for Anadromous Salmonids*, dated January 1997
- Southwest Region's Experimental Fish Guidance Position Statement, dated January 1994
- Southwest Region's Water Drafting Specifications, dated August 2001

This document provides criteria and guidance for passage of anadromous salmonids only. For additional passage guidance concerning non-salmonids, refer to applicable state and federal entities.

This document contains introductory chapters, technical chapters, and appendices. The introductory chapters (Chapters 1 and 2) provide the statutory and biological background for the requirement to provide safe, timely, and effective passage of salmonids around barriers and definitions of key terms. The technical chapters (Chapters 3 through 10) present design criteria and guidelines that result in hydraulic conditions salmonid fish require to successfully pass barriers and minimize effects to salmonid populations, along with the scientific basis for criteria for which applicable references are available. The appendices provide information on aspects of fish passage facility design that are under development and may change over time after additional testing. Additionally, the appendices contain background information that was removed from the technical chapters to make the chapters more streamlined, but still needs to be available to the reader because the information is informative and relevant.

Throughout the chapters all criteria are italicized to be easily identifiable. In addition, chapter and appendix sections are cross-referenced where applicable. For example, the chapter on screens may direct the reader to the chapter on design flows so a reader interested in screens will understand that additional information is available in another chapter.

NMFS has separated these fish passage engineering guidelines into two volumes. This first volume entitled *NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual* provides design guidance for structural fish passage, protection, and exclusion projects not associated with river or stream crossings. This first volume represents guidelines that are based on decades of research, monitoring, and NMFS' experience with these types of passage systems. NMFS considers material in this volume to be in a mature state and does not anticipate it will change significantly over time.

The guidance in Chapter 4 of this volume applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat in those states. Due to significantly different hydrologic conditions in California and those conditions impact on life history of NMFS trust species, project proponents should work with NMFS engineering staff to determine the appropriate design flows following the Pre-Design Guidelines for California Fish Passage Facilities.

The second volume, entitled *Guidelines for Salmonid Passage at Stream Crossings in Oregon, Washington, and Idaho* (NMFS 2022b) represents a growing body of work relating to fish passage at stream crossings that NMFS expects will expand significantly in the future. Separating these guidelines into two volumes will allow NMFS to refine and expand this additional volume in the near future as new information becomes available, without having to reopen and modify the entire guidelines document. NMFS 2022b includes introduction matter as well as two technical chapters relating to stream crossings and grade control fishways.

The guidance in Chapters 3 and 4 of NMFS 2022b applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat. Given significantly different hydrologic conditions, stream crossing projects in California should refer

to: *Guidelines for Salmonid Passage at Stream Crossings in California* (NMFS 2019, addendum).

These criteria and guidelines were developed based on 60 years of agency experience in creating successful fish facility designs and have been further refined through a collaborative process with regional fish facility design experts. The criteria and guidelines in Volume 2 address more emerging fields of fish passage engineering and stream restoration. The criteria and rationale provided will be revised as needed if new information suggests that updated criteria would further improve passage conditions for fish.

1.1 Statutory Background

NMFS is mandated by U.S. Congress to manage, conserve, and protect living marine resources within the U.S. Exclusive Economic Zone. NMFS is authorized to conduct these actions under the Federal Power Act (FPA; administered by the Federal Energy Regulatory Commission [FERC]), the Fish and Wildlife Coordination Act (administered by the U.S. Fish and Wildlife Service), the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSA). This document provides criteria and technical assistance to project proponents on the design of fish passage facilities in order to provide safe, timely, and effective fish passage, consistent with NMFS responsibilities under the ESA, FPA, and MSA.

The requirement of safe, timely and effective passage derives from the unofficial but reliable definition of a fishway presented by Congress in a report related to the Energy Policy Act of 1992. The definition of "safe and timely passage" was expanded to include both passage structures and operations "necessary to ensure the effectiveness" of such structures. None of the terms "safe," "timely," or "effective" are further defined. However, in practice NMFS typically includes provisions which give these terms meaning. Regarding "safe" passage, NMFS requires licensees to design and operate their fishways so that they minimize the occurrence of injury or mortality experienced by fish while attempting to utilize the fishway. Regarding "timely" passage, a fishway prescription may include provisions for reducing the time in which a fish utilizing the fishway is subjected to stressful interactions, such as time spent in a trap or in transit, or a requirement for flows which will attract fish to a passage facility. Regarding "effective" passage, NMFS typically includes provisions requiring the operator to ensure that its facility succeeds in passing as close to 100% of the fish attempting to migrate through the system as possible.

Following these criteria will likely streamline processes, improve certainty, and improve the likelihood of success. NMFS also provides support and advice to states regarding the management of living marine resources in areas under state jurisdiction. This includes salmon (*Oncorhynchus spp.*) and steelhead (*O. mykiss*) due to their economic, cultural, recreational, and symbolic importance to society (NRC 1996).

NMFS pursues fish passage to contribute to its fishery management and ESA recovery goals. In reviewing, planning, designing, and implementing fish passage facilities, NMFS engineers will coordinate with NMFS biologists to make sure the particular target species, population numbers, migration timing and recovery goals are met.

1.2 Biological Background

Fish species within the family Salmonidae spawn in fresh water. Some species spend their entire lives in fresh water. Others spend a portion of their lives in marine waters where they grow and become sexually mature before returning to fresh water to spawn (Quinn 2005). The life history pattern that involves marine residence is known as anadromy, and salmonid species that display this pattern are referred to as anadromous salmonids.

NMFS has identified several key parameters that are used to judge the overall status and viability of salmon and steelhead populations. These include abundance, genetic diversity and life history diversity, productivity, and spatial structure (McElhany et al. 2000). NMFS considers a population to be viable if over a 100-year timeframe it can withstand threats and the risk of extinction from demographic variation, local environmental variation, and genetic diversity changes (McElhany et al. 2000). For examples of how these population parameters are used in viability assessments and recovery planning, see Lindley et al. (2007) and NMFS (2014). NMFS assesses any effects of barriers to migration and water intake structures on anadromous salmonids in the context of these parameters and overall population viability. The viability parameters are briefly described as follows:

Abundance. This is a commonly used species conservation and management parameter that refers to the number of organisms in a population.

Genetic diversity and life history diversity. Diversity refers to the distribution of traits within and among populations, which range in scale from DNA sequence variation at single genes to complex life history traits (McElhany et al. 2000). Genetic diversity and life history diversity are interrelated; thus, this parameter is not as straightforward as abundance. For example, a unique characteristic of anadromous salmonids is their high degree of fidelity to natal streams or rivers (Quinn 2005), which is a genotypic trait. This trait in turn facilitates local adaptations that result in phenotypic expressions of highly variable life history patterns (Taylor 1991; Waples 1991).

Life history diversity is often cited as a crucial component of salmonid population resiliency. This is based on evidence that maintaining multiple and diverse salmon stocks that fluctuate independently of each other reduces extinction risk and long-term variation in regional abundances (Roff 1992; Hanski 1998; Hilborn et al. 2003). Schindler et al. (2010) describe this as the portfolio effect, where risk is spread across multiple stocks. Preserving and restoring life history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). In addition, it is increasingly recognized that strengthening a population's resilience to environmental variability, including climate change, will require expanding habitat opportunities to allow a population to express and maintain its full suite of life history strategies (Bottom et al. 2011).

Productivity. Productivity represents the ability of a population to grow when conditions are suitable, which is essential to conservation success. In the absence of density-dependent factors, productivity is a measure of a population's ability to survive to reproduce and its reproductive success (McElhany et al. 2000). Populations that are below cohort replacement rate

or have limited ability to respond to favorable environmental conditions are less viable and at higher risk of extinction.

Spatial structure. This parameter refers to the geographic distribution of individuals in a population or populations. A population's spatial structure comprises the geographic distribution of individuals and the processes that generate that distribution (McElhany et al. 2000). The structure of a population depends on the quality of habitat available to the population, how the habitat is configured spatially, the dynamics of the habitat, and the dispersal characteristics of individuals in the population among the available habitats (McElhany et al. 2000).

The viability of salmonid populations can change over time, and NMFS considers the potential for this to occur when reviewing fish passage designs. Changes in population viability could occur from multiple factors, including the following:

- Terminating or adding new hatchery supplementation programs
- Recolonization of historical habitats after removal of a migration barrier
- Increased partitioning of the spatial structure of a population due to new barriers being installed and loss of access to habitat
- Habitat degradation and restoration
- Shifts in river hydrology and water temperature due to climate change
- Disasters (fires, landslides, etc.)
- Changes in water management

1.3 Migration Barriers

Anthropogenic barriers include, but are not limited to, hydroelectric dams, water storage projects, irrigation diversions, water withdrawals, and tide gates. Dams can have significant effects on the structure and function of river ecosystems (Ward and Stanford 1979), and change in flow regulation is considered one of the most pervasive changes to rivers worldwide (Stanford et al. 1996). The effects of restricted access to migrating fish caused by dams and weirs have been broadly implicated in population declines of freshwater species around the world (Northcote 1998).

Dams can block access to habitat, eliminate habitat in the footprint of a dam and reservoir, affect the amount and timing of water flow, and result in mortality during passage (Ruckelshaus et al. 2002). Columbia River dams have blocked access to nearly 40% of the habitat historically available to salmon (NRC 1996). Construction of Hells Canyon Dam resulted in the loss of 90% of the historical spawning habitat of fall-run Chinook salmon (*O. tshawytscha*) in the Snake River, Idaho (McClure et al. 2001). In California, approximately 95% of Chinook salmon spawning habitat has been lost or is no longer accessible (Yoshiyama et al. 1996). Smaller water diversions can block access to habitats as well as cause mortality from entrainment at unscreened (or improperly screened) diversions and predation above or below the diversion. Another example, is the substantial amount of historical spawning and rearing steelhead habitat rendered unavailable in the Santa Clara River (due to the construction of dams). Santa Felicia Dam blocks 95% of the steelhead habitat within the Piru Creek watershed; more than 30 miles of stream lies between Santa Felicia Dam and Pyramid Dam (NMFS 2006 and references therein).

Dams blocking passage of steelhead to upstream habitats constitute an obstruction within a freshwater migration corridor for the species and, therefore, an impact to steelhead habitat.

In summary, some anadromous salmonid populations migrate hundreds of miles in fresh water, and barriers in their migration corridors can affect population viability (Ruckelshaus et al. 2002). This includes barriers that are complete blockages as well as barriers that are partial blockages due to localized hydraulic conditions or poorly functioning passage facilities. NMFS is responsible for evaluating the degree to which barriers affect anadromous salmonid populations and providing guidance on how to resolve any migration effects.

1.4 Design Process

Resolving effects on salmonid migrations from barriers involves the integration of information on fish behavior and physiology, biomechanics, hydraulic and hydrologic conditions, and civil engineering. Simply installing a fish passage structure does not constitute providing satisfactory fish passage. A successful design requires that information on each of these components be factored into the design.

Instances can also occur where a fish passage facility may not be a feasible solution for correcting a passage impediment due to biological, societal, or economic constraints. In these situations, removal of the impediment or altering project operations may be a suitable surrogate in lieu of constructing fish passage facilities (Clay 1995).

When determining whether NMFS will promote or prescribe solutions to fish passage issues, NMFS will rely on a collaborative approach that considers the views of other fisheries resource agencies, Native American tribes, non-governmental organizations, citizen groups, and other governmental agencies. The approach strives to consider fish passage objectives developed by other parties (e.g., well-placed stakeholder groups) to support fisheries restoration and habitat enhancement actions identified in conservation plans.

This document addresses design features that may provide for to the safe, timely, and effective passage of fish. It is the responsibility of the design engineer to ensure that other design requirements are met such as the structural integrity of the facility and public safety.

This document provides specific fish passage facility design criteria and technical assistance for actions within the WCR pertaining to the various authorities of NMFS. When reviewing fish passage proposals by project proponents, NMFS will apply the criteria to major upgrades to existing facilities and the design of new fish passage facilities to the extent practicable. Existing facilities that are not compliant with this document may have to be modified using the criteria identified herein if fish passage problems are observed at these facilities. If the project is unable to meet the criteria, then the project proponent should continue to work with NOAA staff in developing a recommended solution that would best attain fish passage goals for the project.

1.5 Experimental Technologies

Experimental technologies include devices or systems that have demonstrated some potential for protecting or passing fish, but for which adequate scientific evidence has not been collected to verify effectiveness and gain agency acceptance or to be considered for general application (AFS 2000). Experimental technologies are new, innovative and unproven technologies that could be broadly applied, rather than deviations from criteria applying to a single site.

NMFS considers experimental technologies to include designs with major departures from conventional fish passage technologies as covered in this document. Experimental technologies may also include application of proven techniques to unusual environmental conditions or facility operations. Site specific deviations from criteria may not rise to the level of experimental designs, but rather warrant a conversation between the applicant and appropriate NMFS staff.

Proponents of experimental fish passage designs should provide NMFS with a sound biological or scientific basis to support the proposed design. This may include the following proof-of-concept steps as appropriate:

- A demonstrated, favorable fish behavioral response in a laboratory setting
- An acceptable plan for evaluating the prototype installation
- An acceptable alternate fish passage design developed concurrently with the unproven fish passage design that satisfies the criteria listed herein, should the prototype not perform as anticipated nor adequately protect fish

Appendix C (Experimental Technologies) provides additional information on the NMFS approval process for unproven fish passage technologies.

1.6 Temporary and Interim Passage

Where construction and/or modifications to artificial impediments (e.g., dams), natural impediments (rockslides, other natural issues) or upstream passage facilities are planned, upstream and downstream passage may be adversely impacted or interrupted. If possible, these activities should be scheduled for periods when migrating fish are not present, as specified in the in-water work period allowable for construction of facilities in streams. However, this may not always be possible or advisable. In these cases, an interim fish passage plan should be prepared and submitted to NMFS for review, in advance of work in the field.

In the interim plan, upstream and downstream fish passage should be provided for any adult or juvenile fish likely to be present in the action area during construction, unless passage did not exist before construction or where the stream reach is naturally dry at the time of construction. Methods for work area isolation and dewatering, as necessary, should be determined in consultation with NMFS.

Design criteria listed elsewhere in this document also apply to the interim passage plan. Where this is not possible, project owners should seek NMFS review of alternate interim fish

passage design criteria, and a final interim passage plan. Coordination with NMFS ahead of time is advised to determine appropriate work windows and other recommended alternatives or both.

1.7 Section 7 Consultation under the Endangered Species Act

This fish passage manual can be useful during ESA Section 7(a)(2) and Essential Fish Habitat (EFH) consultations. Incorporating the criteria within this document will help project proponents design projects that provide fish passage in a variety of situations. During the design process project developers can incorporate criteria within this document and work with NMFS engineers and biologists to ensure their projects meet these fish passage criteria. While this document provides substantial criteria related to fish passage, there are aspects of project design that are beyond the scope of this document. For instance, this manual does not identify or endorse specific construction best management practices. Project developers should coordinate with NMFS on project elements that fall outside the scope of this document.

This manual can also be used to achieve regulatory streamlining by aiding in the development of programmatic ESA and EFH consultations on activities involving fish passage. By incorporating these criteria into programmatic actions, action agencies and other stakeholders can help ensure their actions provide fish passage and appropriate conservation for protected resources, while streamlining the regulatory process.

1.8 Additional Information

Additional information on fish passage is available at the WCR website: <http://www.westcoast.fisheries.noaa.gov/>. Questions regarding this document and requests for assistance from NMFS fish passage specialists can be directed to the following offices:

For Washington, Oregon, and Idaho:

NOAA Fisheries West Coast Region
Environmental Services Branch
1201 Northeast Lloyd Boulevard, Suite 1100
Portland, Oregon 97232
503-230-5400

For California:

NOAA Fisheries West Coast Region
Environmental Services Branch
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404

707-387-0737

2 Definition of Terms

Anadromous – pertaining to a fish species that displays the life history pattern known as anadromy in which adults spawn in fresh water and juveniles migrate to sea to grow to their final size and then return to fresh water to spawn (Quinn 2005).

Active screens – juvenile fish screens equipped with efficient mechanical cleaning capability that are automatically cleaned as frequently as necessary to keep the screens free of any debris that may restrict flow through the screen area. NMFS requires active screen designs in most cases.

Applicant – a person or entity that proposes to design, modify, or construct a fish passage facility at an existing or new barrier, water diversion, or water conveyance that NMFS will review under its authorities identified in Chapter 1.

Approach velocity – the vector component of canal velocity that is normal (perpendicular) to, and immediately upstream of, the screen surface. Approach velocity is calculated based upon the submerged area of the screen for conical screens, all cylindrical screens (torpedo, T-screen, and end-of-pipe or hose screens) where submergence and clearance criteria are met, and inclined screens where angle and submergence requirements are met. For rotary drum screens, approach velocity is the vector component of canal flow velocity that is normal to, and immediately upstream of, the vertical projection of the screen surface.

Approach velocity is a design parameter that is used to calculate the minimum amount of effective screen area required to protect fish. The amount of effective screen area required to meet screen performance criteria is calculated by dividing the maximum diversion flow by the approach velocity. Approach velocity can be measured in the field with precise flow measurement equipment, and average operating approach velocity can be calculated by dividing the measured screen flow by the effective screen area. Approach velocity should be measured as close to the boundary layer of turbulence generated by the screen face as is physically possible. Chapter 8 provides a more detailed discussion of approach velocity.

Apron – a flat or slightly inclined slab of concrete below a flow control structure that provides erosion protection and produces hydraulic characteristics suitable for energy dissipation or, in some cases, fish exclusion.

Attraction flow – flow that emanates from a fishway entrance with sufficient velocity and quantity, and in the proper location and direction, to attract upstream migrants into the fishway entrance. Attraction flow consists of gravity flow from the fish ladder and any auxiliary water system (AWS) flow added at points within the lower fish ladder.

Auxiliary water system or auxiliary water supply system (AWS) – a hydraulic system that augments fish ladder flow at various points in a passage facility for upstream migrating fish. Large amounts of auxiliary water flow are typically added near the fishway entrance pool to increase the amount of attraction flow emanating from the fishway entrance and the attractiveness of the entrance to fish.

Backwash – a system that removes debris from dewatering screens by using pressurized flow against the screen surface in the opposite direction of the approach flow.

Backwater – a condition whereby a hydraulic drop is influenced or controlled by a water surface control feature located downstream of the hydraulic drop.

Baffles – physical structures placed in the water flow path designed to dissipate energy or redirect flow to achieve more uniform flow conditions.

Bankfull flow – the bank height when a stream or river channel is inundated under a flow that occurs at the 1.2-year to 1.5-year average flood recurrence interval. Bankfull height may be estimated by morphological features in the channel such as: 1) a topographic break from a vertical bank to a flat floodplain or from a steep to a gentle slope; 2) a change in vegetation from bare ground to grass, moss to grass, grass to sage, grass to trees, or no trees to trees; 3) a textural change of depositional sediment; 4) the elevation below which no fine debris (e.g., needles, leaves, cones, seeds) occurs; and 5) a textural change of fine sediment deposits (matrix material) between cobbles or rocks.

Bedload – sand, silt, gravel, soil, and rock debris transported by moving water on or near the streambed.

Bifurcation (trifurcation) pools – pools in a fish ladder below which the fish ladder (and flow) is divided into two or three separate routes.

Brail – a device that is moved upward (vertically) through a water column to crowd fish into an area for collection.

Bypass flow – in the context of dewatering screen design, the portion of diverted flow that is specifically used to return fish to the river.

Bypass reach – the portion of the river between the point of flow diversion and where bypassed flow and fish are returned to the river.

Bypass entrance – an unscreened opening in a facility that fish can enter, and after which are conveyed in flow to a sampling facility or back to the stream or river. The number and locations of entrances at a facility can range from one to several and are discussed in Chapter 8.

Bypass system – the component of a downstream fish passage facility that conveys (transports) fish from the diverted flow back into the body of water from which they originated. Bypass systems typically consist of entrance, conveyance (flume or pipe), and outfall structures.

Canal velocity – the water particle speed (feet per second) in a canal flowing parallel to the streambank.

Channel bed width – the width of the streambed under bankfull channel conditions.

Conceptual design – an initial design concept based on the site conditions and biological needs of the species intended for passage, also sometimes referred to as preliminary design or

functional design. This is the first phase in the design process of a fish passage facility and is discussed in Chapter 3.

Crowder – a combination of static or mobile panels installed in a fishway, raceway, or holding pool for the purpose of moving fish into a specific area for sampling, counting, broodstock collection, or other purposes. Crowder panels are usually porous and constructed of perforated plate or picket bars. The panels can also be fabricated using solid, non-porous materials. Also, see the definition for picket leads in this chapter.

Diffuser – a system of hydraulic components arranged to control water flow rate and convert high-velocity, high-pressure, non-uniform flow into low-energy, uniform flow. A diffuser also includes one or more panels of narrowly spaced horizontal or vertical bars to prevent fish from passing through the bars and entering the area upstream of the panels.

Distribution flume – a channel used to route fish to various points in a fish trapping system.

Effective screen area – the total wetted screen area minus the area occluded by major structural elements.

End of pipe screen – juvenile fish screening devices attached directly to the intake of a diversion pipe.

Entrainment – the diversion of fish into an unsafe area or passage route.

Exclusion barriers – facilities that prevent upstream migrants from continuing to migrate upstream. These are typically used to prevent fish from entering areas that have no egress route or may result in fish being injured.

Exit control section – the upper portion of an upstream passage facility that provides suitable passage conditions to accommodate varying forebay water levels. Water level fluctuation is accommodated by adjusting the pool geometry and weir design, and by adding or removing flow at specific locations.

False weir – a specialized floor diffuser used to introduce water at the top of a fishway or entrance to a distribution flume for the purpose of attracting and encouraging fish to move into a specific area. The device usually creates a strong upwelling flow that cascades over a weir. Fish are attracted to the cascading flow and swim through the upwelling into a distribution flume.

Fish ladder – the structural component of an upstream fish passage facility (or fishway) that allows fish to move over a barrier by dissipating the potential energy caused by the head differential that results from a barrier being placed in a waterway. The ladder dissipates energy using a series of discrete pools, a series of baffled chutes and resting pools, or uniformly with a single baffled chute placed between an entrance pool and an exit pool.

Fish lift – a mechanical component of an upstream passage system that provides fish passage by lifting fish in a water-filled hopper or other lifting device into a conveyance structure that delivers upstream migrants past the impediment.

Fish lock – a mechanical and hydraulic component of an upstream passage facility that raises fish over a dam by attracting or crowding fish into a chamber, closing access to the chamber, and filling the chamber until the water surface in the lock chamber reaches (or comes sufficiently close to) the reservoir forebay level. Once at this water surface elevation, a gate to the chamber is opened, allowing fish to swim into the reservoir above the dam (Clay 1995). Fish locks can also be used as part of a trap and haul system to lift fish from the river level to a higher elevation for sorting, or transportation, or both.

Fish passage season – the range of dates that characterize when juvenile or adult life stages of a species will arrive at a specific location during their downstream or upstream migration. The locations could include, for example, a dam or an existing or proposed fishway.

Fish weir (also called picket weir, picket lead, or fish fence) – a device with closely spaced pickets or bars that allows water flow to pass, but precludes fish from migrating farther upstream. This term is normally applied to the device used to guide adult fish into a trap or counting window. This device is not a weir in the hydraulic sense.

Fishway – the suite of facilities, structures, devices, measures, and project operations that constitute and are essential to the success of an upstream or downstream fish passage system. The suite provides a water passage route around or through an obstruction that is designed to dissipate the energy in such a manner that enables fish to ascend the obstruction without undue stress (Clay 1995).

Fishway entrance – the component of an upstream passage facility that discharges attraction flow into the tailrace of a barrier and that upstream migrating fish use to enter the facility.

Fishway entrance pool – the pool immediately upstream of the fishway entrance(s) where fish ladder flow combines with AWS flow to form the attraction flow.

Fishway exit – the component of an upstream fish passage facility where flow from the forebay of the dam or barrier enters the fishway, and where fish exit the ladder and enter the forebay upstream of the dam.

Fishway weir – the partition that divides two pools in a fishway and passes flow between adjacent pools.

Flood frequency – the probable frequency that a streamflow will recur based on historical flow records. For example, a 100-year flood event refers to a flood flow magnitude that is likely to occur on average once every 100 years or has a 1% chance of being exceeded in any given year. Although calculating possible flood recurrence is often based on historical records, there is no guarantee that a 100-year flood will occur within the 100-year period, or not occur several times within that period.

Floodplain – the area adjacent to a stream that is inundated during periods of flow that exceed the channel capacity the stream has established over time.

Flow control structure – a structure in a water conveyance designed to maintain flow in a predictable fashion.

Flow duration exceedance curve – the plot of the relationship between the magnitude of daily flow and the percentage of time during a specific period that flow is likely to be equaled or exceeded. Flow exceedance curves may use flow data from an entire year or part of a year. For example, the 1% annual exceedance flow is the flow level exceeded 1% of the time within the entire year (i.e., 3.6 days on average), whereas the 1% exceedance flow for the fish migration window is the flow level exceeded 1% of the time during the fish passage season for a particular species and location. Exceedance values are usually derived using daily average flow data.

Forebay – the waterbody located immediately upstream of a dam that results from the dam impounding river flow behind the structure.

Freeboard – the height of a structure that extends above the maximum water surface elevation.

Fry – a juvenile salmonid with an absorbed egg sac that is less than 60 millimeters in total length (as defined for the purposes of this document). An embryo develops within an egg until it hatches. The hatchling (alevins) feeds off the large external yoke sac for nourishment, grows, and emerges from the spawning gravel as a fry when it can feed on its own (Quinn 2005).

Functional design – an initial design concept based on the site conditions and biological needs of the species intended for passage. This is also sometimes referred to as preliminary design or conceptual design. Also, see the definition for conceptual design in this chapter. The functional design commonly includes the general layout, interior dimensions, and specifications covering the hydraulic features of the fishway (Clay 1995).

Hatchery supplementation – hatchery programs designed for hatchery-origin fish to spawn in the wild and make a contribution to the conservation of a species or population (HSRG 2009).

Head loss – the irreversible reduction in total head (total energy per unit weight) of water as it flows through conduits, open channels, spillways, turbines, and other hydraulic structures. Total head is the sum of elevation head, pressure head, and velocity head. Head is described in units of length, usually in feet or meters.

Hopper – a device used to lift fish in water from a collection or holding area for release upstream of a barrier or into a transportation truck.

Hydraulic drop – the difference in total head between an upstream water surface and a downstream water surface. It includes the sums of the elevation head, pressure head, and velocity head at the upstream and downstream water surface locations. Also, see the definition for head loss in this chapter.

For fishway entrances and fishway weirs, the differences in velocity head and pressure head are usually negligible, and only water surface elevation differences are considered when estimating hydraulic drop across the structure.

Impingement – the condition where a fish comes in contact with the surface of a dewatering screen and remains on the screen. This occurs when the approach flow velocity immediately upstream of the screen exceeds the swimming capability of a fish given its size and condition. Impingement can injure a fish, and prolonged contact with a screen surface or bar rack can result in mortality. One objective of NMFS’ approach velocity criterion is to eliminate the possibility for healthy salmonid fry or larger fish to become impinged on a screen surface or bar rack.

Infiltration gallery – a facility used to withdraw surface water from beneath the streambed.

Intermediate bypass entrance – a bypass entrance installed upstream of the main bypass entrance. Also, see the definition of bypass entrance in this chapter. Chapter 8 provides guidelines on the number of bypass entrances needed in a bypass facility and their location.

Invert – the lowest inside surface of a culvert or flume.

Kelts – an adult steelhead that survived spawning and is migrating downstream (Quinn 2005).

Off-ladder trap – a facility or system for capturing fish located adjacent to a fish ladder in a flow route that is separate from the normal fish ladder route. This system allows fish to pass a barrier via the ladder or be routed into the trap, depending on the management objectives for the species or population at the facility.

Minimum effective screen area – the maximum screen flow divided by the allowable approach velocity.

Passive screens – juvenile fish screens that do not have an automated mechanical cleaning system.

Picket leads or pickets – a set of narrowly spaced vertical or inclined flat bars or slender circular cylinders designed to exclude fish from a specific route of passage. Picket leads are similar to diffusers, but picket leads generally lack the ability to control the flow rate or significantly alter the flow distribution. Also, see the definitions of a fish weir and crowder in this chapter.

PIT-tag detector – a device used to scan fish for the presence of a passive integrated transponder (PIT) tag implanted in the fish. While passing through the detector, PIT tags transmit a unique identifying number that can be read at a short distance, depending on the tag size, type, and antenna design. These passive tags operate in the radio frequency range and are inductively charged and read by the detector. They do not have a battery and can remain operational for decades.

Plunging flow – flow over a weir that falls into a receiving pool where the water surface elevation of the receiving pool is lower than that of the weir crest elevation. Surface flow in the receiving pool is typically in the upstream direction, downstream from the point of entry into the receiving pool. Also, see the definition for streaming flow in this chapter.

Porosity – the percent open area of a mesh, screen, rack, or other flow area relative to the entire gross area.

Positive exclusion – a means of excluding fish by providing a barrier the fish cannot physically pass through.

Preliminary design – an initial design concept based on the site conditions and biological needs of the species intended for passage. This is also sometimes referred to as a functional design or conceptual design. Also, see the definition for conceptual design in this chapter.

Ramping rates – the rate at which the water surface level at a specific point in a river is artificially altered (either increased or decreased) over a specific time period as a result of changes in the regulation of flow upstream. The rate is typically measured and stated as the change in vertical inches per hour.

Rating curve – graphed data depicting the relationship between water surface elevation and streamflow.

Redd – the nest a female salmonid excavates, deposits embryos into, and immediately buries with gravel substrate. Redds can be located in streams, rivers, or lake beaches. The locations selected vary with populations and species (Quinn 2005).

Rotary drum fish screen – a horizontally oriented cylinder (drum) constructed of fish screen material. Rotary drum screens include an active cleaning method and at least one fish bypass route. The drum rotates on its horizontal axis during each cleaning cycle. Debris deposited on the upstream surface of the drum is lifted by the rotating drum and washed off the downstream surface of the drum by the flow passing through the drum. Fish are guided to a bypass entrance upstream of one end of the screen array.

Screen material – the material that provides physical exclusion to reduce the probability of entraining fish into diverted flow. Examples of screen material include perforated plate, bar screen, and woven wire mesh.

Scour – erosion of streambed material resulting in the temporary or permanent lowering of the streambed profile.

Soffit – the inside top of culvert or underside of a bridge.

Smolt – a juvenile salmonid that has completed its freshwater rearing cycle and initiated a downstream migration to reach a marine environment. To prepare for seawater, the freshwater life stage (parr) undergoes a physiological and osmoregulatory transition and begins its downstream migration. Fish in this transitional stage between fresh water and marine rearing that are actively migrating downstream are termed smolts (Quinn 2005).

Streaming flow – flow over a weir that falls into a receiving pool and where the water surface elevation of the receiving pool is above the weir crest elevation. In these situations, surface flow in the receiving pool is typically in the downstream direction and away from the point where flow enters the receiving pool.

Sweeping velocity – the vector component of water particle speed that is measured parallel to, and immediately upstream of, the screen surface.

Tailrace – the portion of the water channel below a dam that conveys turbine and spillway discharge downstream from the dam.

Tailwater – the body of water immediately downstream of a dam or other in-stream structure.

Total project head – the difference in water surface elevation from upstream to downstream (or from the headwater to the tailwater) of a barrier such as a dam or weir. Normally, total project head encompasses a range of values based on streamflow and the operation of flow control devices.

Thalweg – the streamflow path following the deepest parts (i.e., the lowest elevation) of a stream channel.

Tide gate – a mechanical device that allows flow to pass in one direction but not in the opposite direction. Tide gates are often used as part of a levee or dike system to allow streamflow into a bay or estuary during ebb tides and prevent the flow of saltwater to pass in the opposite direction and enter the area upstream of the levee or dike during flood tides.

Training wall – a physical structure designed to direct flow to a specific location or in a specific direction.

Transport channel – a hydraulic conveyance designed to allow fish to swim between different sections of a fish passage facility.

Transport velocity – the velocity of the flow within a transport channel of a fishway.

Trap and haul – the collection, loading, and transportation of adult fish from a collection site at or below a barrier to a release point located upstream from the barrier or at another location, and juvenile fish from a collection site at or above a barrier to a release point located downstream from the barrier or at another location.

Trash rack – a rack of vertical bars with spacing designed to catch debris and preclude it from entering the fishway or other hydraulic structure but allows fish to pass through the openings between bars. Trash racks are also referred to as a grizzly.

Trash rack, coarse – a rack of widely spaced vertical bars designed to catch large debris and preclude it from entering a fishway, while providing sufficient openings between the bars to allow adult fish to exit the fishway.

Trash rack, fine – a rack of narrowly spaced vertical bars designed to catch both small and large debris and reduce or eliminate the entry of fish into the intake of an AWS.

Turbine intake screens – partial flow screens positioned within the upper portion of a turbine intake that guide fish entering the turbine into a collection system for transport or bypass

back to the river. Turbine intake screens are installed at most mainstem Columbia and Snake River dams operated by the U.S. Army Corps of Engineers (USACE; Appendix G).

Upstream fish passage – fish passage relating to the upstream migration of adult and juvenile fish.

Upstream passage facility – a fishway system designed to pass fish upstream of a passage impediment, either by volitional passage (i.e., under their own swimming capability) or non-volitional passage (i.e., via a lift or transport vehicle).

Vee screens – a pair of vertically oriented juvenile fish screens installed in a vee configuration (i.e., positioned symmetrically about a centerline), and where the bypass entrance is located at the apex of the two screens. Vee screens are also referred to as chevron screens.

Velocity head, h_v – the kinetic energy per unit weight of fluid due to its velocity; h_v has the units of length (usually in feet or meters) and is calculated as shown in the following equation:

$$h_v = v^2/2g$$

where:

v = velocity of the fluid (feet per second, meters per second)
 g = acceleration due to gravity (32.2 feet per second², 9.81 meters per second²)

Vertical barrier screens – screens located between the bulkhead (upstream) and operating (downstream) gate slots at mainstem dams on the Columbia and Snake rivers operated by the USACE. The screens keep fish diverted into the bulkhead slot by turbine intake screens from passing back into the turbine through the operating slot. Fish retained in the bulkhead gate slot by the vertical barrier screen enter a specially designed juvenile fish bypass system through orifices. (Figure G-4 in Appendix G.)

Volitional passage – fish passage whereby fish transit a passage facility under their own swimming capability, using timing and behavior they choose, and under all naturally passable flows. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish pass through the facility without the aid of any apparatus, structure, or device (i.e., they are not trapped, mechanically lifted or pumped, or transported).

Wasteway – a conveyance that returns excess water originally diverted from an upstream location back to the stream or channel from which it was diverted.

Weir – a low wall or dam built across the width of a river that pools water behind it while allowing water to flow steadily over the top of the structure.

3 Design Development

3.1 Introduction

Chapter 3 describes the general process NMFS follows and the types of information required during project design. Fish passage project designs subject to NMFS engineering review are typically developed in two major phases. The major phases are the preliminary design (Section 3.2.1), also referred to as the functional or conceptual design, and the final design (Section 3.2.2), which results in the development of detailed plans and specifications.

A review by NMFS of an applicant's fish passage facility designs will be conducted in the context of whether they meet the recommended criteria and technical assistance listed in this document.

Fish passage facilities refer to physical structures, facilities, or devices used to provide safe, timely, and effective passage for all life stages of fish as identified in Section 1.1 of this document. During its review, NMFS will consider site-specific information, including site limitations, biological information, and operations and maintenance (O&M) information provided by the applicant. Although the submittal of all information discussed in Chapter 3 may not be required in writing, the applicant should be prepared to describe how the biological and site information was included in the development of the project design.

3.2 Design Process

Both the preliminary and final designs should be developed in cooperation and interaction with WCR biological staff from effected Branch and engineering staff from the Environmental Services Branch.

To facilitate an iterative, interactive, and cooperative process, project applicants are encouraged to initiate coordination with NMFS early in the development of the preliminary design. Early and frequent interactions can aid in a smooth review process. NMFS' preference is to work with applicants in developing alternatives that comply with ESA. In general, NMFS cannot complete a project review of design plans that are submitted without the supporting information (listed in Section 3.3).

Project applicants should consult with NMFS on all phases of a design. Section 3.2.2 provides the minimum information needed for NMFS review. Large, complex projects will likely have multiple iterations within each of the two major design phases. As multiple design iterations are developed, each iteration should be made available to NMFS for review.

3.2.1 Preliminary Design

Depending on the size and complexity of the project, NMFS typically requests that it be allowed to review and provide comments on the 30%, 60%, and 90% design iterations of the preliminary design. Due to the nature of the review process, such as applications for a FERC license and ESA consultation, a preliminary design should be developed in cooperation and interaction with biological and engineering staff from the NMFS WCR. The preliminary design should be complete and to allow the application or engineering review to move forward.

The preliminary design establishes a preferred alternative based on comprehensive evaluations of the key elements of the design. This first phase in the design of a fish passage facility includes the following steps. Project proponents should:

1. Engage with project stakeholders and ascertain their operational requirements.
2. Identify and prioritize project objectives and the associated functional requirements.
3. Assemble the design criteria of the federal, state, and tribal fish resource agencies.
4. Collect pertinent biological, hydrological, and engineering information.
5. Develop appropriately scoped geomorphic assessments for the project.
6. Define project reliability and backup or contingency parameters.
7. Develop a process for evaluating and ranking alternative designs and operations.
8. Generate alternative designs and select the preferred alternative.
9. Develop initial layout drawings and models as needed to describe the facility.
10. Describe the operational requirements of the major facility sub-components

The preliminary design results in a facilities layout that includes section drawings and the identification of component sizes and water flow rates for the primary project features. Cost estimates are also included in the preliminary design. Completion of the preliminary design commonly results in a document that may be used for budgetary and planning purposes and for soliciting (and subsequently collating) design review comments provided by other reviewing entities. The preliminary design is usually considered to be at the 20% to 30% completion stage of the design process. The preliminary design may include the following sub-phases of design work:

- Reconnaissance study: Typically, this study investigates the optimal design and construction specific to each site. The study usually occurs early in the preliminary design process.
- Conceptual alternatives study: This study lists the types of facilities that may be appropriate for accomplishing the fish passage objectives at a selected site. It does not entail much on-site investigation. Its purpose is to develop a narrowed list of alternatives that merit additional assessment.
- Feasibility study: This study includes an incrementally greater amount of development of each design concept (including a preliminary cost estimate) than does the conceptual alternatives study. It enables the most-preferred alternative to be identified.

3.2.2 Detailed or Final Design

The final design should be based on the preliminary design that NMFS reviewed. Any significant deviation from the accepted preliminary design will trigger a new review. Once the detailed design process commences, NMFS should have the opportunity to review and provide

comments on the designs developed at the 30%, 60%, 90%, and 100% stages, or near each of these stages.

The details of the final design phase uses the preliminary design as a springboard for beginning the final design and specifications in preparation for the bid solicitation (or negotiation) process. NMFS reviews usually provide refinements in the detailed design that will lead to O&M and fish safety benefits. Electronic drawings are the preferred review medium, though NMFS may request scaled 11-by-17-inch paper drawings in addition to electronic media.

3.2.3 Smaller Projects

For smaller projects where the review process may involve only one or two steps, each submittal to NMFS should include enough information about the project to ensure that the reviewing engineer is able to discern the goals of the project, any biological and physical constraints of the project, and how the proposed design intends to meet the goals of the project given constraints that were identified.

3.2.4 Review Timelines

NMFS should be allowed at least 30 days to review and comment on each stage of the design process (30%, 60%, 90%, and 100%).

Although NMFS may waive or voluntarily shorten a review period for a specific stage, project applicants should develop their design schedules using the standard 30-day review period for each stage of the design.

3.3 Information Requirements

The design of all fish passage facilities should be developed based on a synthesis of the required site and biological information listed below, with a clear understanding of how the facility will be operated and maintained. The following project information is needed for, and should be provided with, the preliminary design. In some cases, NMFS may need additional information not listed herein.

3.3.1 Functional Requirements

The project design should describe the functional requirements of the proposed fish passage facilities as related to all anticipated project operations and streamflows. The design should describe the expected median, maximum, and minimum monthly diverted flow rates and any special operations (e.g., the use of flash boards) that modify forebay or tailrace water surface elevations.

3.3.2 Site and Physical Information

The following physical information should be provided and used in developing the project design.

3.3.2.1 Plans

Design submittals should include visual representations of various project features. These plans may include any or all of the following:

- Site plan drawings: Showing the location and layout of the proposed fish passage facility relative to existing project facility features
- Surveys: Topographic and bathymetric surveys, particularly where they might influence locating fishway entrances and exits and personnel access to the site
- Additional drawings: Drawings of existing facilities illustrating longitudinal profile, elevations, and plan views, including details showing the intake configuration, location, and capacity of the project's hydraulic features
- Project Location Map including nearby town and north arrow along with Latitude and Longitude
- Temporary passage facility drawings: Drawings demonstrating plans for temporary or interim passage during construction of the primary facility. These temporary facilities should provide passage at a level no worse than existed prior to commencing construction on primary facility.

3.3.2.2 Hydrology

Design submittals should include information on the hydrology of the basin—including daily and monthly streamflow data and flow duration exceedance curves at the proposed site for a fish passage facility—based on the entire period of available records, which may be modified based upon site specific issues as approved by NMFS staff.

If stream gage data are unavailable for a proposed facility location (or if records exist for only a brief period of time), flow records may be generated using synthetic methods to develop the necessary basin hydrology information, which is used to develop the high and low fish passage design flows for the project (Chapter 4).

3.3.2.3 Project operations and basic information

Information on project operations that may affect fish migration should be provided.

Project information is key to understanding basic design parameters for fish passage (both for baseline conditions and for future fish passage changes). This could include information on powerhouse flow capacity, periods of powerhouse operation, turbine sequencing, debris management, flashboard or crest gate operation, flood or waster gate operation staffing levels, planned outages, pulse flows, project forebay and tailwater rating curves that encompass the entire operational range of the project, water temperature etc.

3.3.2.4 Morphology

Information on the stream or river channel at the site of the fish passage project should be provided, and includes but is not limited to the following:

- *Determine the potential for channel degradation, aggregation/subsidence, or channel migration, which may alter stream channel geometry and compromise fishway performance (if the fish passage facility is proposed at a new or modified diversion).*
- *Describe whether the stream channel is stable, conditionally stable, or unstable.*
- *Identify the overall geomorphology of the channel (e.g., straight, meandering, or braided).*
- *Provide the rate of lateral channel migration and change in stream gradient that has occurred during the last decade if migration is evident or likely to occur in the future using aerial photography, anecdotal information, or physical monitoring.*
- *Describe the effect the proposed fish passage facility may have on the existing stream alignment and gradient.*
- *Describe the potential for future channel modification to occur; this could be from construction of the facility or natural channel processes (i.e., instability).*
- *Describe the substrate of the channel and provide the D50.*

3.3.2.5 Sediment and debris

Any sediment and debris conditions that may influence the design of the fish passage facility or present potentially significant problems should be described.

3.3.3 Biological Information

Section 3.3.3 outlines miscellaneous information that should be provided and used in developing the project design. Contact the NMFS biologist in your area to determine which of the following is needed for the project.

3.3.3.1 Salmonid biological information

The following biological information should be provided for site specific conditions:

- Salmonid species present in the basin that are affected by the project, or are expected to be in the basin in the future
- Approximate abundance of each salmonid species and run (e.g., winter, spring, summer, fall, and late fall)
- Various life stages present, or expected to be present, in the future and their migration timing (fish passage season)
- Location and timing of spawning in the basin
- Location and timing of juvenile downstream migration

3.3.3.2 Non-salmonid passage

Information on any non-salmonid species (and life stages) present at the proposed fish passage site should be provided to address passage requirements for these species.

3.3.3.3 Predation risk

Information on predatory species that may be present at the proposed site should be provided along with information on conditions that favor or help to prevent their preying on

salmonids. Information should include, but is not limited to, species type, life stage, spawning ground, and location of predator habitat.

3.3.3.4 Fish behavior characteristics

Any known fish behavioral traits of salmonid or non-salmonid passage that might affect the design of the facility should be provided.¹

3.3.3.5 Additional research needs

Any uncertainty associated with how migrating fish approach the site where a new facility is being considered should be identified through directed studies, including routes fish may use when approaching the site. For more information related to large projects, see Appendix G.

3.3.3.6 Streamflow requirements

The minimum streamflow required to allow migration around the impediment during low water periods (See Design Flow Range in Chapter 4).

3.3.3.7 Poaching risk

The degree of poaching or illegal trespass activity in the immediate area of the proposed facility should be identified, along with any security measures needed to reduce or eliminate illegal activity.

3.3.3.8 Water quality

Water quality factors that may affect fish passage at the site should be described. For example, fish may not migrate if water temperature and quality are marginal and may instead seek coldwater refugia (e.g., deep pools fed by groundwater) or holding zones where dissolved oxygen levels are higher than surrounding reaches until water quality conditions improve. Water temperature issues are important considerations that can effect design. Therefore, it is also important to document other temperature issues (eg. reservoir stratification, or effluent releases in the project area, among other issues).

3.3.4 Operations and Maintenance Information

In order to provide a degree of certainty that necessary maintenance will be funded and performed, the following O&M information should be provided for in development of the preliminary design.

Historically, many fish passage facilities have been built and have subsequently fallen into disrepair due to improper operations or lack of maintenance or funding. New project designs

¹ For example, most salmonid species pass readily over a fishway weir with either plunging or streaming flow. However, pink and chum salmon have a strong preference for streaming flow conditions and may reject plunging flow. Therefore, if pink or chum salmon are in the basin, this needs to be identified. Similarly, American shad prefer streaming flow conditions and generally reject both plunging flow and orifice passage.

should consider the need for proper operations and long-term maintenance. Start up, daily, and yearly maintenance procedures, daily logs, and annual reports should be considered in the design development and included as part of the O&M plan.

3.3.4.1 Maintenance funding

The O&M plan should identify the party responsible for funding the O&M of the proposed facility.

3.3.4.2 Operating and maintaining entity

The O&M plan should identify the party responsible for operating the facility and carrying out maintenance actions.

3.3.4.3 Facility shutdown

The O&M plan should describe maintenance actions that will require the facility to be taken out of service and the timeline for these actions.

3.3.4.4 Schedule of operations

The O&M plan should identify the proposed schedule of operations for intermittently operated facilities, such as weirs or traps, and the accompanying plans for salvaging fish from these facilities after they are operational. This should include plans for how the facility will be dewatered and how salvaged fish will be returned to the stream or river.

4 Design Flow Range

Prior to determining the fish passage design flows, the steps in the 2022 NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change should be followed to determine what if any climate impacts should be considered and included in the design. The guidance in Chapter 4 applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat. Due to significantly different hydrologic conditions in California, project proponents should work with NMFS engineering staff to determine the appropriate design flows for site conditions.

4.1 Introduction

A fishway design and facility must allow for the safe, timely, and efficient passage of fish within a specific range of streamflow. The design streamflow range is bracketed by the designated fish passage design low flow and high flow described in Sections 4.2 and 4.3.

Within the design streamflow range, a fish passage facility should operate within its specific design criteria. Outside of the design streamflow range, fish should either not be present, not be actively migrating, or should be able to pass safely without need of a fish passage facility.

Site-specific information is critical to determining the design time period and river flows for the passage facility—local hydrology may require that the design streamflow range be modified for a particular site.

4.2 Design Low Flow for Fish Passage

Design low flow for fishways is the average daily streamflow that is exceeded 95% of the time during periods when migrating fish are normally present at the site.

This is determined by summarizing the previous 25 years of mean daily streamflow occurring during the fish passage season, or by an appropriate artificial streamflow duration methodology (if streamflow records are not available). Shorter data sets of streamflow records may be useable if they encompass a broad range of flow conditions. The fish passage design low flow is the lowest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.3 Design High Flow for Fish Passage

Design high flow for fishways is the average daily streamflow that is exceeded 5% of the time during periods when migrating fish are normally present at the site.

This is determined by summarizing the previous 25 years of mean daily streamflow occurring during the fish passage season, or by an appropriate artificial streamflow duration methodology (if streamflow records are not available). Shorter data sets of streamflow records

may be used if they encompass a broad range of flow conditions. The fish passage design high flow is the highest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.4 Fish Passage Design for Flood Flows

The general fishway design should have sufficient river freeboard to minimize overtopping by 50-year flood flows.

Above a 50-year flow event, fishway operations may include shutdown of the facility to allow the facility to quickly return to proper operation when the river drops to within the range of fish passage design flows. Other mechanisms to protect fishway operations after floods will be considered on a case-by-case basis. A fishway should never be inoperable due to high river flows for a period greater than 7 days during the migration period for any anadromous salmonid species. In addition, the fish passage facility should be of sufficient structural integrity to withstand the maximum expected flow. It is beyond the scope of this document to specify structural criteria for this purpose. If the fish passage facility cannot be maintained, the diversion structure should not operate, and the impediment should be removed.

5 Upstream Adult Fish Passage Systems

5.1 Introduction

Chapter 5 provides criteria and guidelines for designing upstream adult fish passage facilities as well as selecting appropriate ladder types for specific site conditions. These criteria and guidelines apply to adult upstream fish passage facilities in moderately sized streams. Where applicable, supplementary criteria for facilities located in small streams will be noted. Chapter 5 does not address fish passage systems, such as fish locks and mechanical lifts, which may provide passage over barriers or be used as part of a trap and haul system. Fish lifting devices are covered in Section 7.6.

Chapter 5 also discusses upstream passage impediments, which are artificial or natural structural features or project operations that cause adult or juvenile fish to be injured, killed, blocked, or delayed in their upstream migration to a greater degree than in an unobstructed river setting. These impediments can present total or partial fish passage blockages. Artificial upstream passage impediments require approved structural and operational measures to mitigate, to the maximum extent practicable, for adverse impacts to upstream fish passage. These impediments require a fish passage design based on conservative criteria because the natural complexity of streams and rivers that usually provide passage opportunities has been substantially altered. The criteria in this chapter also apply to natural barriers, when passage over the barrier is desired and consistent with watershed, subbasin, or recovery plans.

Examples of passage impediments include, but are not limited to, the following:

- Permanent or intermittent dams
- Hydraulic drops over artificial instream structures² in excess of 1.5 feet
- Weirs, aprons, hydraulic jumps, or other hydraulic features that produce depths of less than 10 inches, or flow velocity greater than 12 feet per second (ft/s) for more than 90% of the stream channel cross section
- Conditions that create false attraction, including the following:
 - Project operations or features that lead upstream migrants into impassable routes
 - Discharges that may be detected and entered by fish with no certain means of continuing their migration (e.g., poorly designed spillways, cross-basin water transfers, canal wasteways, or unscreened diversions) or have the potential to result in mortality or injury (e.g., turbine draft tubes, shallow aprons, and flow discharges)
- Insufficient flow, which includes the following:
 - Diffused or braided flow that impedes approach to the impediment

² This is based on the *Fisheries Handbook of Engineering Requirements and Biological Criteria* (Bell 1991), which recommends using fishways for head differences as low as 2 feet.

- Insufficient flow in a bypass reach, such that fish cannot enter or are not stimulated to enter the reach and move upstream; bypass reaches are commonly located adjacent to a powerhouse or wasteway return
 - Water diversions that reduce instream flow
- Poorly designed headcut control or bank stabilization measures that create poor upstream passage conditions such as those listed above
- Degraded water quality in a bypass reach, relative to the water quality downstream of the confluence of bypass reach and flow return discharges (e.g., at the confluence of a hydroelectric project tailrace and bypass reach)
- Ramping rates in streams or in bypass reaches that delay or strand fish
- Upstream passage facilities that do not satisfy the criteria and guidelines described in Chapter 5

The typical components of an upstream adult fish passage system are shown in Figure 5-1.

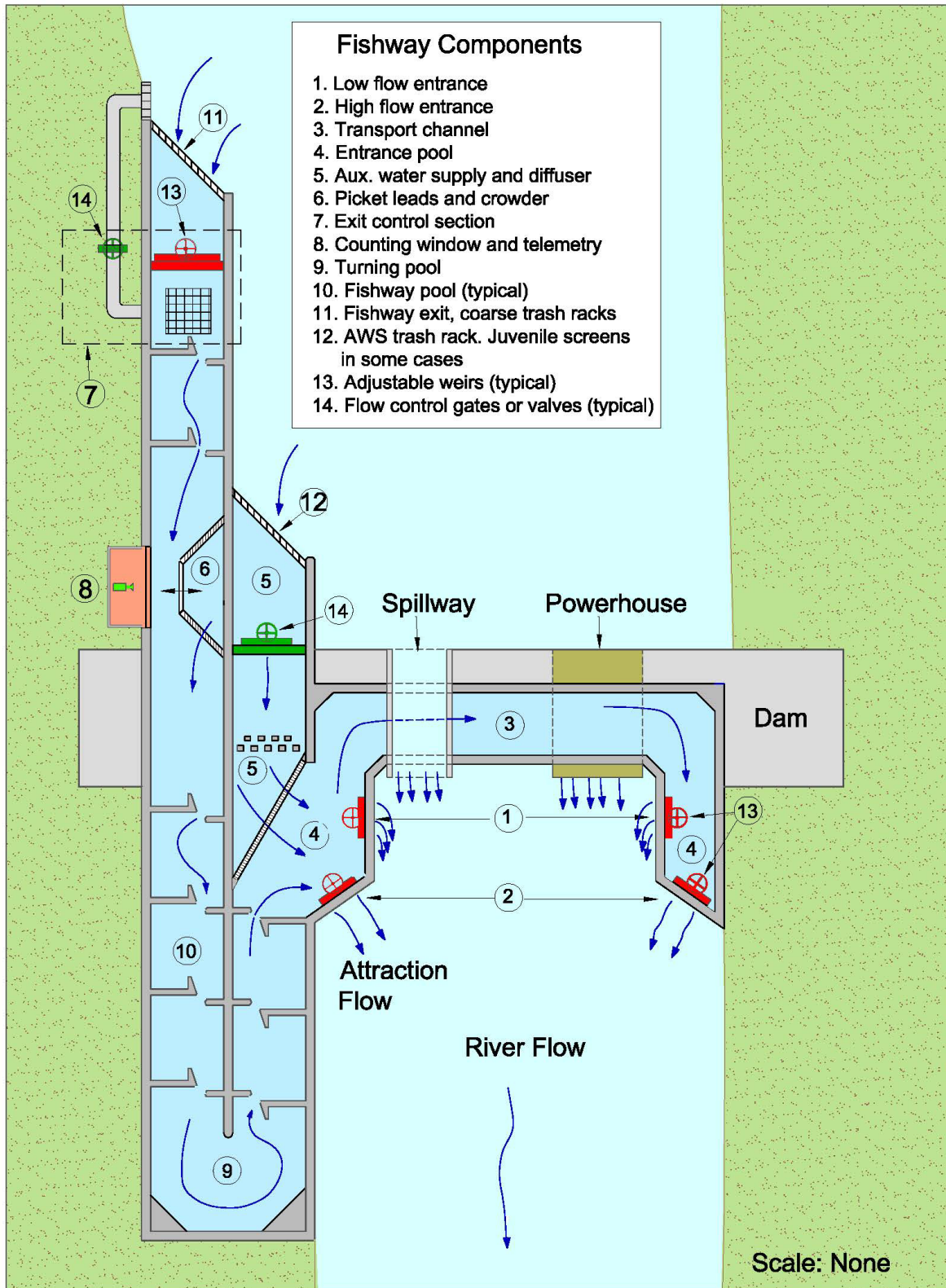


Figure 5-1. Components of vertical slot fishway for upstream passage

5.1.1 Passage Alternatives: Volitional and Non-volitional

Volitional passage is preferred for passage facilities over non-volitional passage. Non-volitional systems may be considered where volitional passage facilities are not feasible due to significant engineering constraints or biological limiting conditions.

NMFS typically prefers volitional fish passage as these systems afford passage opportunities for migrating fish at all times, and fish can transit a passage facility under their own swimming capability, using timing and behavior they choose, and under all naturally passable flows. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish migrate through a volitional passage facility without the aid of any mechanical apparatus, structure, or device.

Volitional passage systems at dams usually consist of hydraulically engineered fish ladders that use one of the designs described in this manual. Under certain site conditions, a volitional passage system for a dam of low or moderate height may be designed as a nature-like channel; or it may be a hybrid design that incorporates features of both nature-like and traditional designs. Volitional systems for applications other than dams generally seek to emulate nature-like conditions with stream simulation techniques.

There are some situations where a volitional passage system is infeasible due to biological factors, engineering constraints, fish management objectives, or other project-specific limitations. In these instances, non-volitional systems may be appropriately considered to meet fisheries management goals and objectives, provided they are designed, constructed, and operated following the guidance in chapter 7 of this Manual.

Non-volitional systems, due to long term operations and maintenance requirements, can have higher total life-cycle costs when compared to fish ladders. Project proponents should carefully weigh the pros and cons of the different alternative modes of passage to select the most appropriate design that will consistently accomplish the project's fish passage goals. There may be instances where the inability of a project proponent to consistently and correctly operate and maintain a proposed collection and transport system represents an unacceptable risk to the managed fish species.

Although site specific challenges exist, non-volitional designs can be a viable management tool that provides Pacific salmonids access to some historic habitats, including cold-water sites that will be increasingly important given climate projections.

5.1.2 Passage of Other Species

Where appropriate, upstream adult fish passage systems should incorporate passage requirements for other species (e.g., shad, sturgeon, Pacific lamprey, and suckers) that may use the system, provided that the changes do not compromise the passage of target species (salmonids).

Failure to account for the passage requirements of other species may create a biological blockage in the ladder that could delay or compromise the passage of the target species. For

example, if American shad (*Alosa sapidissima*) cannot pass a fishway, the numbers of shad in the fishway may build up to the point where other fish do not enter or move through the fishway.

5.1.3 Temperature Considerations

In certain cases, water temperature control may be a critical factor for fish ladder designs, particularly at high head dams. Some reservoirs or head ponds may become thermally-stratified at some point during the fish passage season, resulting in a potential temperature mismatch between the fish ladder's discharge and the dam's other tailwater or tailrace discharges. Also, during summer seasons, water temperature may increase as water passes through long fish ladders whose exterior concrete surfaces are exposed to solar energy for a considerable period of time. Such temperature mismatch situations may cause salmonids (or other species) to reject the fish passage route. To the degree these conditions exist, artificial temperature modulation at fishways and ladders may be necessary (Caudill et al. 2013).

5.2 Fishway Entrance

5.2.1 Description and Purpose

A fishway entrance is a gate or slot through which fishway attraction flow is discharged in a manner that encourages and allows adult fish to enter the upstream passage facility. The fishway entrance is often the most difficult (Bates 1992)—yet most critical—component to design for an upstream passage system, particularly at dams (Clay 1995). Fishway entrances should be placed to ensure that fish are attracted to and enter the best passage routes past the passage impediment throughout the entire design flow range. The most important aspects of fishway entrance design are as follows:

- Location of the entrance
- Pattern and amount of flow from the entrance
- Approach channel immediately downstream of the entrance
- Flexibility in adjusting entrance flow to accommodate variations in tailrace elevation, stream or river flow, and project operations

5.2.2 Specific Criteria and Guidelines – Fishway Entrance

5.2.2.1 Configuration and operation

Unless otherwise approved by NMFS, at sites where the entrances are located in deeper water, fishway entrances should be equipped with downward-opening slide gates or adjustable weir gates that rise and fall with the tailwater elevation. At locations where the tailwater is not deep, orifice entrances or downward-closing slide gates (which create an orifice entrance) may be used. The entrance gate should be able to completely close off the entrance when not in use. Gate stems or other adjustment mechanisms should not be placed in any fish migration pathway. Fishway entrance gates operating in an orifice configuration should not be closed to an opening height less than 12-inches except when fully closed.

The fishway entrance gate configuration and its operation may vary based on site-specific project operations and streamflow characteristics. Entrance gates are usually operated in either a

fully open or fully closed position, with the operation of the entrance being dependent on tailrace flow characteristics. Sites with limited tailwater fluctuation may not require an entrance gate to regulate the entrance head, while other sites may maintain proper entrance head by regulating auxiliary water flow through a fixed-geometry entrance gate.

5.2.2.2 Location

Fishway entrances should be located at points where fish can easily locate the attraction flow and enter the fishway. When choosing an entrance location, high-velocity and turbulent zones in a powerhouse or spillway tailrace should be avoided in favor of relatively tranquil zones adjacent to these areas. A site-specific assessment must be conducted to determine entrance location and entrance jet orientation. A physical hydraulic model is often the best tool for determining this information (Bell 1991).

The fishway entrance should be located as far upstream as possible since fish will seek the farthest upstream point (Bell 1991). This is especially the case with low flow entrances. This guideline is subject to adjustment by NMFS based on site-specific constraints that include the configuration of the project, flow level, and flow patterns associated with powerhouse or facility operations and spill discharge in relation to site conditions.

Some fishway entrances at a project should be located on the shoreline (Bell 1991). This is because fish orient to shorelines when migrating upstream. Locating an entrance on the shoreline takes advantage of this behavior, where the shoreline serves to lead fish to the entrance.

One of the most significant design decisions for a fishway entrance is its location (WDFW 2000). Turbulence can be a barrier to fish passage because velocities, turbulence, upwells, reverse currents, and aeration can affect attraction and access to fishways (WDFW 2000). At locations where the tailrace is wide, shallow, and turbulent, excavation to create a deeper, less-turbulent holding zone adjacent to the fishway entrance(s) may be necessary. Therefore, it is important to fully characterize and understand flow patterns when locating a fishway entrance at a site.

5.2.2.3 Additional entrances

If the site has multiple zones where fish accumulate, each zone should have a minimum of one fishway entrance. For long powerhouses or dams, additional entrances may be required. Multiple entrances are usually required at sites where the high and low design flows create different tailwater conditions. All entrances should meet the requirements of Section 5.2.

Since tailrace hydraulic conditions usually change with project operations and hydrologic events, it is often necessary to provide two or more fishway entrances to accommodate the differences between high- and low-flow river conditions (often referred to as high- and low-flow entrances). When switching between high- and low-flow conditions, it is often necessary to close some entrances that are operating poorly or those the fish can no longer access, and open others where fish are congregating and holding. These features should be designed so that entrance changes can be performed simply, swiftly, and easily.

5.2.2.4 Attraction flow

Additional attraction flow from the fishway entrance is needed to extend the area of intensity of velocity of the outflow (from the entrance) to increase fish attraction into the entrance (Clay 1995). Attraction flow from the fishway entrance should be between 5% and 10% of the fish passage high design flow (Chapter 4). For smaller streams, NMFS may conclude that attraction flows up to 100% of streamflow may be required.

Larinier et al. (2002) conclude that a major cause of poor fishway performance is a lack of adequate attraction flow. At dams, the entrance flow for fish attraction should be sufficient to compete with spillway or powerhouse discharge flow (Bates 1992). Generally speaking, the higher the percentages of total river flow used for attraction into the fishway, the more effective the facility will be in providing upstream passage. The proportion of attraction flow needed is based on extensive research and results of laboratory studies.³ The proportion selected should be sufficient to allow fish to both find and want to enter fishway entrances.

Under conditions where ladder entrances are optimally situated near the impediment and fish are naturally led to an entrance, an attraction flow of 5% of the fish passage design flow is used. However, some situations may require that more than 10% of the passage high design flow be used. For example, if a site features obscure approach routes to the passage facility or if entrances are located in a less than optimal location, a higher proportion of the design flow is needed as attraction flow. Additionally, facilities with multiple entrances may require more attraction flow (not to exceed a total of 10% of the fish passage design flow).

Powerhouse and spillway flows are not considered part of the proportion of project flow used for fishway attraction. Powerhouse and spillway flows should be shaped, and turbine unit and spill gate operation prioritized, to create tailrace conditions that naturally lead to and allow fish to rapidly locate the fishway entrances (Bell 1991).

5.2.2.5 Hydraulic drop

The fishway entrance hydraulic drop (also called entrance head) should be maintained between 1 and 1.5 feet, depending on the species present at the site, and designed to operate from 0.5 to 2 feet of hydraulic drop (USFWS 1960; Junge and Carnegie 1972).

A range of 1 to 1.5 feet is considered a normal operating range that helps establish streaming flow conditions (Bates 1992). Gauley et al. (1966) found in laboratory studies that Chinook salmon and steelhead made significantly faster ascents up an experimental ladder with orifice flow and flow over a weir when head on the weir was increased from 0.95 to 1.2 feet.

The hydraulic drop criterion is based in part on results of laboratory studies where an increasing number of Chinook and sockeye salmon and steelhead failed to enter all entrances tested when head was increased from 2 to 3 feet. Pink and chum salmon have more specific

³ For example, Weaver (1963) conducted a study wherein he provided salmon and steelhead with a choice of entering adjacent channels of the same width but different velocities; a higher proportion chose to enter the channel with higher velocity.

requirements. Fish from these species can easily swim through an entrance with 1.5 feet or more of head differential, but they will not jump even a portion of that height (Bates 1992).

5.2.2.6 Dimensions

For larger streams, the minimum fishway entrance width should be 4 feet, and the entrance depth should be at least 6 feet, although the shape of the entrance is dependent on attraction flow requirements and should be shaped to accommodate site conditions.

For smaller streams, the ladder entrances should be as large as possible, consistent with available fishway entrance flow, to maximize fish attraction and minimize plugging by debris. The minimum size for an orifice-style entrance should be 1.5 feet by 1.5 feet. The minimum width for a vertical slot-style entrance should be 1.25 feet if large Chinook salmon are present and 1 foot otherwise, and the depth (i.e., bottom of the slot to the tailwater level) should be at least 2 times the slot width.

In general, the dimensions of the fishway entrance should create a compact, strong attraction flow jet that projects out of the entrance a significant distance into the tailrace.

For identical water velocities, attraction jets created by entrances that are small, narrow, and deep, or are wide and shallow, do not project as far into the tailrace as does a compact entrance (Section 5.2.2.8; also, see requirements for mainstem Columbia and Snake rivers in Appendix G). The entrance width criterion is based partly on results of laboratory studies where Chinook salmon and steelhead preferred 3.9-foot-wide entrances over 1.5-foot-wide entrances under a constant velocity condition of 8 ft/s and lighted conditions. However, under dark conditions, all of these species preferred the wider opening, and coho salmon preferred the wider opening under both lighted and dark conditions (Weaver et al. 1976).

For ladder entrances at facilities located in small streams, orifice size is based on the minimum orifice size for an Ice Harbor-style ladder (Section 5.5.3.3). For a slot-style entrance at a facility in a small stream, the slot width is based on the minimum slot widths for vertical slot ladders (Section 5.5.2.1.1), and the minimum depth is based on the square area of a 1.5-foot by 1.5-foot orifice. For example, the criterion above states that slot depth (the depth from the bottom of the vertical slot-style entrance to the tailwater water surface elevation) should be double the slot width, and the minimum width should be 1.25 feet if large Chinook salmon are present and 1 foot otherwise. Therefore, when sizing a 1-foot-wide slot, the design should submerge the slot 2 feet, which is close to the 2.25 square foot (ft²) open area of a 1.5-feet by 1.5-feet orifice.

5.2.2.7 Types of entrances

Fishway entrances may be adjustable submerged weirs, vertical slots, orifices, or other shapes, provided that the requirements specified in Section 5.2.2 are achieved.

Care should be taken to select a fishway entrance that generates a good attraction jet and is passable by all species of interest (Junge and Carnegie 1972). For example, American shad typically refuse to pass through orifices. Therefore, at sites where American shad are present, orifice entrances should be avoided, and surface routes in fishways are required (Larinier et al. 2002). This is true of all species in the genus *Alosa*. Also, American shad orient to walls when

migrating through fishways and can be trapped in corners if no surface-oriented route is available (Junge and Carnegie 1972; Bell 1991; WDFW 2000).

5.2.2.8 Flow conditions

The fishway entrance should create either streaming flow or hydraulic conditions similar to a submerged jet.

The desired flow condition for entrance weir and slot discharge jet hydraulics is streaming flow (WDFW 2000). A streaming flow is an intact plume of water moving almost horizontal near the water surface or at the elevation of an orifice entrance. In contrast, plunging flow drops vertically over an entrance sill or weir and then upwells downstream a few feet from an entrance. Plunging flow sets up a hydraulic roll where surface flow is moving in an upstream direction toward the entrance (Figure 5-2). This induces fish to jump at the flow, which may cause injuries, and it presents hydraulic conditions that some species may not be able to pass or may refuse to pass. This includes American shad and pink and chum salmon. Plunging flow also directs the attraction jet downward toward the stream bottom rather than across the tailrace. Streaming flow may be accomplished by placing the entrance weir (or invert of the slot) elevation such that flow over the weir falls into a receiving pool with a water surface elevation above the weir crest elevation (Katopodis 1992).

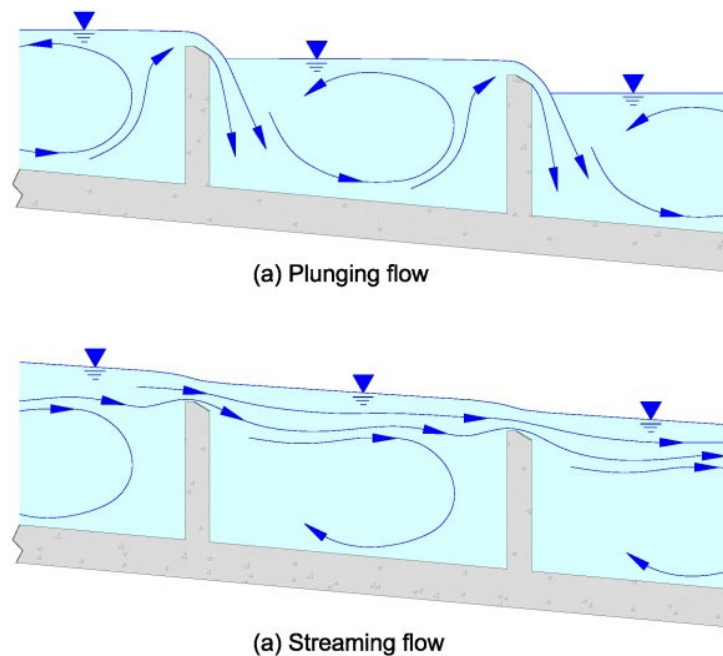


Figure 5-2. Plunging (a) and streaming (b) flows in pool and weir style of fishways

5.2.2.9 Orientation

Generally, low-flow entrances should be oriented nearly perpendicular to the streamflow (Figure 5-1; Bates 1992). High-flow entrances should be oriented to be more parallel to streamflow or at an angle away from the shoreline (Figure 5-1). A site-specific assessment should be conducted to determine entrance location and entrance jet orientation.

Low-flow entrances are designed to be used by fish during periods when flow conditions approach the low design flow. They are generally the entrances furthest upstream and closest to the passage barrier. High-flow entrances are designed for use during periods when flow conditions approach the high design flow. Bates (1992) suggests that high-flow entrances be placed at a 30-degree angle to the high-flow streamline, ideally along the edge of a high-flow hydraulic barrier. In general, high-flow entrances are located slightly downstream from the barrier at a point in the tailrace where the turbulence from the barrier under high flow conditions has just dissipated. A physical hydraulic model is often the best tool for determining this information; this model is used to test various design alternatives that favor fish passage (Bell 1991).

5.2.2.10 Staff gages

The fishway entrance design should include staff gages to allow for a simple determination of whether the entrance head criterion (Section 5.2.2.5) is met. Staff gages should be located in the entrance pool and in the tailwater just outside of the fishway entrance in an area visible from an easy point of access. Gages should be readily accessible to facilitate in-season cleaning.

Staff gages are important tools for determining whether a fish ladder entrance is meeting criteria. Care should be taken when locating staff gages to avoid placement in turbulent areas and locations where flow is accelerating toward a fishway entrance.

5.2.2.11 Entrance pools

The fishway entrance pool should be designed to combine ladder flow with auxiliary water system (AWS; also known as auxiliary water supply system) flow in a manner that encourages fish to move from the entrances in an upstream direction and optimizes the attraction of fish to lower fishway weirs.

The fishway entrance pool is at the lowest elevation of the upstream passage system. It discharges flow into the tailrace through the entrance gates to attract upstream migrants. In many fish ladder systems, the entrance pool is the largest and most important pool in terms of providing proper guidance of fish from the entrance to the ladder section of the upstream passage facility. Ladder flow and AWS flow through diffuser gratings are combined in the pool to form the entrance attraction flow (Section 5.3, Figure 5-1).

Attraction to the lower fishway weirs may be optimized by the following:

- Shaping the entrance pool to create a natural funnel leading fish to the ladder weirs
- Angling vertical AWS diffusers toward the ladder weirs
- Locating the jet from the ladder weir adjacent to the upstream terminus of the vertical AWS diffusers

The pool geometry will normally influence the location of attraction flow diffusers.

5.2.2.12 Transport velocity

Transport velocities between the fishway entrance and first fishway weir, fishway channels, and over-submerged fishway weirs should be consistent with the guidance found in section 5.4.2.1.

Gauley et al. (1966) reported that Chinook and sockeye salmon and steelhead passage times did not differ significantly between water velocities of 1 and 4 ft/s in an experimental 270-foot-long transportation channel. However, Weaver (1963) reported that Chinook salmon moved progressively slower in a test flume as velocities increased from 2 to 8 ft/s.

Note that as tailwater level rises and the lower fishway weirs become submerged, it becomes necessary to increase the flow in this area of the ladder to meet the transport velocity criterion (Bell 1991).

An AWS can be used to supply additional water through wall or floor diffusers. Care should be taken to design the fishway weirs that will be submerged to accommodate the additional flow in the ladder so that other fish passage (or hydraulic) criteria are not exceeded. The transport channel velocity guidelines do not apply to individual ladder pools since these are governed by design criteria specific to these pools.

5.3 Auxiliary Water Systems

5.3.1 Description and Purpose

An AWS should be used to supply additional water to the fishway when the required attraction flow (as specified in Section 5.2.2.4) is greater than ladder flow.

Auxiliary water is often required at fishways to provide additional attraction flow from the entrance pool to fishway entrances (Bell 1991). Adding AWS flow is based on the concept that fish migrating upstream are attracted by flow velocity of certain magnitudes, which the fish swim against to continue their migration upstream (Clay 1995). Auxiliary water can also be supplied through an AWS to areas between fishway weirs that are partially submerged by high tailwater elevations and fail to meet the flow velocity criterion, as discussed in Section 5.2.2.12. In addition, an AWS can be used to provide additional flows to various transition pools in the ladder such as bifurcation or trifurcation pools, multiple entrances, pools in fish trapping facilities, exit control sections, and counting station pools.

5.3.1.1 AWS supply source

The source of water for the AWS flow should be of the same quality (e.g., temperature, turbidity, and water chemistry) as the flow in the ladder (i.e., the receiving water).

The AWS flow is usually routed from the forebay to the ladder via gravity, but water quality may vary from the ladder flow depending on the location of the AWS intake. The AWS flow can also be pumped from the tailrace or delivered via a combination of gravity and pumped sources. Differences in the water sources could cause fish to reject the ladder.

5.3.2 Specific Criteria and Guidelines – AWS Fine Trash Racks

5.3.2.1 Bar spacing

A fine trash rack should be provided at the AWS intake with clear space between the vertical flat bars of 0.875 inch or less.

The purpose of an AWS fine trash rack is to stop debris from entering the AWS, which might plug the upstream side of the diffuser panel. Since the normal, clear opening between bars on the diffuser panels is 1 inch (Section 5.3.7), the AWS fine trash rack should be 0.875 inch or less. At sites where Pacific lamprey may be present and diffusers with 0.75-inch clear openings are used (Section 5.3.7), the AWS fine trash rack should have a maximum clear opening of 0.625 inch or less.

5.3.2.2 Velocity

Maximum velocity through the AWS fine trash rack should be less than 1 ft/s, as calculated by dividing the maximum flow by the submerged area of the fine trash rack.

5.3.2.3 Cleaning consideration

The support structure for the fine trash rack should not interfere with cleaning requirements and should provide access for debris raking and removal.

5.3.2.4 Slope

The fine trash rack should be installed at a 1H:5V (horizontal:vertical) or flatter slope for ease of cleaning. The fine trash rack design should accommodate maintenance requirements by considering access for personnel, travel clearances for manual or automated raking, and removal of debris.

5.3.2.5 Staff gages and head differential

Staff gages should be installed to indicate head differential across the AWS intake fine trash rack and should be located to facilitate observation and in-season cleaning. Head differential across the AWS intake fine trash rack should not exceed 0.3 foot in order to facilitate cleaning, minimize velocity hot spots, and maintain hydraulic efficiency in gravity and pumped systems.

Staff gages are used for determining whether the head across a trash rack is within criteria or not. Care should be taken when locating staff gages so that they can be easily read by personnel.

5.3.2.6 Structural integrity

AWS intake fine trash racks should be of sufficient structural integrity to avoid the permanent deformation associated with maximum occlusion.

5.3.3 Specific Criteria and Guidelines – AWS Screens

In instances where the AWS poses a risk to the passage of juvenile salmonids because of its design involving high head and convoluted flow paths, the AWS intake should be screened to the standards specified in Chapter 8 to prevent juvenile salmonids from entering the AWS.

Trip gates, pressure relief valves, or other alternate intakes to the AWS may be included in the design to ensure that AWS flow targets are achieved if screen reliability is uncertain under high river flow conditions. Debris and sediment issues may preclude the use of juvenile fish screen criteria for AWS intakes at certain sites. Passage risk through an AWS will be assessed by NMFS on a site-specific basis to determine whether screening of the AWS is warranted and how to provide the highest reliability possible.

5.3.4 Specific Criteria and Guidelines – AWS Flow Control

The AWS should have a flow control device located sufficiently far away from the AWS intake to ensure the flow at the AWS fine trash rack or screen is uniformly distributed. To facilitate cleaning, the flow control system should allow flow to be easily shut off for maintenance and then restarted (and reset) to proper operating conditions.

The flow control device may consist of a control gate, pump control, turbine intake flow control, or other flow control systems located sufficiently far away from the AWS intake to ensure uniform flow distribution at the AWS fine trash rack for all AWS flows. Flow control is necessary to ensure that the correct quantity of AWS flow is discharged at the appropriate location during a full range of forebay and tailwater levels.

5.3.5 Specific Criteria and Guidelines – AWS Excess Energy Dissipation

Excess energy should be dissipated from AWS flow prior to passage through diffusers.

Dissipation of excess energy is necessary to minimize surging and induce relatively uniform velocity distribution at the diffusers because surging and non-uniform velocities may cause adult fish jumping and associated injuries or excess migration delay. The introduction of highly turbulent or aerated water will discourage fish from entering or passing through a fishway and possibly result in fish delay or injury (Clay 1995). Examples of methods to dissipate excess AWS flow energy include the following:

- Routing flow into a fishway pool with adequate volume (Section 5.3.6.2)
- Passing AWS flow through a turbine
- Passing AWS flow through a series of valves, weirs, or orifices
- Passing AWS flow through a pipeline with concentric rings or other hydraulic transitions designed to induce head loss

All of these dissipation systems require that AWS flow passes through a baffle system that has a porosity of less than 40% to reduce surging through fishway entrance pool diffusers. Adjustable baffles may be required in some systems to properly balance flow across the diffuser.

Figure 5-3 provides a schematic of a fishway AWS diffuser system showing the components needed, and their shape and arrangement, to control water flow rate and convert high-velocity, high-pressure, non-uniform flow into low-energy uniform flow.

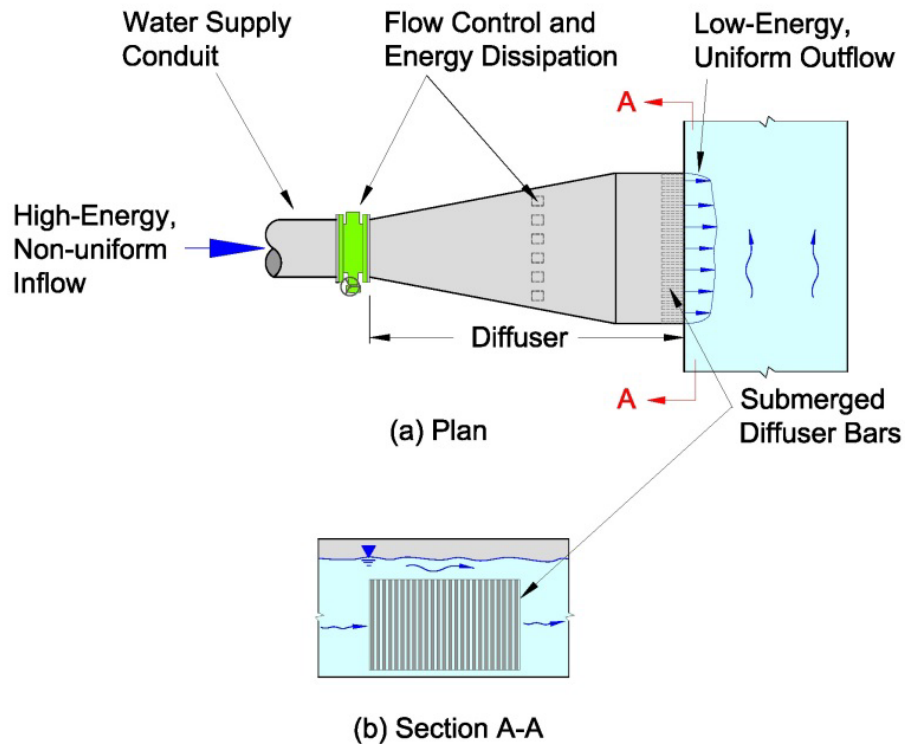


Figure 5-2. Schematic of a fishway AWS diffuser system in plan (a) and section (b) views

5.3.5.1 Energy dissipation pool volume

An energy dissipation pool in an AWS should have a minimum water volume established by the formula shown in Equation 5-1.

$$V = \frac{(\gamma)(Q)(H)}{16 \text{ ft-lb / ft}^3/\text{s}} \quad (5-1)$$

where:

- V = pool volume in cubic feet (ft^3)
- γ = specific weight of water, 64.2 pounds (lb) per ft^3
- Q = AWS flow, in ft^3/s
- H = energy head of pool-to-pool flow, in feet drop into the AWS pool

Note that the pool volumes required for AWS pools are smaller than those required for fishway pools. This is due to the need to provide resting areas in fishway pools and because AWS systems require additional elements (e.g., diffusers and valves) to dissipate energy and are not pathways for upstream fish passage.

5.3.6 Specific Criteria and Guidelines – AWS Diffusers

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bell 1991; Bates 1992). For adult salmonid passage, the maximum clear spacing between bars is 1 inch between diffusers bars. At sites where adult Pacific lamprey may be present, diffusers should have a maximum 0.75-inch clear spacing between bars.

Wall diffusers should consist of non-corrosive, vertically oriented diffuser panels of vertically oriented flat bar stock. Similarly, floor diffusers should consist of non-corrosive, horizontally oriented diffuser panels of horizontally oriented flat bar stock. Orientation of flat bar stock should maximize the open area of the diffuser panel. If a smaller species or life stage of fish is present, smaller clear spacing between bar stock may be required.

5.3.6.1 Material

The bars and picket panels used as part of AWS diffuser systems should be made of aluminum, stainless steel, or epoxy-coated carbon steel. The use of submerged galvanized steel should be minimized or eliminated, especially when used in close proximity to fish (i.e., fishways).

Galvanized steel is coated with zinc, a metal that can be toxic to fish.

5.3.6.2 Velocity and orientation

The maximum AWS diffuser velocity should be less than 1 ft/s for wall diffusers and 0.5 ft/s for floor diffusers based on the total submerged diffuser panel area (Bell 1991). Wall diffusers should only be used when the orientation can be designed to assist with guiding fish within the fishway. Diffuser velocities should be nearly uniform, which may require the use of porosity control panels (Section 5.3.6.3). The face of the diffuser panels (i.e., the surface exposed to the fish) should be flush with the wall or floor.

These criteria are based on *Design of Fishways and Other Fish Facilities* (Clay 1995), which states that 1 ft/s “has been adopted as the best compromise between practicality and efficiency.” These criteria are also based on the results of laboratory studies where spring- and fall-run Chinook salmon and steelhead passage times increased when diffuser flows were added and were progressively longer as floor diffuser velocity increased from 0.25 to 1.25 ft/s (Gauley et al. 1966).

An example of wall diffusers being used to assist in guiding fish is when the diffusers in the entrance pool of a fishway are situated such that fish are naturally lead upstream to the first ladder pool.

When wall diffusers are used in conjunction with a half Ice Harbor-style ladder, the diffuser should be located on the same side as the overflow weir, and the diffuser bars should be oriented horizontally.

5.3.6.3 Porosity control baffles

Similar to juvenile fish screens, diffusers should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure that average velocities at the face of the diffuser are uniform and can meet criteria (Section 5.3.6.2).

The purpose of the porosity control panels is to control the amount of flow through the diffuser pickets and create a uniform flow condition at the face of the pickets.

5.3.6.4 Debris removal

The AWS design should include access for personnel to remove debris from each diffuser unless the AWS intake is required per the criteria listed in Section 5.3.4 to be equipped with a juvenile fish screen (Chapter 8).

5.3.6.5 Edges

All flat bar diffuser edges and surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.

5.3.6.6 Lamprey passage

At sites where Pacific lamprey are present, horizontal diffusers should not extend the complete width of the floor of the fishway or entrance pool. A solid surface, approximately 1.5 feet wide, should be located along the floor between the lateral sides of the diffuser panels and the base of either wall.

5.3.6.7 Elevation

Wall AWS diffusers should be submerged throughout the range of operation (i.e., the top elevation of the wall diffuser should be below the lowest water surface elevation that will occur based on the fishway design).

This is to prevent water from cascading through the diffuser, which can induce fish to leap at the surface disturbance.

5.3.7 Specific Criteria and Guidelines – Bedload Removal Devices

At locations where bedload may cause accumulations at the AWS intake, sluice gates or other simple bedload removal devices should be included in the design.

5.4 Transport Channels

5.4.1 Description and Purpose

A transport channel conveys flows between different sectors of the upstream passage facility, providing a route for fish to pass.

5.4.2 Specific Criteria and Guidelines – Transport Channels

5.4.2.1 Velocity range

The transport channel velocities should be between 1.5 and 4 ft/s (Gauley et al. 1966; Bates 1992), including flow velocity over or between fishway weirs inundated by high tailwater (Bell 1991).

Gauley et al. (1966) reported that Chinook and sockeye salmon and steelhead passage times did not differ significantly between water velocities of 1 and 4 ft/s in an experimental 270-foot-long transportation channel. However, Weaver (1963) reported that Chinook salmon moved progressively slower in a test flume as velocities increased from 2 to 8 ft/s.

5.4.2.2 Dimensions

The transport channels should be a minimum of 5 feet deep and 4 feet wide.

This is based on providing the narrowest, shallowest flow path that adult fish are known to move through readily while also displaying the least amount of fallback behavior and delay. In addition, this size of channel relates to the goal of keeping water velocities in the transport channel low.

5.4.2.3 Lighting

Ambient natural lighting should be provided in all transport channels, if possible. If ambient (natural) lighting is not available, acceptable artificial lighting should be used.

In laboratory tests, fish were presented with the choice of a large entrance (3.9 feet by 3.9 feet) that was dark or a smaller entrance (1.5 feet by 2 feet) that was lighted. Study results corroborate the understanding that fish prefer lighted entrances and channels: 80% of Chinook salmon, 90% of coho salmon, 69% of steelhead, and 86% of sockeye salmon chose the lighted entrance (Bates 1992).

5.4.2.4 Design (general)

Based on the literature and experiences of fish biologists at many facilities located in the WCR, the following features should be included in the design of transport channels:

- *The transport channels should be of open channel design (Bell 1991).*
- *Designs should avoid hydraulic transitions or lighting transitions (USFWS 1960; Bell 1991).*
- *Transport channels should not expose fish to any moving parts.*
- *Transport channels should be designed so that there is no standing water in the channel when the system is dewatered.*
- *Transport channels should be free of exposed edges that protrude from channel walls.*

5.5 Fish Ladder Design

5.5.1 Description and Purpose

The purpose of a fish ladder is to convert total project head at the passage barrier into passable increments and provide suitable conditions for fish to hold, rest, and ultimately pass upstream. Nearly all of the energy from the upstream ladder pool is dissipated in the downstream ladder pool volume, resulting in a series of relatively calm pools that migrating fish may use to rest and stage before ascending upstream. The criteria provided in this section have been developed to provide conditions to pass all anadromous salmonid species upstream with minimal delay and injury.

5.5.2 Common Types of Fish Ladders

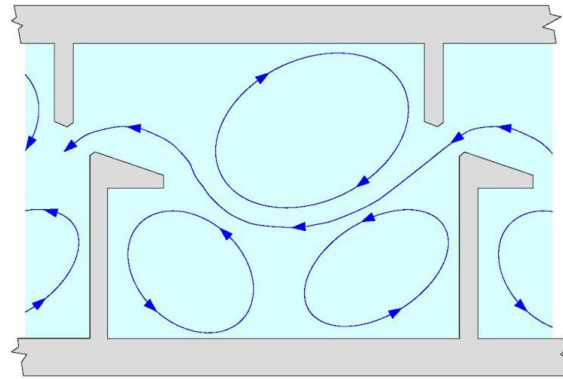
Fish ladders or fishways, in one form or another, have been around for more than 300 years (Clay 1995). Over time, ladder designs have developed and evolved and have been adapted to meet site-specific conditions. For the purpose of this document, fish ladders are divided into the following two categories:

- Pool-style ladders, including:
 - Vertical slot
 - Pool and weir
 - Weir and orifice
 - Pool and chute
- Roughened (Baffled) chute-style ladders, including:
 - Denil steep pass
 - Alaska steep pass (ASP)

The following sections present brief discussions of criteria and guidelines for the more common styles of fish ladders.

5.5.2.1 Vertical slot ladder

The vertical slot configuration is a pool-style of fish ladder (Figures 5-3 through 5-5; Table 5-1). The vertical slot ladder is suitable for passage impediments that have tailrace and forebay water surface elevations that fluctuate within large ranges. The maximum head differential—typically associated with the lowest river flows—establishes the design water surface profile, which usually parallels the fishway floor gradient.



(a) Generalized Flow Path



(b) In actual fishway pools

Figure 5-3. Plan view of a vertical slot ladder showing generalized flow paths



Figure 5-4. Oblique view of a vertical slot ladder baffle when dewatered

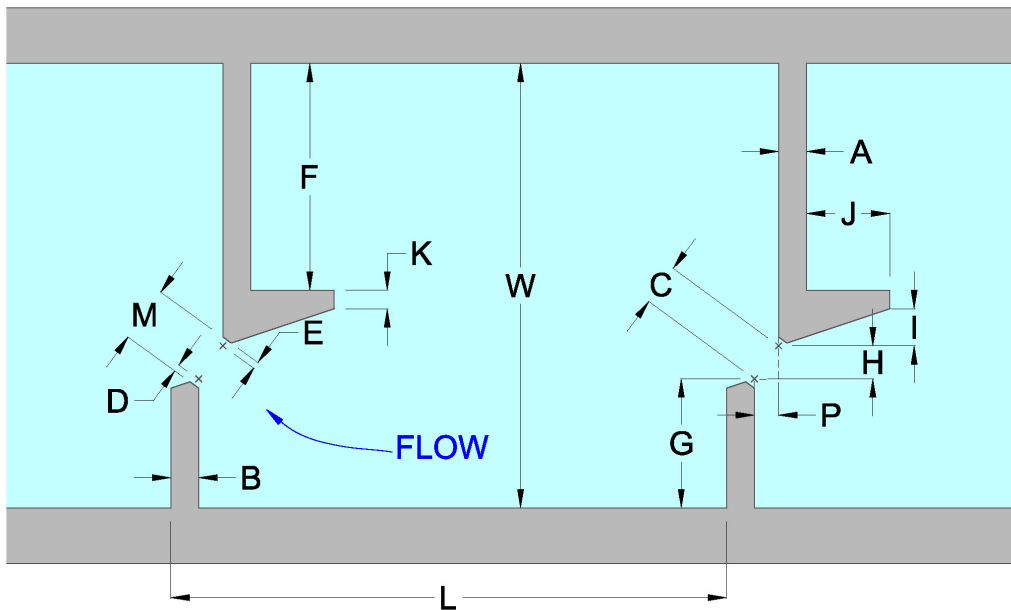


Figure 5-5. Dimensions of a typical vertical slot ladder pool

(Note that information for Figure 5-6 is provided in Table 5-1. “D” is the dimension of the layout points used during ladder design and construction (i.e., the framing and the form work for the concrete pours); it determines the chamfer for the slot and the width of the slot; and knowing “D” allows the designer to layout the complex angles used during construction.)

Table 5-1. Dimensions for vertical slot ladder components measured in feet.

Symbol		Dimension Nomenclature (Refer to Figure 5-6)			
L		Pool length	10'0"	10'0"	10'0"
W		Pool width	6'0"	8'0"	8'0"
A		Long baffle width ^A	0'6"	0'6"	0'6"
B		Short baffle width ^A	0'6"	0'6"	0'6"
M		Slot width	1'0"	1'0"	1'3"
C		Slot width layout points	0'9"	0'9"	0'9"
D, E		Dimension "C" layout points (separation from baffles)	0'1½"	0'1½"	0'3"
F		Long baffle wall length	3'1"	4'1"	4'1"
G		Short baffle wall length (wall to layout point)	1'¾"	2'¾"	2'¾"
I		Flow deflector width change	0'7"	0'8"	0'7"
J		Flow deflector length	1'3"	1'6"	1'3"
K		Flow deflector upstream width	0'5"	0'4"	0'5"

Note:

A: Short baffle and long baffle widths may need to be increased in certain instances for structural integrity in large fishway installations.

The full-depth vertical slots allow fish passage at any depth (Clay 1995). Fish are assumed to be able to move directly from slot to slot in a straight path, although this has not been verified (Clay 1995). However, hydraulic studies have verified that velocity through the slot is constant throughout the vertical profile (Katopodis 1992). The vertical slot may not be well suited for species that require overflow weirs for passage or that tend to orient to walls such as American shad.

5.5.2.1.1 Vertical slot width and depth

For adult anadromous salmonids, slots should never be less than 1 foot in width. If larger Chinook salmon are expected to pass, the minimum slot width is 1.25 feet (Clay 1995). Bell (1991) recommends a minimum slot depth of 3 feet, although they are typically on the order of 5- to 6-feet deep to match the required pool depth.

The passage corridor typically consists of 1- to 1.25-foot-wide vertical slots between fishway pools. However, narrower slots have been recommended (Clay 1995) and used in applications for other fish species that are smaller than salmon or steelhead. In some situations, wider slots (or two slots per ladder weir) are used if AWS flow is not being added to the ladder.

Vertical slot ladders tend to require more water to operate properly compared with other styles of fishways because of the width and depth of the slot and the head differential between pools. Low sills can be added to the bottom of each slot to reduce the overall amount of flow in

the ladder that is required. However, these sills may block the passage of species that prefer or need to travel along the floor of a ladder.

5.5.2.1.2 Vertical slot geometry (pool size)

Standard, proven design dimensions should be adhered to unless it can be proven through physical hydraulic modeling that changes do not affect the function of the ladder.

Vertical slot ladders are sensitive to changes in pool geometry (e.g., pool width, length, slope, and slot width; Clay 1995), and initial construction costs are higher than other types of ladders because of the more complex design and concrete placement.

5.5.2.2 Pool and weir ladder

The simplest style of fish ladder is the pool and weir ladder (Bell 1991); it is also one of the oldest styles of fish ladder. The pool and weir fish ladder passes the entire, almost constant, fishway flow through successive pools separated by overflow weirs that break the total project head into passable increments (Figure 5-6). This design allows fish to ascend to higher elevations by passing over weirs, and it provides resting zones within each pool. When passing this style of ladder, fish must leap or swim over the weir flow. Pools are sized to allow flow energy to be nearly fully dissipated through turbulence within each receiving pool (Clay 1995).



Figure 5-6. Examples of pool and weir ladders

(Note that the orifices in the weir wall on the left-side photo are to drain each of the pools and are not meant for fish passage.)

In contrast to vertical slot ladders, pool and weir ladders require nearly constant water surface elevations in the forebay pool to function properly (Bell 1991; Clay 1995). When the water surface elevation fluctuates outside of the design elevation, too much or too little flow

enters the fishway. This flow fluctuation may affect upstream passage by causing fishway pools to be excessively turbulent or providing insufficient flow. To accommodate forebay fluctuations and maintain a consistent flow in the ladder, pool and weir ladders are often designed with an AWS (Section 5.3) and fishway exit control section (Section 5.7; Bell 1991). To accommodate tailwater fluctuations, pool and weir ladder designs may include an adjustable fishway entrance (i.e., adjustable geometry and attraction flow) and an AWS to provide additional flow to meet the channel velocity criterion (Section 5.4.2.1; Bell 1991).

5.5.2.3 Weir and orifice ladder

The weir and orifice fish ladder passes flow from the forebay through successive fishway pools connected by overflow weirs and submerged orifices, which divide the total project head into passable increments (Figures 5-7 and 5-8, Table 5-2; Clay 1995). Weir and orifice ladders are similar to pool and weir ladders in the following ways:

- Weir and orifice ladders require nearly constant water surface elevations in the forebay pool (unless adjustable components are included to accommodate the varying forebay level); water surface elevations outside of the design elevation result in too much or too little flow entering the fishway, which may affect fish passage due to turbulence or insufficient flow.
- Weir and orifice ladders are often designed with an AWS and fishway exit control section (Section 5.7), an adjustable fishway entrance (i.e., adjustable geometry and attraction flow), and an AWS to provide additional low diffusers to meet the transport channel velocity criterion (Section 5.4.2.1).

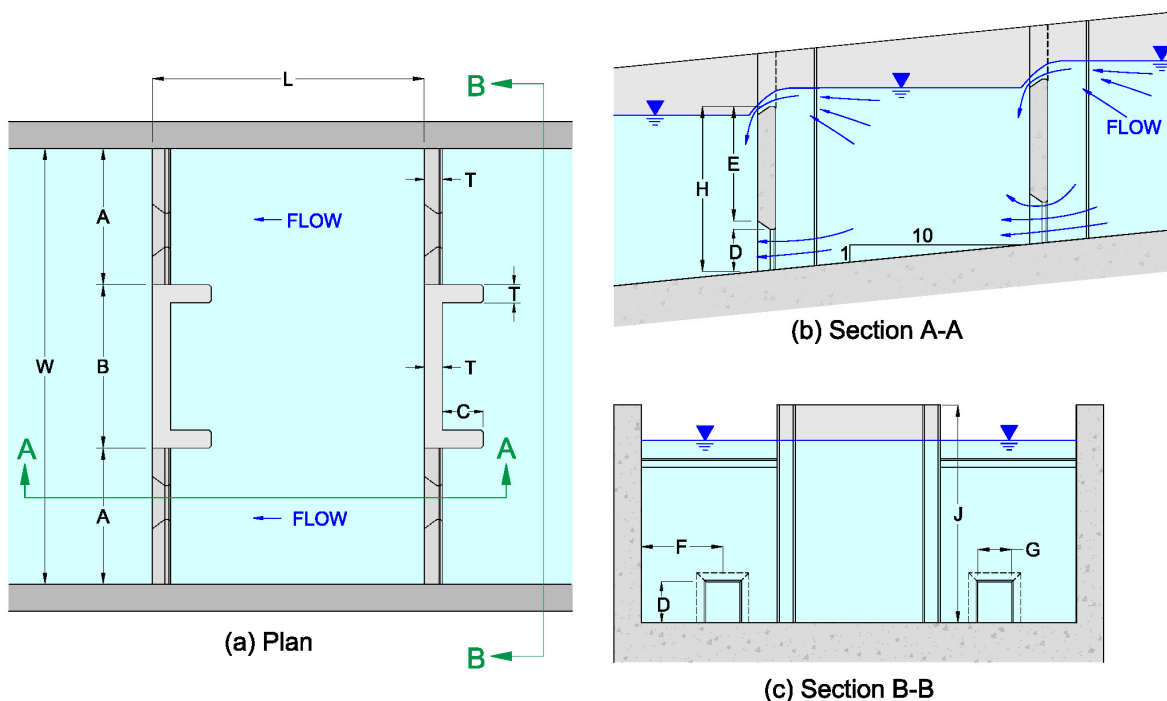


Figure 5-7. Ice Harbor-style weir and orifice ladder (adapted from Gauley et al. 1966

(Note that information for Figure 5-7 is provided in Table 5-2.)



(a) Looking downstream

(b) Looking upstream

Figure 5-8. Overhead views of Ice Harbor-style weir and orifice fish ladders

Table 5-2. Dimensions for Ice Harbor fishways measured in feet

Symbol	Dimension Nomenclature (Refer to Figure 5-8)	Bell 1991	Gauley et al. 1966
L	Pool length	8–20	10
W	Pool width	6–20	16
A	Weir length	1.5–5	5
B	Center baffle width	$W/2^*$	6
C	Flow stabilizer length	NA	1'6"
D	Orifice height	1'6"	1'6"
E	Baffle height above orifice	4'3"	4'6"
F	Wall to orifice center line	NA	3
G	Orifice width	1'3"	1'6"
H	Weir height	6	6
J	Wing baffle height	8	8
T	Weir and baffle thickness	NA	NA

Notes:

* See “W” in panel (a) of Figure 5-8.

Dimensions listed under Bell (1991) are taken from

https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Bell_1991_Fisheries_handbook_of_engineering_requirements_and.pdf.

Dimensions listed under Gauley et al. 1966 are taken from the report located here:

https://www.nwfsc.noaa.gov/assets/26/7778_08132014_135336_Gauley.et.al.1966.pdf.

NA: not available

When passing this style of ladder, fish have the choice of leaping or swimming over the weir or swimming through the orifice, and it is NMFS' experience that most salmonids prefer to swim through the orifice. The Ice Harbor ladder is an example of a weir and orifice fish ladder. This ladder design was developed in the 1960s for use at Ice Harbor Dam on the Snake River in Washington by the Bureau of Commercial Fisheries at USACE Fisheries-Engineering Research Laboratory (FERL), which was located at the Bonneville Dam on the Columbia River in Oregon (Figure G-1 in Appendix G). Fish passage research was conducted at FERL from 1955 until it was decommissioned in the 1980s (see Appendix I for a listing of reports of research conducted at the FERL). The research provided basic knowledge of the behavior, abilities, and requirements of fish in fish passage situations (Collins 1976).

Development and testing at FERL resulted in the design of the 1-on-10 slope ladder for Ice Harbor Dam, which was studied in a full-scale section of the ladder consisting of six ladder pools. A prototype ladder was tested during its first year of operation at Ice Harbor Dam. The design is a pool and weir ladder with submerged orifices, flow stabilizers, and a non-overflow section in the middle of each weir (Figures 5-7 and 5-8). See Table 5-2 for typical dimension of this type of fishway. There is a 1-foot rise between pools, and the average water depth under normal operating conditions is 6.5 feet (Gauley et al. 1966). The Ice Harbor-style of ladder includes two rectangular orifices centered on and located directly below each overflow weir. The position and depth of the orifices were found to have a significant effect on the passage of fish through rectangular submerged orifices (Thompson et al. 1967). The orifice and weir combinations are located on each side of the longitudinal centerline of the ladder. Between the two weirs is a slightly higher non-overflow wall with an upstream-projecting flow baffle located at each end. An adaptation for lower flow designs is the half Ice Harbor ladder design, which consists of a weir, an orifice, and a non-overflow wall between fishway pools.

5.5.2.4 Pool and chute ladder

A pool and chute ladder is a hybrid that operates under varying river flow conditions. This ladder is designed to operate as a pool and weir ladder at low river flows and as a roughened chute-style fishway at higher river flows (Figure 5-9). This ladder is an alternative style of ladder for sites with a low hydraulic drop that must pass a wide range of streamflows with a minimum of flow control features. Placement of stoplogs—a cumbersome and potentially hazardous operation—is required to optimize operation of this ladder. However, once suitable flow regimes are established, the need for additional stoplog placement may not be required. Criteria for this type of ladder design are still evolving, and design proposals will be assessed by NMFS on a site-specific basis. Bates (1992) provides specific criteria and guidelines for this style of ladder where fish have the option of swimming over, or leaping the overflow weir, or swimming through the orifice. The lateral slope of the weirs presents fish with flow conditions that range from plunging flow near the edges to streaming flow towards the center of the ladder.



Figure 5-9. Pool and chute ladder dewatered (at left) and watered (at right)

5.5.2.5 Half Ice Harbor and half-pool and chute ladders

The flow rate available to pass through a fishway at small projects is often too low to take advantage of the benefits of the standard Ice Harbor or pool and chute ladder designs. In these situations, it is possible to design and construct weirs shaped as one-half of an Ice Harbor-style weir and orifice ladder or one-half of a pool and chute-style ladder (Figure 5-10). These designs share the same advantages and disadvantages as their full-sized counterparts and should meet all of the design criteria for each type of full-sized ladder. The hydraulic design process used for half-ladders is analogous to the design process used for full-sized ladders.



Figure 5-10. Half ladder designs for projects with reduced available fishway flows

(Note: panel on left is a half-Ice Harbor ladder weir and orifice design; panel on right is a half-pool and chute ladder with weir design.)

5.5.3 Specific Criteria and Guidelines – Fish Ladder Design

5.5.3.1 Hydraulic drop

The maximum hydraulic drop between fish ladder pools should be 1 foot or less (Bell 1991; Clay 1995). Where pink or chum salmon are present, the maximum hydraulic drop between pools should be 0.75 foot or less (Bates 1992; Clay 1995).

5.5.3.2 Flow depth

Fishway overflow weirs should be designed to provide at least 1 foot (± 0.1 foot) of flow depth over the weir crest (Clay 1995; WDFW 2000).

The depth should be indicated by locating a single staff gage in an observable, hydraulically stable location that is representative of flow depth throughout the fishway. The zero reading of the gage should be at the overflow weir crest elevation.

5.5.3.2.1 Streaming flow

Some fish species will not leap or are poor leapers and will refuse to pass or become delayed by plunging flow conditions in a ladder. They may also refuse to pass through the orifices in a ladder (e.g., all shad species). For those species, streaming flow should be created

between ladder pools to provide acceptable passage conditions. When pink or chum salmon are present, the upstream weir crest should be submerged by at least 0.5 foot by the downstream water surface level (Bates 1992). Where American shad are present, the upstream weir crest should be submerged by at least 0.3 foot by the downstream water surface level.

Streaming flow occurs when the weir is backwatered by the downstream weir (Bates 1992; Katapodis 1992). The transition between plunging flow and streaming flow is hydraulically unstable and should be avoided according to Bell (1991) and Bates (1992) because passage can be delayed when flow is in this transition. Hydraulic instability occurs in the transition regime between the upper range of plunging flow and the lower range of streaming flow. The instability can also cause large oscillations that are transmitted throughout the fishway because energy is not dissipated in each pool of the fishway, which makes the streaming flow jet difficult to manage. For these reasons, streaming flow in a fishway should be used cautiously (Bates 1992).

Submerging the upstream weir crest by 0.3 foot is based on experience with adjusting ladder flows at Columbia River dams to pass American shad. In addition, Larinier and Travade (2002) state that a head of around 1.3 feet and streaming flow in an Ice Harbor-style ladder are needed for shad passage. Rideout et al. (1985) report substantial improvements in American shad passage at the Turners Falls dam fishway in Massachusetts when flow over weir crests was changed from plunging to streaming.

5.5.3.3 Pool dimensions

In general, pool dimensions should be a minimum of 8 feet long (upstream to downstream), 6 feet wide, and 5 feet deep. However, specific ladder designs may require pool dimensions that are different from the minimums specified in this criterion, depending on site conditions and ladder flows (see Clay 1995).

For small stream ladders, Bell (1991) provides minimum dimensions for some pool and weir fishway designs. The minimum pool should not be less than 6 feet long, 3 feet deep, and 4 feet wide. It is recommended that the fishway slope not exceed 1:8. For pools less than 8 feet in length, the drop between pools should be reduced proportionally. To allow for the proper dissipation of the orifice flow, the pool dimensions for a pool and orifice-style ladder should not be reduced (Clay 1995).

Ladder pools should be designed so that there is no standing water in the pools when the system is dewatered. The floors of the ladder should be sloped from the sides to the floor orifice to encourage fish to move downstream during salvage operations conducted when a ladder is dewatered for maintenance.

5.5.3.4 Turning pools

Turning pools (i.e., pools where the fishway direction changes more than 90 degrees) should be at least double the length of a standard fishway pool, as measured along the centerline of the fishway flow path. The orientation of the upstream weir to the downstream weir should be such that energy from flow over the upstream weir does not affect the hydraulic conditions at the downstream weir.

5.5.3.5 Pool volume

The pool volume within the fishway should provide sufficient volume (i.e., hydraulic capacity) to absorb and dissipate the pool-to-pool energy and accommodate the maximum daily run of fish (i.e., fish capacity; Appendix H).

Generally, the volume required to provide adequate hydraulic capacity governs pool sizing (Bell 1991; Bates 1992). To provide adequate hydraulic capacity, the fishway pools should be a minimum volume (of water) based on Equation 5-2.

$$V = \frac{(\gamma)(Q)(H)}{4 \text{ ft-lb / ft}^3/\text{s}} \quad (5-2)$$

where:

- V = pool volume in ft^3
- γ = specific weight of water, 64.2 lb per ft^3
- Q = specific weight flow, in ft^3/s
- H = energy head of pool-to-pool flow, in feet

This pool volume should be provided under every expected design flow condition, with the entire pool volume having active flow and contributing to energy dissipation.

If large numbers of fish are expected to pass the fish ladder in a relatively short amount of time, overcrowding can occur, leading to delay. Delay in passage is minimized by providing ample volume to accommodate the peak of the run without overcrowding (Clay 1995). Therefore, it may be necessary to increase the individual pool volume to accommodate the peak run of fish. See Appendix H for sizing a fish ladder based upon run size.

5.5.3.6 Freeboard

The freeboard of the ladder pools should be at least 3 feet at high design flow.

5.5.3.7 Orifice dimensions

At sites where large salmonids are expected, the minimum dimensions of the orifice should be 18 inches high by 15 inches wide (Bell 1991), based on the Ice Harbor ladder design dimensions (Section 5.5.3.3).

The minimum dimensions of orifices where large salmonids are not expected should be at least 15 inches high by 12 inches wide.

The top and sides of the orifice should be chamfered 0.75 inch on the upstream side and chamfered 1.5 inches on the downstream side of the orifice to provide the most stable flow (Bates 1992).

For sites where Pacific lamprey are present, the floor of the fishway should provide a continuous, uninterrupted surface through the orifice. USACE (Portland District) has developed and installed an orifice with rounded edges to facilitate Pacific lamprey passage.

The primary concern with smaller orifices is the increased risk of plugging by debris (WDFW 2000).

5.5.3.8 Lighting

Ambient lighting should be provided throughout the fishway, and abrupt lighting changes should be avoided (Bell 1991). In enclosed systems, such as transport tunnels, provisions for artificial lighting should be included. In cases where artificial lighting is required, lighting in the blue-green spectral range should be provided. Artificial lighting should be designed to operate under all environmental conditions at the installation.

These lighting criteria are based in part on laboratory studies where a majority of Chinook and sockeye salmon and steelhead entered the lighted orifice when given a choice between a dark experimental orifice and a lighted control orifice where head was equal between the two orifices (Weaver et al. 1976).

5.5.3.9 Change in flow direction

At locations where the flow changes direction more than 60 degrees, 45-degree vertical miters (minimum 20 inches wide) or a 2-foot minimum, vertical radius of curvature should be included in the design of the outside corners of fishway pools (Bell 1991).

Bell reports that “Fish accumulate when pool hydraulic patterns are altered. If the design includes turn pools, fish will accumulate at that point. Square corners, particularly in turn pools, should be avoided as fish jump at the upwelling so created” (1991). Depending upon the pool configuration, size of the turning pool, and amount and velocity of the flow in the ladder, larger radii of curvatures may be necessary.

5.6 Counting Stations and Windows

5.6.1 Description and Purpose

Counting stations provide a location and facility to observe and enumerate fish utilizing the fish passage facility. Although not always required, a typical counting station includes a video camera or fish counting technician, crowder, and counting window (Bell 1991). Counting stations are often included in a fish ladder design to allow fishery managers to assess fish population status, observe fish size and condition, and conduct scientific research.

5.6.1.1 Operation

Counting stations should not interfere with the normal operation of the ladder and should not create excessive fish passage delay.

A decision to include a counting station as part of the ladder design should be carefully considered. Regardless of how well the counting station is designed, oftentimes fish hold and delay at counting stations because of conditions that change the facility such as crowding, lighting, and hydraulics. Instead of a counting station, other means of enumeration may be acceptable, including the use of submerged cameras and their associated lighting, adult PIT-tag detectors, and orifice counting tubes.

5.6.2 Specific Criteria and Guidelines – Counting Stations

5.6.2.1 Location

Counting stations should be located in a hydraulically stable, low velocity (i.e., around 1.5 ft/s), and accessible area of the upstream passage facility.

5.6.2.2 Downstream and upstream pools

The pool downstream of the counting station should extend at least two standard fishway pool lengths from the downstream end of the picket leads. The pool upstream of the counting station should extend at least one standard fishway pool length from the upstream end of the picket leads. Both pools should be straight and in line with the counting station (Bell 1991).

5.6.3 Specific Criteria and Guidelines – Counting Windows

5.6.3.1 Design and material

The counting window should be designed such that cleaning of the window can be accomplished completely, conveniently, and at a frequency that ensures window visibility will be maintained and accurate counting can be accomplished. The counting window material should be abrasion-resistant to accommodate frequent cleaning.

5.6.3.2 Orientation

Counting windows should be vertically oriented.

5.6.3.3 Sill

The counting window sill should be positioned to allow full viewing of the fish passage slot (from floor to water surface).

5.6.3.4 Lighting

The counting window design should include sufficient indirect, artificial lighting to provide satisfactory fish identification at all hours of operation and without causing passage delay.

5.6.3.5 Dimensions

The minimum observable length of the counting window in the upstream-to-downstream flow direction should be 5 feet, and the minimum height (depth) should be full water depth.

5.6.3.6 Counting window slot width

The width of the counting station slot (the area between the counting window and the vertical surface at the back of the slot) should be at least 18 inches. The design should include an adjustable crowder to move fish closer to the counting window (but not closer than 18 inches) to allow fish counting under turbid water conditions. The counting window slot width should be maximized as water clarity allows and when not actively counting fish.

5.6.3.7 Picket lead

A downstream picket lead should be included in the design to guide fish into the counting window slot, and it should be oriented at a deflection angle of 45 degrees relative to the direction of fishway flow. An upstream picket lead oriented at a deflection angle of 45 degrees to the flow direction should also be provided. Picket orientation, picket clearance, and maximum allowable velocity should conform to specifications for diffusers (Section 5.3.7).

Combined maximum head differential through both sets of pickets should be less than 0.3 foot. Both upstream and downstream picket leads should be equipped with witness marks to verify correct position when picket leads are installed in the fishway. A 1-foot-square opening should be provided in the upstream picket lead to allow smaller fish that pass through the downstream picket lead to escape the area between the two picket leads.

Picket leads may comprise flat stock bars oriented parallel to flow or other cross-sectional shapes, if approved by NMFS.

5.6.3.8 Transition ramps

If the counting window requires a false floor to force fish to swim higher in the water column to be more easily identified, then transition ramps should be included in a counting station design. The ramps should smoothly transition from the floor of the counting station pool to the false floor at the counting window and then back to the counting station floor.

These ramps provide gradual transitions between walls, floors, and the false floor in the counting window slot. The purpose is to minimize flow separations created by head loss that may impede fish passage and induce fallback behavior at the counting window. In situations where space is available, the transitions should be more gradual than 1:8, and where space is confined, a 1:4 transition should be used.

5.6.3.9 Water surface through the counting slot

A free water surface should exist over the length of the counting window.

5.7 Fishway Exit Control

5.7.1 Description and Purpose

This section describes and provides criteria for a ladder exit control channel for fish to egress the fishway and enter the forebay of a dam to continue upstream migration. The exit

control channel may include the following features: add-in auxiliary water valves and diffusers, exit pools with varied flow, exit channels, a coarse trash rack that keeps large debris out of the ladder but allows fish to pass through the trash rack and exit the ladder, and fine trash racks and control gates on AWS systems. The exit control section of the ladder also attenuates fluctuations in forebay water surface elevation, thus maintaining hydraulic conditions suitable for fish passage in the ladder pools. Other functions that should be incorporated into the design of the exit control section include minimizing the entrainment of debris and sediment into the fish ladder. Different types of ladder designs (Section 5.5) require specific fish ladder exit design details unique to each type of ladder.

5.7.2 Specific Criteria and Guidelines – Fishway Exit Control

5.7.2.1 Hydraulic drop

The exit control section hydraulic drop per pool should range from 0.25 to 1 foot.

5.7.2.2 Length

The length of the exit channel upstream of the exit control section should be a minimum of two standard ladder pools.

5.7.2.3 Design requirements

Exit section design should utilize the requirements for AWS diffusers, channel geometry, and energy dissipation as specified in Sections 5.3, 5.4, and 5.5.

5.7.2.4 Closure gates

Any closure gate that is incorporated into the exit control section should be operated either in the fully opened or closed position (i.e., the gates cannot be partially open to regulate flow).

5.7.2.5 Location

In most cases, the ladder exit should be located along a shoreline, in a velocity zone of less than 4 ft/s, and sufficiently far enough upstream of a spillway, sluiceway, or powerhouse to minimize the risk of fish non-volitionally falling back through these routes (Clay 1995).

The distance the exit needs to be upstream of these hazards depends on bathymetry near the dam spillway or crest and associated longitudinal river velocities (Bell 1991).

5.7.2.6 Public access

Public access near the ladder exit should be prohibited.

5.8 Fishway Exit Sediment and Debris Management

5.8.1 Description and Purpose

As stated in Section 5.7.1, the design of the ladder exit should strive to minimize the entrainment of debris and sediment into the fish ladder. Floating and submerged debris can become lodged in ladder orifices or on weir crests, alter hydraulic conditions in these fish passage routes, and impact fish behavior and passage rates. Similarly, sediment transported into the fishway can deposit in low-velocity areas, alter hydraulic conditions, and impact fish passage. Removing debris and sediment from ladders can be difficult and costly. Therefore, preventing debris and sediment from entering the ladder from the forebay should be a goal of the ladder exit design.

5.8.1.1 Coarse trash rack

For facilities where maintenance is frequently required and provided, coarse trash racks should be included at the fishway exit to minimize the entrainment of debris into the fishway (Figure 5-9; Bell 1991).

5.8.2 Specific Criteria and Guidelines – Coarse Trash Rack

5.8.2.1 Velocity

The velocity through the gross area of a clean coarse trash rack should be less than 1.5 ft/s to reduce debris accumulation and thus facilitate cleaning of the racks regularly (Bates 1992).

Bell (1991) indicated there is no evidence of fish refusing to pass through trash racks at velocities normal to the trash rack of 2 ft/s or less.

5.8.2.2 Depth

The depth of flow through a coarse trash rack should be equal to the pool depth in the ladder exit channel.

5.8.2.3 Maintenance

At locations where manual cleaning is anticipated, the coarse trash rack should be installed at 1:5 slope (or flatter) for ease of cleaning (Bates 1992). The coarse trash rack design should allow for easy maintenance and provide access for personnel, travel clearances for manual or automated trash raking, and the removal of debris.

5.8.2.4 Bar spacing

The coarse trash rack on the ladder exit should have a minimum clear space between vertical flat bars of 10 inches if Chinook salmon are present, and 8 inches for all other species and instances. Lateral support bar spacing should be a minimum of 24 inches and should be sufficiently set back from the face of the coarse trash rack to allow trash rake tines to fully

penetrate the rack for effective debris removal. Coarse trash racks should extend to the appropriate elevation above water to allow debris raked from the trash racks to be easily removed.

Bell (1991) recommends that the clear openings of a trash rack be adapted to the width of the largest fish to be passed, which is usually 12 inches for large salmon. Figure 5-11 shows an example of a sloping coarse trash rack on the exit channel of a small fishway.



Figure 5-11. Sloping coarse trash rack on a fishway exit channel

5.8.2.5 Orientation

The fishway exit coarse trash rack should be oriented at a deflection angle greater than 45 degrees relative to the direction of river flow.

5.8.3 Specific Criteria and Guidelines – Debris and Sediment

5.8.3.1 Coarse floating debris

Debris booms, curtain walls, or other provisions should be included in the design of a fishway if coarse floating debris is expected.

5.8.3.2 Debris accumulation

If debris accumulation is expected to be high, the fishway design should include an automated mechanical debris removal system. If debris accumulation potential is unknown, the

design should anticipate the need for debris removal in the future and include features to allow an automated mechanical debris removal system to be retrofitted to the design.

5.8.3.3 Sediment entrainment and accumulation

The fishway exit should be designed to minimize sediment entrainment into the fishway and sediment and debris accumulation at the exit under normal operations.

5.9 Roughened (Baffled) Chute Fishways

5.9.1 Description and Purpose

This section discusses the baffled chute, which is another general type of fish passage system. It consists of a hydraulically roughened flume that has nearly continuous energy dissipation throughout its length.

5.9.2 Specific Criteria and Guidelines – Baffled Chutes

The baffled chute fishway utilizes a relatively steep, narrow flume with internal roughness elements that generate lower water velocities that allow the fish to swim through the fishway. Denil and ASP fishways are examples of baffled chute fishways that share a similar design philosophy. Baffled chute fishways are designed to operate with less flow and at steeper slopes than traditional ladders.

5.9.2.1 Uses

Denil and ASP fishways should not be used as the primary route of passage at permanent fishway installations in the WCR.

Baffle chute fishways are not considered a substitute for a permanent style of ladder (e.g., a pool and weir ladder) because of their tendency to collect debris and their limited operating range. Denil and ASP fishways are primarily used at sites where the fishway can be closely monitored and inspected daily. This includes off-ladder fish traps, temporary fishways used during construction of permanent passage facilities, and fishways operated temporarily each year to collect hatchery broodstock. Baffle chute fishways should not be used at locations or in situations where the downstream passage of adults or juvenile salmonids occurs.

5.9.2.2 Debris

Denil and ASP fishways should not be used in areas where even minor amounts of debris are expected (Bell 1991).

Debris accumulation in any fishway, in combination with turbulent flow, may injure fish or render the fishway impassable. Because of their internal baffle geometry and narrow flow paths, baffle chute fishways are especially susceptible to debris accumulation, creating a blockage to passage.

5.9.2.3 Design

Denil and ASP fishways are designed with a sloped channel that has a constant discharge for a given normal depth, chute gradient, and baffle configuration (Figure 5-12). Energy is dissipated consistently throughout the length of the fishway via channel roughness and results in an average velocity compatible with the swimming ability of adult salmonids. The passage corridor consists of a chute flow between and through the baffles. A wide range of flows are possible for Denil fishways depending on fishway size, slope, and water depth (Bates 1992).

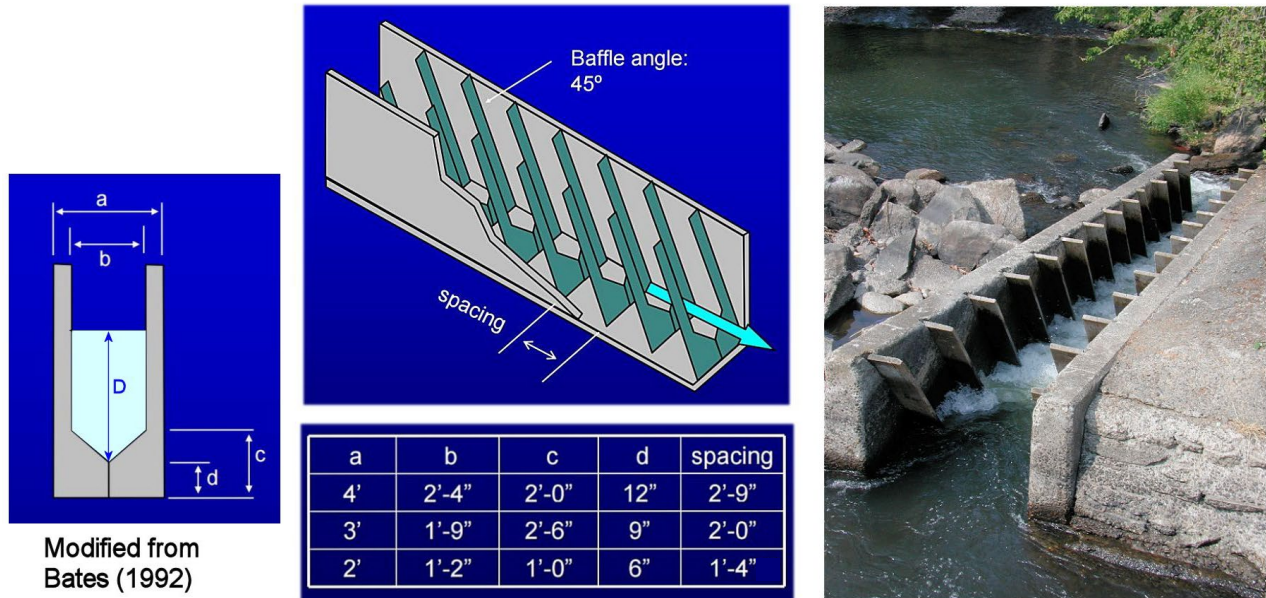


Figure 5-12. Drawings, dimensions, and a photo of a Denil fishway

5.9.2.3.1 Specific design information – Denil fishways

The standard dimensions shown in Figure 5-12 and the following design information for Denil fishways is taken from Bates (1992):

- *NMFS recommends a maximum slope of 20%.*
 - The normal slope for a Denil-style fishway is 17% (Bell 1991), though they have been used at slopes up to 25% (Bates 1992).
- *Discharge through Denil fishways can be calculated using Equation 5-3 (Bates 1992).*

$$Q = 5.73D^2\sqrt{bS} \quad (5-3)$$

where:

- Q = ladder flow, in ft³/s
- D = depth (feet) of flow above the vee baffle
- b = clear opening in the baffle (feet)
- S = slope (feet/feet)

- *The average chute design velocity should be less than 5 ft/s (Bell 1991).*
 - The most common size of Denil fishway used is the 4-foot-wide flume (Bates 1992).
- *Flow control is important though not as critical for a Denil fishway as for a weir and pool ladder. The forebay should be maintained within several feet to maintain good passage conditions in a Denil fishway.*
 - According to the velocity profiles developed by Rajaratnam and Katopodis (1984), centerline velocities increase towards the water surface in Denil fishways where the ratio of flow depth to width (D/b in Figure 5-13) is more than 3. The height of the Denil fishway is not limited; additional height adds attraction flow and operating range without additional passage capacity because of the higher velocities in the upper part of the fishway (Bates 1992).
- *Minimum depth in a Denil fishway should be 2 feet, and depth should be consistent throughout the fishway for all flows.*
 - Bates (1992) reports that Denil fishways are typically constructed with depths from 4 to 8 feet.
- *The standard length is 30 feet (Bell 1991).*
- *Denil fishways can be constructed out of plywood, steel, or concrete with steel or plywood baffles.*

5.9.2.3.2 *Specific design information – Alaska steeppass fishways*

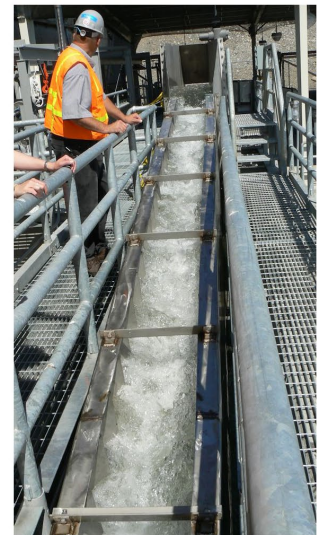
The ASP fishway is a specially designed baffle chute fishway developed for use in a variety of locations in Alaska (Figure 5-14; Ziemer 1962). It is typically constructed in sections that can be bolted together on site, making the system portable.



(a) Downstream end.



(b) Upstream end.



(c) In operation.

Figure 5-13. Examples of ASP fishways

The following design information for ASP fishways is taken from Rajaratnam and Katopodis (1984):

- *Discharge through the ASP fishway can be calculated as shown in Equation 5-4:*

$$Q = 1.12S^{0.5} D^{1.55} g^{0.5} \quad (5-4)$$

where:

- Q = flow (ft³/s)
- S = slope (ft/ft)
- D = depth (feet) of flow above the floor vane
- g = gravitational acceleration (32.2 ft/s²)

Most of the following design information on ASP fishways is taken from Bates (1992), and standard ASP fishway dimensions are shown in Figure 5-14.

- *NMFS recommends a maximum slope of 28%.*
 - The normal slope is about 25%, but ASP fishways have been tested and used up to a slope of 33% (Bates 1992).
- *The average chute design velocity should be less than 5 ft/s.*
- *Flow control is very important for properly functioning ASP fishways. The forebay water surface cannot vary more than 1 foot without creating passage difficulties, and the tailwater should be maintained within this same range to prevent a plunging flow or backwatered condition from forming. Backwatering the entrance results in reduced entrance velocity and fish attraction (Bates 1992).*
 - For example, Slatick (1975) found that the median passage time for salmon increased fourfold, and 25% fewer salmon entered the fishway when the downstream end was submerged by 2.5 feet.
- *Minimum depth in an ASP fishway is 1.2 feet.*
- *The standard length of each unit is 10 feet. Individual units can be bolted together to create lengths of 20 to 30 feet.*
- *ASP fishways are usually constructed of heavy gauge aluminum.*

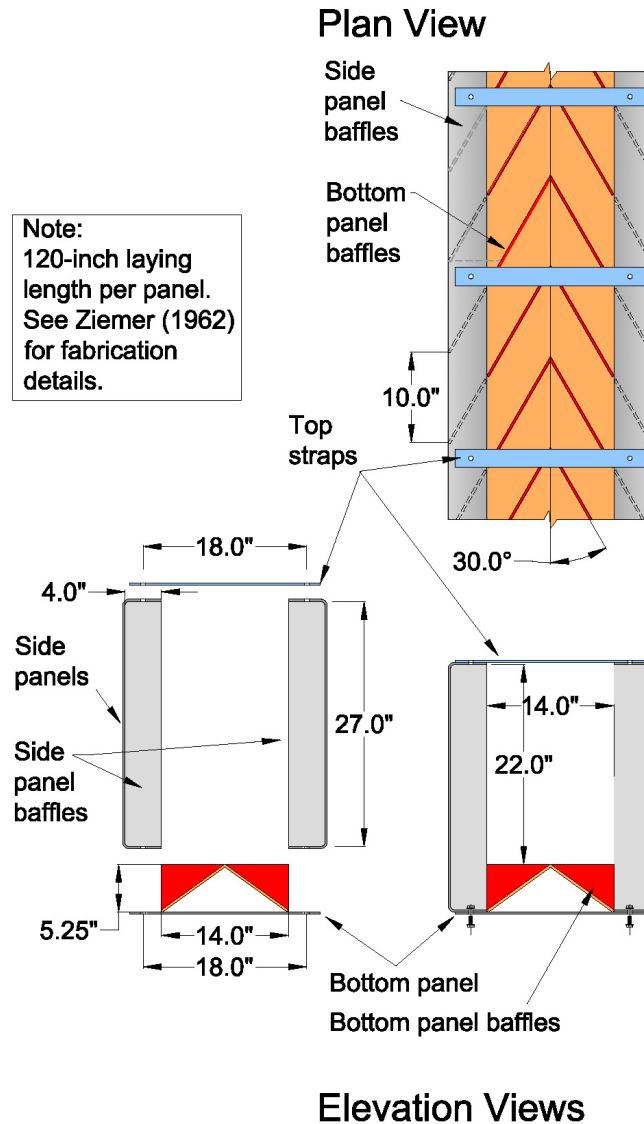


Figure 5-14. Plan and elevation views of a typical ASP fishway

5.9.2.3.3 *Special considerations for Denil and Alaska steep pass fishways*

The following unique aspects of Denil or ASP fishways must be carefully considered: intermediate resting pools, minimum resting pool volume, and exit locations.

- Intermediate resting pools:

If the Denil or ASP fishway is long, intermediate resting pools should be included in the design. Resting pools (where water velocities are less than 1 ft/s) should be provided for Denil fishways longer than 30 feet in length (Bell 1991); resting pool size should be based on minimum pool size or EDF (energy dissipation factor) calculations. These guidelines also apply to ASP fishways longer than 30 feet in length.

Typically, there are no resting locations within a given length of Denil or ASP fishway. Once a fish starts to ascend a length of an ASP or Denil fishway, it must pass all the way upstream and exit the fishway or risk injury when falling back downstream. Therefore, if the Denil or ASP fishway is long, intermediate resting pools should be included in the design. Clay (1995) recommends that resting pools be provided for every 12 feet of height ascended and that average velocity in the resting pool should not exceed 1 ft/s. NMFS recommends that the designer size the resting pool based on the minimum pool size necessary to achieve either an average velocity of 1 ft/s or an adequate pool size based on the expected run size, if known (Appendix H), or on the EDF formula for pool volume (Equation 5-5), whichever is larger.

- Minimum resting pool volume:

The minimum volume of the resting pool is calculated as shown in Equation 5-5, which is similar to Equation 5-2 in Section 5.5.3.5 except that the volume required is increased by a factor of 2 since this equation is for a resting pool.

$$V = (\gamma)(Q) \left(\frac{v^2}{2g} \right) / \left\{ \left(2 \text{ ft } \frac{\text{lbs}}{\text{s}} \right) / \text{ft}^3 \right\} \quad (5-5)$$

where:

V	= volume, in ft^3
γ	= specific weight of water, 62.4 lb per ft^3
Q	= Denil or ASP flow, in ft^3/s
v	= velocity of pool-to-pool flow, in ft/s
g	= gravitational acceleration ($32.2 \text{ ft}/\text{s}^2$)

Blackett (1987) conducted experimental modifications to an ASP fishway at a 10-meter-high falls to improve sockeye salmon entry and passage. Sockeye salmon passage was equivalent between an ASP fishway of approximately 200 feet in length with no resting pools and an adjoining ASP fishway where three resting pools were incorporated into the design—although significant year-to-year differences in passage occurred amongst each ASP fishway. However, resting pools were beneficial for holding slower or descending salmon without blocking the passage of other salmon. Also, sockeye salmon passage was greater in the original ASP fishway with three resting pools than in another ASP fishway tested that contained a single resting pool.

- Exit locations:

Denil and ASP fishway exits should be located to minimize the potential for fish to fallback over the barrier.

5.10 Nature-Like Fishways

The nature-like fishway is a fishway type characterized by its use of natural materials (such as rocks and boulders) and incorporation of natural riverine characteristics in its construction and design (Katopodis et al. 2001; Wildman et al. 2003). Nature-like fishway design simulates the hydraulic conditions of natural channels, natural passage windows, and migration timing for target fish species. The resulting project should provide natural hydraulic conditions

for target species (mimicking the geomorphic form and complexity found in natural channels the target species inhabit).

Nature-like fishways are thought to facilitate the passage of a wide assemblage of fish and aquatic species, sometimes purported to provide better passage than traditional methods (fish ladders). However, Castro-Santos (2011) concluded that nature-like fishway designs evaluated in his study were not superior to traditional fish ladders for the 23 fish species from the northeastern United States (of those that were evaluated). More recently, Landsman et al. (2018) compared the passage of salmonid and non-salmonid species at nature-like fishway and pool-and-weir fishways in eastern Canada and reported similar results. Nature-like fishways have been observed to pass anadromous and resident salmonids with varying degrees of success at projects of varying hydraulic complexity (Aarestrup et al. 2003; Calles and Greenberg 2005, 2009; Dodd et al. 2017).

At the project-scale, design variables related to nature-like fishways are nearly synonymous with more traditional fish ladder designs typically used at these same locations (such as a vertical slot or ice harbor). The main difference being that nature-like fishways are constructed using natural materials, not concrete. Like any other fishway, if the design variables between the tailrace and the forebay are improperly designed, the result may be adverse passage effects to the project. All project-scale passage variables should be properly analyzed, accounted for, and work together to provide safe, timely, and effective upstream passage for salmonids and other target species (the same expectation as had for any other style of fishway).

5.10.1 Experimental Applications

Nature-like concepts and methods are sometimes used in conjunction with more traditional fishway designs. When combining nature-like methods with traditional methods many of the passage assumptions and anticipated hydraulic conditions associated with traditional fishways do not hold, or are hard to predict. Combined designs are classified by NMFS as experimental. Experimental designs are addressed in Section 1.5 and should be vetted using the guidelines contained in Appendix C.

5.10.2 Design Methods

Nature-like fishways are intended to simulate passage conditions of a natural channel. Like natural channels, there is a high degree of hydraulic variability within the fishway. This high variability makes recommending a universal design approach challenging. The following guidelines will help designers better understand critical components of nature-like fishway design, regardless of the engineering methods and approaches implemented.

Nature-like fishway designs may simulate the form and roughness of a reference reach selected as a design template from a natural channel, or the design may rely on hydraulic analysis and physical modeling, or both. The following sources provide additional information on the hydraulic and geomorphic concepts and potential design methods used in nature-like fishway design: Acharya et al. 2000; Keils et al. 2000; Katopodis et al. 2001; Courtice et al. 2016.

5.10.3 Specific Criteria and Guidelines

The criteria contained in this section apply primarily to fish passage projects where the fishway is designed to provide passage around a dam or diversion.

5.10.3.1 Maximum average channel velocity

Maximum average channel velocity at the 5% exceedance flow should be no greater than 5 ft/s, regardless of channel slope. The relationship between channel roughness and channel slope should be carefully engineered to ensure this criterion is not exceeded.

Barnard (2013) indicates that at the 10% exceedance flow, high gradient streams in Washington State exhibit similar average channel velocities, regardless of channel slope, on the order of 4 ft/s. The velocity criterion in the section is presented to help designers express a more realistic relationship between channel slope and roughness in nature-like fishway designs. When channel slope and roughness have the proper relationship to maintain a 5 ft/s average channel velocity at the 5% exceedance flow, energy dissipation and turbulence are much more likely to be within the range observed in natural high gradient streams of similar slope and roughness. This criterion also simplifies and improves design and monitoring by providing a simple value to compare against hydraulic models and field measurements. An in-depth discussion on turbulence in higher gradient natural channels is contained in CH 6 of Barnard (2013).

The origin of the 4ft/s criterion used the 10% exceedance flow to back calculate EDF in high gradient natural channels. When using a 5% exceedance flow it seems reasonable to increase the maximum average channel velocity to 5 ft/s. When using a 1% exceedance flow, it seems reasonable to use a maximum average channel velocity of 6 ft/s. These assumptions are supported by data from Castro and Jackson (2001) which indicates the average bankfull channel velocity in the Pacific Northwest can be well represented as an average of 6 ft/s. Work by Love and Lang (2014) reported that annual exceedance values associated with a discharge equal to 50% of the 2-year return interval ranged between 0.2% and 1.8%. Annual exceedance flows between 10% and 1% exceedance are likely well represented by a range of average channel velocities between 4ft/s and 6ft/s.

5.10.3.2 Pool depth

If drop structures are used in the fishway, minimum pool depth should be 4 feet in the receiving pool of each drop structure.

5.10.3.3 Maximum hydraulic drop

Maximum hydraulic drop is 1 foot for adult salmonids and 0.5 foot for juvenile salmonids.

5.10.3.4 Maximum fishway slope

Maximum fishway slope is 5% for all salmonid species.

5.10.3.5 Channel stability

Beds and banks should be designed to be immobile at all anticipated fishway discharges.

5.10.3.6 Channel roughness

Simulated or modeled roughness values should be physically expressed in the post-construction roughness of the channel design. Actual fishway roughness should produce a maximum 5 ft/s average velocity at the high fish passage design flow. Designers should provide a summary discussion of how modeled roughness will be translated and transformed into actual project roughness.

Modeling requires the use of roughness values to estimate the effects of boundary roughness on water depth and velocity in channel design. NMFS has observed there can be large discrepancies between modeled roughness values and the actual roughness physically expressed in the design post-construction. These discrepancies are typically expressed as higher velocities, increased turbulence, unanticipated scour and erosion, and a fewer holding and resting areas than were expected. Individually and in aggregate these issues can adversely affect fish passage. It is expected that documentation of the methods, assumptions, and specifications used to detail and explain the roughness design process will result in fewer projects failing to meet passage requirements.

Channel roughness providing the bulk of fish passage benefits are best described and specified comparing the size of the elements to the depth of water at the high fish passage design flow. Large roughness elements will possess an exposed dimension above the thalweg that is analogous to the high fish passage design depth. Meaning once stable, the element should have a portion exposed to the air, or nearly exposed, at the high fish passage design flow. This relationship between water depth and roughness size is critical to providing the necessary energy dissipation and velocity reduction for fish to rest and move in higher gradient channels. Channels with low relative roughness (uniformly sized bed and bank material), are characterized as hydraulically smooth. Hydraulically smooth channels at high gradients provide little to no resting or holding areas for fish. Hydraulically smooth channels commonly fail to meet fish passage velocity criteria.

The above discussion was developed based on the relationship between natural D84 and D90 class material and bankfull depth for streams in Washington State with slopes greater than 2% (Barnard et al. 2013). Barnard et al. measured stream discharge and bed roughness, observing that the rock providing the bulk of velocity reduction and hydraulic diversity were those elements which had a dimension analogous to the bankfull depth of the channel. Over a diverse range of project sizes, NMFS has also observed that velocity conditions are most often passable when somewhere in the range of 20%-40% of the project surface area is occupied by roughness elements extending significantly into the water column at the bankfull discharge.

5.10.3.7 Technical components

The technical components, and their associated criteria, used in nature-like fishway project remain consistent with more traditional fish ladder designs and include the following:

Section 5.2, Fishway Entrance

Section 5.3, Auxiliary Water Systems

Section 5.6, Counting Stations

Section 5.7, Fishway Exit Control

Section 5.8, Fishway Exit Sediment and Debris Management

Section 5.11, Miscellaneous Considerations

Appendix H: Sizing Fish Ladder Pools Based on Energy Dissipation and Fish Run Size

5.10.4 Monitoring and Maintenance

A monitoring and maintenance plan for nature-like fishways is required. The frequency of monitoring and maintenance needed will be determined in consultation with NMFS. The plans should address how morphology and fish passage hydraulics will be monitored and modified, as needed, by developing an adaptive management approach that identifies triggers for when additional actions are to be implemented that address changes in nature-like fishway channel morphology and hydraulic conditions.

5.10.4.1 Passage assessment

Depending on project-specific considerations, monitoring may include an assessment of passage efficiency via fish tagging or fish counts. This monitoring criterion will be identified by NMFS on a project-by-project basis.

5.10.4.2 Channel stability

The loss or displacement of bed and bank material after a high-flow event does not necessarily equate with a failure of the nature-like fishway to maintain passage conditions. Any resulting loss or displacement of bed and bank material should be evaluated to determine the effects, if any, on passage criteria. Needed modification or repairs to bring the fishway into criteria should be discussed with NMFS and implemented by the facility owner. Proposed actions to bring the design into compliance with velocity criteria should be approved by NMFS.

5.10.4.3 Channel velocity

Channel velocity should be verified through post construction monitoring. When average channel velocity exceeds 5 ft/s at the high fish passage design flow needed modifications or repairs to bring the fishway into criteria should be identified be discussed with NMFS and

implemented by the facility owner. Proposed actions to bring the design into compliance with velocity criteria should be reviewed by NMFS.

Two methods of measuring average velocity are used. First, longitudinal, or reach average velocity is measured. This is defined as the travel time of a particle beginning at the fishway exit and ending at the entrance, divided by the fishway length, and reported in ft/s. The velocity. Second, cross section average velocity is measured. Cross section velocity is measured at discrete sections of the fishway not associated with a hydraulic drop. Cross sections are measured every 40 feet of fishway beginning immediately upstream of the fishway entrance.

5.11 Miscellaneous Considerations

5.11.1 Security

Fishway facilities and areas should be secured to discourage vandalism, preclude poaching opportunity, and provide for public safety.

Security fencing around the facility and grating over the fishway may be required.

5.11.2 Access

Access for personnel to all areas of the fishway should be provided to facilitate operational and maintenance requirements. Walkway grating should allow as much ambient lighting into the fishway as possible. Consideration should be given to providing access for personnel to each pool of the ladder to support fish salvage operations.

5.11.3 Edge and Surface Finishes

All metal edges in the flow path used for fish migration should be ground smooth and rounded to minimize risk of lacerations. Concrete surfaces should be finished to ensure smooth surfaces, with 1-inch-wide, 45-degree corner chamfers.

5.11.4 Protrusions

Protrusions that fish could contact, such as valve stems, bolts, gate operators, pipe flanges, and permanent ladders rungs, should not extend into the flow path of the fishway.

5.11.5 Exposed Control Gates

All control gates exposed to fish (e.g., entrances in the fully open position) should have a shroud or be recessed to minimize or eliminate fish contact.

5.11.6 Maintenance Activities

To ensure fish safety during in-season fishway maintenance activities, all fish ladders should be designed to provide a safe egress route or safe holding areas for fish prior to any temporary (i.e., less than 24 hours) dewatering. Longer periods of fishway dewatering for

scheduled ladder maintenance should occur outside of the passage season and with procedures in place that allow fish to be evacuated in a safe manner.

5.12 Operations and Maintenance Considerations

5.12.1 Activity Near the Ladder

There should be no construction or heavy activity within 100 feet of a ladder entrance or exit or within 50 feet of any other portion of the ladder, but this can be reviewed on a case by case basis.

5.12.2 Maximum Outage Period

A fishway should never be inoperable due to mechanical or operational issues for more than 48 hours during the fish passage season of any anadromous species.

6 Exclusion Barriers

6.1 Introduction

Upstream-migrating salmonids are often attracted to areas of a river where flow is concentrated or velocities are high such as the discharge from a hydroelectric powerhouse. This behavior may cause fish to attempt to ascend a barrier at locations where passage is poor or blocked, which could result in the following:

- Injuries (e.g., lacerations, abrasions) caused by
 - Brushing against rocks or structures while swimming in turbulent areas
 - Jumping and striking rocks or structural projections
- Direct or delayed mortality due to injuries
- Migration delays

Exclusion barriers are structures or devices that are designed and used to halt the upstream migration of fish (BOR 2006). These barriers can guide fish to an area where upstream migration is allowed or to holding, sorting, evaluation, and transportation facilities. They are also used to prevent fish from entering an area where no upstream egress or suitable spawning habitat exists. For example, exclusion barriers could be required to protect upstream-migrating salmon and steelhead from injuries or mortality caused by ascending powerhouse turbine draft tubes or tunnels. Exclusion barriers can also be used for the following:

- Preventing fish from entering return flow from an irrigation ditch; tailrace of a power plant; channels subject to sudden flow changes; and channels with poor spawning gravels, poor water quality, or insufficient water quantity
- Guiding fish to counting facilities as well as trap facilities for upstream transport, research, or broodstock collection

6.1.1 Fish Safety

Exclusion barriers should be designed to minimize both the potential for fish injury and mortality and migration delays.

Fish may be physically injured (e.g., lacerations, abrasions) when attempting to pass exclusion barriers in migration pathways (FERC 1995). Therefore, barrier design and operation should consider and eliminate sources of injury due to shallow depths, exposed components, and rough surfaces. Barriers that are poorly designed can cause fish to delay migration while undertaking multiple attempts to pass the barrier.

6.1.2 Barriers Used to Collect Information

Installing exclusion barriers solely for the purpose of collecting information needed for fisheries management will be discouraged, especially if ESA-listed fish are present in the watershed.

6.1.3 Other Species

Installing an exclusion barrier in river systems with multiple species of migratory fish should be carefully considered because some designs may inadvertently block the upstream and downstream movement of non-target species.

Conversely, exclusion barriers may also be used to restrict the movement of undesirable species into upstream habitat (Clay 1995) such as sea lamprey in the Great Lakes (McLaughlin et al. 2007).

6.1.4 Flow Range

All barriers should be designed to function safely over the expected design range of flow conditions for the site when target fish are present (BOR 2006).

6.2 Types of Exclusion Barriers

Barriers to upstream fish passage are either physical or behavioral (e.g., acoustic, chemical, thermal, or lighting). They can be natural or fabricated. Natural barriers consist mainly of waterfalls and debris jams, whereas fabricated barriers consist mainly of dams, culverts, and log jams (Powers and Orsborn 1985). This chapter focuses on fabricated physical barriers, which present fish with structures or conditions that block farther upstream migration.

Fabricated physical barriers are classified into three categories: diffusers, weirs, and drop structures (Figure 6-1). Picket and weir barriers rely on bars racks, pickets, porous rigid panels, screens, or fences to physically exclude fish from entering an area. Fixed bar racks and picket barriers have similar meanings and purposes, and fish passage designers often use these terms interchangeably. However, the term ‘picket barrier’ carries an added nuance—these barrier panels tend to guide fish in some preferred direction—in addition to blocking farther upstream passage. Figure 6-2 is a schematic illustration of a temporary fish weir that uses pickets to guide fish to a trap at the riverbank.

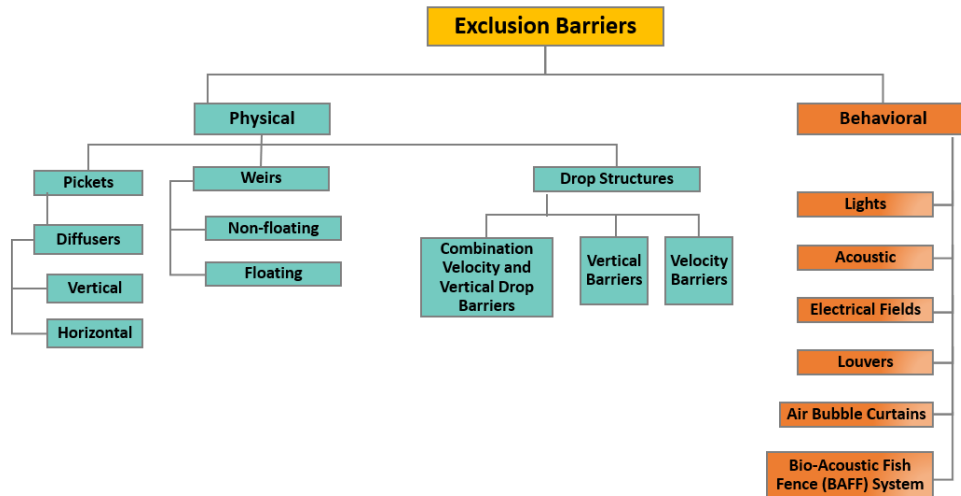


Figure 6-1. Classifications of exclusion barriers

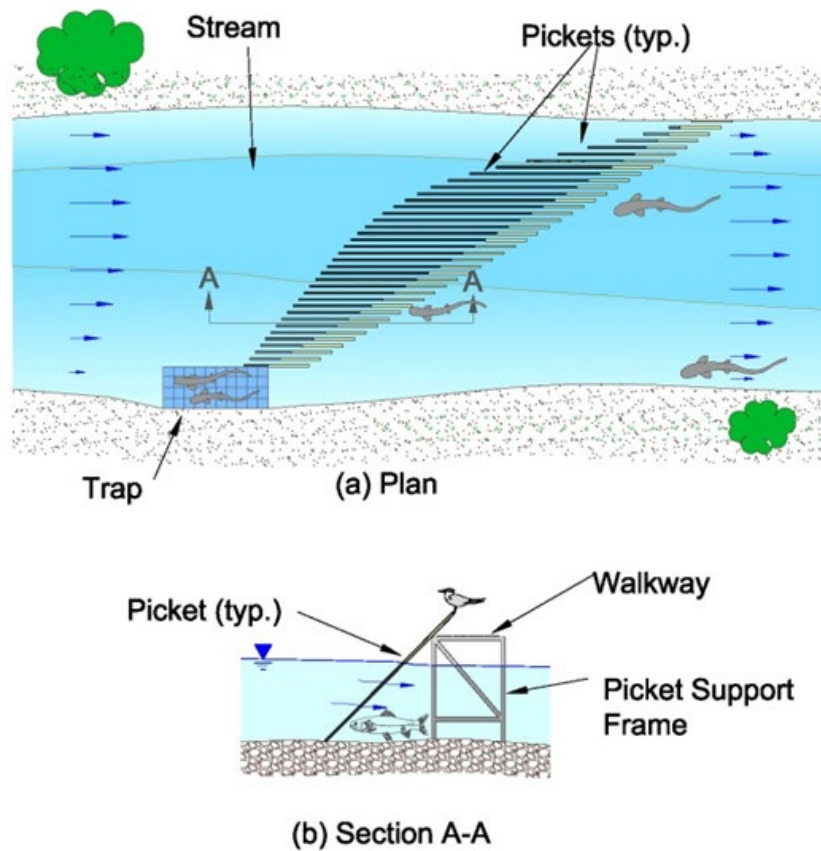


Figure 6-2. Fish weir constructed with pickets in plan (a) and section (b) views

Advantages of pickets and weir barriers include the following:

- They induce a small loss of head under clean and partially plugged conditions.
- They can function over a wide range of river flow stages.
- They can be designed to be removable.

Disadvantages of pickets and weir barriers include the following:

- Bar spacing that is too wide will not function effectively as a barrier, and bar spacing that is too narrow can collect debris more quickly than it can be removed. Striking a balance between the competing design objectives of excluding fish while not collecting more debris than can be managed may be difficult or impossible, depending on the river system and target fish species being excluded.
- Downstream juvenile and adult fish that need to pass the barrier can be excessively delayed and, in some designs, injured or killed. It is important to recognize that this type of barrier can cause injury and mortality to downstream migrants.
- Barrier components require periodic cleaning and are subject to rapid plugging (BOR 2006).

Drop structure barriers involve a combination of local hydraulic conditions downstream of a barrier and the swimming capabilities of the species and life stage to block migration (Powers and Orsborn 1985). They create hydraulic conditions that exceed the swimming or leaping capabilities of the fish to overcome the hydraulic condition. Examples include velocity barriers, vertical drop barriers, and velocity drop barriers. Hydraulic conditions at a specific site function as a barrier when one or more of the following conditions are present:

- Water velocity downstream from a barrier exceeds the swimming speed of fish.
- A standing wave develops downstream of the barrier that fish cannot pass through, or it forms too far downstream to allow the fish to rest before bursting upstream.
- A downstream plunge pool is too shallow to allow fish to jump the barrier.
- Barrier height exceeds jumping ability of fish.

Advantages of drop structure barriers include the following:

- These have lower maintenance requirements compared to picket and weir barriers.
- Debris passes over the barrier with flow (instead of plugging the barrier, which can be the case with structural barriers).
- All species and life stages of fish whose swimming capabilities are weaker than the species the barrier was designed to address are excluded.
- The passage of downstream migrants over drop barriers is usually safer than through picket and weir barriers.

Disadvantages of drop structure barriers include the following:

- They require a significant head to function properly.
- Their performance depends on maintaining a minimum head differential across the barrier.
- The pool upstream of the barrier structure may increase sediment deposition, which reduces channel capacity (BOR 2006).
- Drop structures may create a serious hazard to boaters and swimmers and precautions to protect boaters and swimmers should be included in the design.

Several reports contain additional information on the topic of exclusion barriers and fish swimming performance. Bell (1991) provides information on the swimming and jumping capabilities of various salmonid species. Powers and Orsborn (1985) provide equations for calculating maximum swim distances and estimating leap height and distance. Katopodis (1992)

provides endurance curves for fish of various lengths for the two main modes of fish locomotion and a formula for calculating swimming distance. The two main modes of locomotion are anguilliform body shapes (e.g., lamprey and Burbot) and subcarangiform body shapes (e.g., anadromous salmonids and various freshwater species such as bass, suckers, and chub).

6.3 Picket and Weir Barriers

Physical barriers typically rely on a combination of low-velocity flow discharged through bar racks, pickets, diffusers, screens, or fences to physically block fish from entering an area. Picket and weir barriers include fixed bar racks, picket panels (Figure 6-3), diffusers (a specialized form of picket barrier usually used in AWS in fishways), horizontal outlet diffusers, and a variety of hinged, floating weir designs and framework-supported (rigid) weir designs. The clear opening between bars in bar rack panels or pickets in picket panels should be sufficiently narrow to create a barrier to the smallest-sized migrant fish being excluded from farther passage upstream. Depending on the design and site conditions, weir barriers may need to be removed during high-flow events to prevent structural damage, which potentially reduces the barrier's ability to prevent target fish from passing into undesirable areas.



Figure 6-3. Picket barrier panels under construction at the Slide Creek tailrace barrier located on the North Umpqua River, Oregon

Because both debris and downstream-migrating fish must pass through physical barriers, sites should be selected based on the following design objectives:

- Minimizing the entrainment of debris
- Maximizing the ability to remove debris
- Preventing the entrainment and delay of downstream-migrating fish and adult fish that fall back across the barrier
- Maximizing the ability to rapidly remove and bypass any fish that are entrained on the barrier
- Allowing the most advantageous orientation of the barrier (typically angled to guide fish to a collection point)

6.3.1 Risk of Fish Impingement

If adult fish are exposed to the upstream side of physical barriers, they have a high likelihood of being impinged. Therefore, these types of barriers cannot be used in waters containing species listed under the ESA unless they are continually monitored by personnel on site and have an approved operational plan and a facility design that allows impinged or stranded fish to be removed in a timely manner and prior to becoming injured. Also, these types of barriers should not be used at sites where adult fish are actively migrating downstream or may inadvertently pass over a nearby dam or weir in a downstream direction prior to reorienting again to continue their upstream migration.

In addition to blocking the upstream passage of adult fish, physical barriers can effectively block or injure fish migrating downstream (e.g., steelhead kelts, adult salmon that passed a dam and subsequently migrated back downstream, juvenile salmonids, and resident fish). This can impact population productivity and should be fully considered during the planning process.

6.3.2 Debris

Physical barriers should be continually monitored for debris accumulations, and debris should be removed before it concentrates flow and results in the velocity and head differential criteria being exceeded (Sections 6.3.3.2 and 6.3.3.3). Additionally, excessive debris loading could cause permanent damage to weir structures.

Allowing debris to accumulate on components of physical barriers results in increased water velocity through the remaining open areas. As debris accumulates, the potential for impinging downstream migrants increases progressively and can reach unacceptable levels that result in mortality and injury. Concentrating flow through the remaining open areas of the barrier (e.g., the open picket area) will also attract upstream migrants to these areas. This can increase the potential for injury due to adult fish jumping into structural components and for fish accessing unwanted areas because they jumped and landed over the barrier.

6.3.3 Picket Barriers and Fixed Bar Racks

Picket barriers and fixed bar racks create a uniform, low-velocity flow that is discharged through a series of bars or screens that cover the entire exclusion area.

The following specific criteria or guidelines apply to picket barriers and fixed bar racks.

6.3.3.1 Openings

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bates 1992). The clear opening between bars in bar rack panels, between pickets in picket panels, and between panels and abutments should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Openings larger than 1 inch may allow the heads of small salmon and steelhead to pass through the picket opening. This can lead to salmonids and other species becoming caught on the picket by their operculum that covers and protects the gills. Fish caught in this manner—between bars or pickets and gaps between panels or panels and abutments—often die because they are unable to extricate themselves off the picket.

6.3.3.2 Design velocity

The average velocity through pickets should be less than 1 ft/s for all design flows (Clay 1995). The maximum velocity through the pickets should be less than 1.25 ft/s, or one-half the velocity of adjacent passage route flows, whichever is lower. When river velocities exceed these criteria, such as due to increasing flows or debris accumulations, the picket barrier should be removed.

The average design velocity is calculated by dividing streamflow by the total submerged picket area over the design range of streamflows (Gauley et al. 1966). As discussed in Section 6.3.2, non-uniform or excessive velocities through the structure can create false attraction conditions that delay fish and induce upstream migrants to attempt to jump over the barrier, potentially injuring the fish.

6.3.3.3 Head differential

The maximum head differential under fouled conditions should not exceed 0.3 foot above the normal head differential across the pickets that occurs under clean picket conditions. If this differential is exceeded, the pickets should be cleaned as soon as possible.

Excessive head differential (head loss) through the structure can cause a cascading effect of water through the pickets, which increases the likelihood of upstream migrating fish leaping at the structure. Clay (1995) and DOI (1987) provide formulas to calculate head loss through picket barriers and trash racks.

6.3.3.4 Debris and sediment

A debris and sediment removal plan should be considered in the design of the barrier that anticipates the entire range of conditions expected at the site. Debris should be removed before accumulations develop that violate the average design river velocity and head differential criteria (Sections 6.3.3.2 and 6.3.3.3, respectively).

6.3.3.5 Orientation of physical barrier

Physical barriers should be designed to lead fish to a safe passage route.

Leading fish to a safe passage route can be achieved by angling the structural barrier toward the route, providing nearly uniform velocities across the entire horizontal length of the structural barrier, and providing a sufficient level of attraction flow that leads fish to the route and minimizes the potential for fish being falsely attracted to flow coming through the picket barrier.

6.3.3.6 Picket freeboard

Depending on the angle of the pickets (from vertical), the pickets should be designed such that they extend out of the water and at least 2 vertical feet above the water surface at the upper design flow level.

The purpose of the picket freeboard is to prevent fish from leaping over the barrier. Note that if the angle of the pickets is relatively steep, a freeboard of 2 feet may be insufficient to block stronger fish from leaping over the pickets, depending on site-specific conditions.

6.3.3.7 Submerged depth

The minimum depth at the picket barrier at low design flow should be 2 feet for at least 10% of the river cross section at the barrier. Picket barriers should be sited where there is a relatively constant depth over the entire stream width.

6.3.3.8 Picket porosity

The picket array should have a minimum of 40% open area.

Picket barriers with insufficient porosity may generate excessive head loss for the given river velocity. This head loss is exhibited as a cascade of water as it passes through the pickets, which may induce fish to jump and increase the potential for injury at the barrier.

6.3.3.9 Picket construction and material

Pickets should comprise flat bars where the narrow edge of the bar is aligned with flow or round columns of steel, aluminum, or durable plastic. Other shapes may be approved by NMFS, but should not increase the risk of fish impingement.

Picket panels should be of sufficient structural integrity to withstand high streamflows and some debris loading without deforming (i.e., without exceeding the clear opening criteria cited in Section 6.3.3.1, compromising the cleaning system, or permanently changing the shape of the picket panel). Pickets that become permanently deformed should be repaired or replaced as soon as possible. Pickets that deform or bend to a point where the clear opening criteria cited in Section 6.3.3.1 is no longer met under the design flow and debris loading conditions incorporated into the design can create openings that allow fish to pass the barrier or become injured as they try to force their way through the pickets.

6.3.3.10 Sill

A uniform concrete sill, or an alternative approved by NMFS, should be provided to form a foundation for the pickets and ensure that fish cannot pass under the picket barrier.

6.3.4 Diffusers

Diffusers are a specialized type of picket barriers or fixed bar racks where a flow control or hydraulic baffling structure is incorporated into the design to regulate flow through the barrier

or bar rack. Wall-oriented (i.e., vertical) and floor-oriented (i.e., horizontal) diffusers are most commonly used as part of the AWS in adult ladders to prevent adult fish from entering the AWS system or delaying their migration due to being attracted to AWS flow entering the ladder. Wall diffusers are also used as tailrace barriers to prevent fish from entering tailraces downstream of hydroelectric dams, while encouraging fish to continue to move upstream through another stream, river route, or channel.

The following specific criteria or guidelines apply to diffusers.

6.3.4.1 Openings

The spaces between bars of a diffuser should be sized to prevent fish from passing through the bars or becoming injured (Bates 1992). The clear opening between pickets and between pickets and abutments should be less than or equal to 1 inch to block anadromous salmonids. These clear openings should be less than or equal to 0.75 inch to block Pacific lamprey. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Wall diffusers consist of vertically oriented diffuser panels of flat bar stock using non-corrosive materials. The orientation of flat bar stock should be designed to maximize the open area of the diffuser panel. If smaller fish species or life stages are present, smaller clear openings between the bars may be required.

6.3.4.2 Design velocity and orientation

The average velocity through a wall diffuser should be less than 1 ft/s for all design flows based on total submerged diffuser area. The maximum velocity at any point on the diffuser should be less than 1.25 ft/s, or one-half the velocity of flow in an adjacent passage route, whichever is lower. Diffuser velocities should be nearly uniform. The orientation of the diffuser should be selected that assists in guiding fish towards the safe passage route. The face of the diffuser panels (the surface exposed to the fish) should be flush with the wall or floor.

These criteria are based on results of laboratory studies where passage times of spring- and fall-run Chinook salmon and steelhead increased progressively with increased diffuser flows and where diffuser velocities increased from 0.25 to 1.25 ft/s (Gauley et al. 1966).

6.3.4.3 Porosity control baffles

Similar to juvenile fish screens, a diffuser should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure the average velocities at the face of the diffuser can meet criteria.

Porosity control panels control the amount of flow and velocities through the diffuser pickets and create a uniform flow condition at the face of the pickets.

6.3.4.4 Debris removal

The diffuser design should include access for personnel to be able to remove debris from each diffuser. This criterion is not required when the intake to the diffuser water supply is equipped with a juvenile fish screen (Chapter 8).

The dewatering screen system also removes debris from water being supplied to the diffuser.

6.3.4.5 Edges

The edges of all diffuser surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane.

Rounding and grinding smooth surfaces that fish can contact and making all diffuser surfaces flush reduces the potential for fish injury.

6.3.4.6 Elevation

Wall-style diffusers should be submerged throughout the range of operation (i.e., the top elevation of the wall diffuser should be below the water surface elevation associated with the low flow selected for the design).

Maintaining a submerged wall-style diffuser prevents water from cascading through the diffuser, which can induce adult fish to leap at the surface disturbance and become injured when contacting the diffuser material and wall and delay their migration up the ladder.

6.3.5 Horizontal Outlet Diffusers

A horizontal outlet diffuser is a device that can be used to prevent fish from entering a drain or discharge pipe. They can also be used below a powerhouse at the turbine draft tube outlet to prevent adult fish from ascending up the draft tube discharge during unit start up or shut down or during normal operations if draft tube velocity is low (typically less than 16 ft/s; Figure 6-4). This type of diffuser also prevents fish from entering the draft tube and contacting the turbine runners, which may result in injury or mortality. If the turbine draft tubes are located in close proximity to the entrance of an upstream passage system (e.g., a fishway), a horizontal outlet diffuser system may be the appropriate choice for an exclusion system.

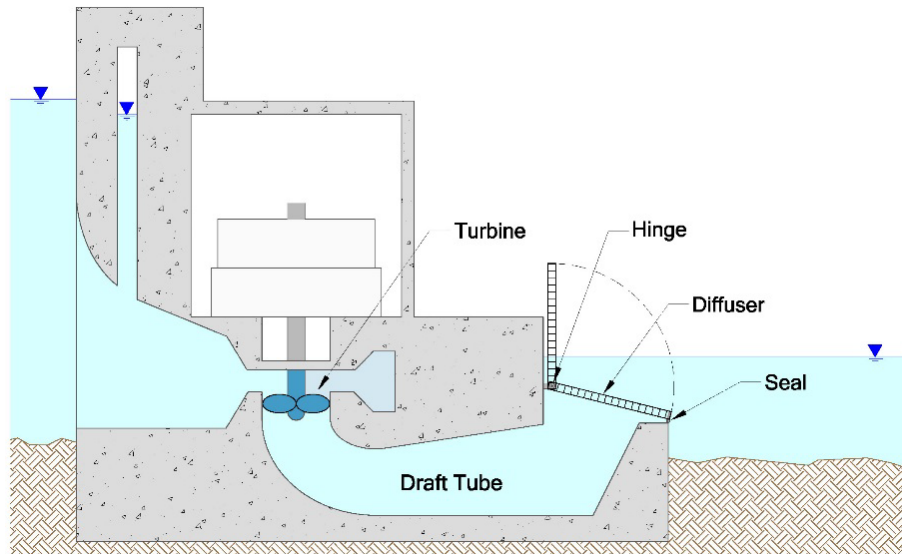


Figure 6-4. Layout of a horizontal outlet diffuser covering the entrance to a turbine draft tube

6.3.5.1 Design velocity

Average flow velocity exiting the horizontal outlet diffuser grating should be less than 1.25 ft/s and be distributed as uniformly as possible. The maximum point velocity should not exceed 2 ft/s.

6.3.5.2 Porosity control baffles

Similar to juvenile fish screens, diffusers should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure the average velocities at the face of the diffusers can meet criteria.

Porosity control panels control the amount of flow and velocities through the diffuser pickets and create a uniform flow condition at the face of the pickets.

6.3.5.3 Openings

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bates 1992). The clear opening between bars, and between bars and abutments, should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to prevent Pacific lamprey from entering the chamber behind the diffuser. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Horizontal outlet diffuser panels consist of non-corrosive, horizontally oriented flat bar stock. The orientation of flat bar stock should be designed to maximize the open area of the diffuser panel.

6.3.5.4 Edges

The edges of all diffuser surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane.

Rounding and grinding smooth surfaces that fish can contact and making all diffuser surfaces flush reduces the potential for fish injury.

6.3.5.5 Debris removal

The diffuser design should include access for personnel to be able to remove debris from each diffuser. This criterion is not required when the intake to the diffuser water supply is equipped with a juvenile fish screen (Chapter 8).

Trash (bar) racks installed at the intake to the diffuser system and a juvenile fish screen (if installed) remove debris from water being supplied to the diffuser.

6.3.5.6 Submergence

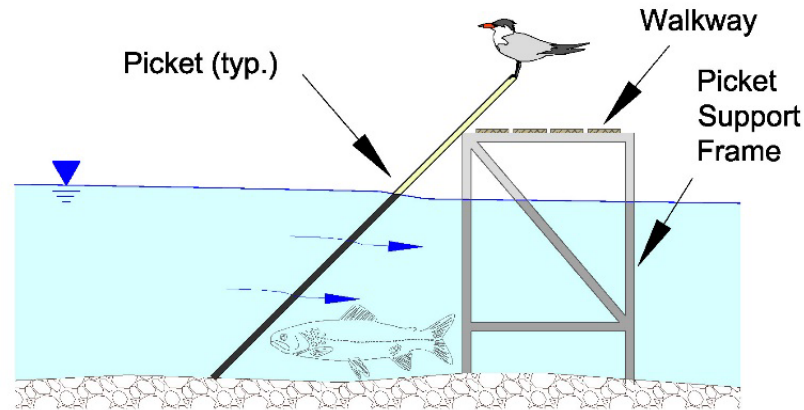
Horizontal outlet diffusers should be submerged a minimum of 2 feet for all tailwater elevations.

6.3.6 Fish Weirs

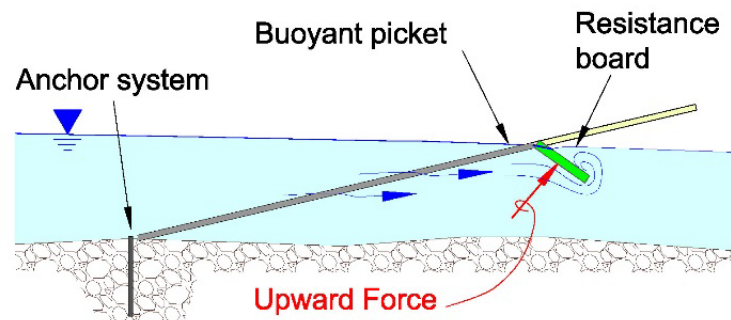
Fish weirs are physical barrier systems that are constructed across a stream (Figure 6-2). The purpose of fish weirs is to prevent fish from passing upstream of the weir and guide upstream-migrating fish to a trap. The weirs are constructed of panels of metal or plastic pickets that extend from the bottom of the stream to an elevation several feet above the water surface. The clear spacing between the pickets is selected based upon the size of the target species being trapped. When viewed from above, weirs are usually placed at angles greater than 90 degrees from the main thread of the current (Figure 6-2). The trap is placed at the most upstream area of the weir. The angle between the direction of stream or river flow and the weir results in the weir being longer than if it was positioned perpendicular to the bank and reduces water velocity through the pickets.

6.3.6.1 Types of fish weirs

The two most commonly used types of weirs in the WCR are rigid (frame-supported) weirs and floating resistance board picket weirs (Figure 6-5). Weirs can be temporary or permanent.



(a) Cross section through rigid (frame-supported) picket weir.



(b) Cross section through floating resistance board picket weir.

Figure 6-5. Cross sections of rigid and floating picket weirs

The pickets in rigid weirs are placed at an angle greater than 45 degrees above the water surface. Clean pickets in a floating weir have a very small angle above the water surface, and increased flow velocity and debris loading can further reduce the angle and can eventually submerge the floating weir panels.

Rigid weirs use panels of solid metal rods or hollow conduits that are supported by rigid frameworks (Figure 6-6). The supporting structures for temporary weirs can be light metal trusses or frames that are installed at the start of the fish passage season and are removed at the end of the trapping season. Permanent installations consist of foundations, frameworks, and abutments that stay in the river. However, the pickets at permanent installations are removed from the weir during periods when fish are not being trapped and during winter at locations that experience icing.



Figure 6-6. Elk Creek Dam picket weir (Elk Creek, Oregon)

The main advantage of rigid weirs is that the pickets are supported both along the river bottom and above the water surface, which may provide greater lateral stability and help to maintain constant spacing between the pickets. The main disadvantage of rigid weirs is that they are more susceptible to damage with increased debris loads experienced during high flows. High flows and debris can create sufficient force on the face of the panels such that the entire structure can be washed away. Some trap operators remove the pickets from the weir when they anticipate the occurrence of high flows.

Floating resistance board weirs are constructed using panels of hollow plastic piping or conduits that are capped at both ends to provide buoyancy. A resistance board at the downstream end of the pickets directs the local flow downwards, which creates an uplift force and a drag force on the pickets (Tobin 1994). In situations where the resistance board does not provide enough uplift (i.e., under conditions of low stream velocities), the board can be replaced with a long, linear float to support the picket panels. The pickets extend downstream and above the water surface to prevent fish from jumping over. The Alaska Department of Fish and Game has developed a user's manual for installing, operating, removing, and storing resistance board weirs used to count adult salmon migrating upstream based on direct experience, providing considerable information on this type of picket barrier (Stewart 2003).

The advantage of floating weirs is that they are less prone to damage over a wider range of flows and debris loads. High flows can also submerge the panels, which also tends to move debris off the panels and reduce the downstream pressure on the panels. The main disadvantages of floating weirs include the following:

- Debris can easily be trapped on top of the pickets due to the low angle of the panels.
- Fish can pass over the pickets when the pickets are submerged during high flows.
- The pickets may be more susceptible to lateral current forces because the pickets are supported only by the bottom of the river.
- In situations where adult fish are upstream of the weir and they fall back downstream, or they are migrating downstream, the fish can easily become stranded on the pickets and die due to

the low approach angle and force of the flow that tends to push the fish up onto the dry part of the pickets.

6.3.6.2 Site selection

Weirs should be constructed at sites that have the following characteristics (Zimmerman and Zabkar 2007):

- *Construction, operation, and maintenance activities can be conducted safely.*
- *The river should be wide and shallow (about 3 feet maximum depth at normal flows) with uniform flow distribution.*
- *The substrate should consist of gravel and small cobbles and be without boulders in the weir alignment.*
- *Traps should have sufficient flow depth during minimum expected river flow stages and be accessible during flood flows. More than one trap location may be required.*

The site should be low gradient and straight, with uniform depth and width, and have areas of sufficient depth for adult holding pools upstream and downstream of the weir (Hevlin and Rainey 1993).

6.3.6.3 Velocity

Water velocity at the river channel cross section of the weir location should be a maximum of 2 ft/s at low flows if a concrete apron is used (Hevlin and Rainey 1993), and velocity and depth should allow for safe access to the weir under normal flows (Zimmerman and Zabkar 2007)

6.3.6.4 Picket spacing and freeboard

The clear spacing between the pickets and the freeboard has the same requirements as those for other structural barriers (Sections 6.3.3.1, 6.3.4.1, and 6.3.5.2). The clear opening between bars in bar rack panels, between pickets in picket panels, and between panels and abutments should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey.

6.3.6.5 Suitability at sites with downstream migrants and monitoring

Fish weirs are not suitable for sites with downstream-migrating adult fish (e.g., steelhead kelts, salmon that pass the structure but migrate downstream [i.e., fallback], and resident fish). If deployed in these situations, weir operators should provide around-the-clock monitoring and fish salvage efforts for as long as these barriers are in place (Section 6.3.1).

While blocking the upstream passage of fish, fish weirs can also block the migration of, or injure, fish migrating downstream (e.g., steelhead kelts, adult salmon, juvenile life stages, and resident fish) and prevent them from completing their life cycle. When weir pickets are at a low angle with respect to the water surface (i.e., floating weirs), downstream-migrating adult fish can become stranded as they are pushed downstream along the pickets and the water becomes shallow. Juvenile passage openings or structures should be provided as part of the design, or

these weirs should be removed during the juvenile salmonid outmigration season. When rigid weirs are properly designed and sited, adult and juvenile fish that are migrating downstream are guided along the face of the weirs to the downstream apex of the weir and the shoreline where they can be trapped or released downstream.

6.4 Drop Structure Barriers

Drop structure barriers create conditions that target species are incapable of overcoming based on their swimming abilities or behavioral traits. A condition affecting swimming ability is the creation of a shallow, high-velocity flow for a significant distance, which most salmonids cannot pass. Hydraulic conditions can also interact with fish behaviors, including the reluctance of American shad to pass through a submerged orifice in a ladder or leap a ladder weir under plunging flow conditions. Both are examples of incorporating knowledge about the swimming ability and behavior of target species into facility designs so that the facility becomes a migration barrier. Note: Drop structures may create a serious hazard to boaters and swimmers, and precautions to protect boaters and swimmers should be included in the design.

6.4.1 Orientation of Drop Structure Barriers

As with physical barriers, drop structure barriers should be designed to lead fish to a safe passage route.

This can be achieved by angling the barrier toward a safe passage route and by providing the following:

- Nearly uniform velocities across the entire horizontal length of the barrier
- Sufficient attraction flow that leads fish into the safe passage route and minimizes the potential for false attraction

6.4.2 Upstream Impacts

Since this type of barrier creates an upstream impoundment, the designer should consider backwater effects upstream of the barrier that may induce loss of power generation, inundation of property, and sediment deposition in the impoundment.

6.4.3 Combination Velocity and Vertical Drop Barriers

6.4.3.1 Description and purpose

A combination velocity and drop barrier consists of a weir and concrete apron (Figure 6-7). Upstream passage is prevented by a shallow, high-velocity flow on the apron with an impassable vertical jump over the weir upstream of the apron. A fish that negotiates the apron and reaches the base of the weir is unable to pass the weir due to insufficient water depth needed to reorient its position and the lack of a pool needed to accelerate to leap over the weir sill (Wagner 1967; Weaver et al. 1976).

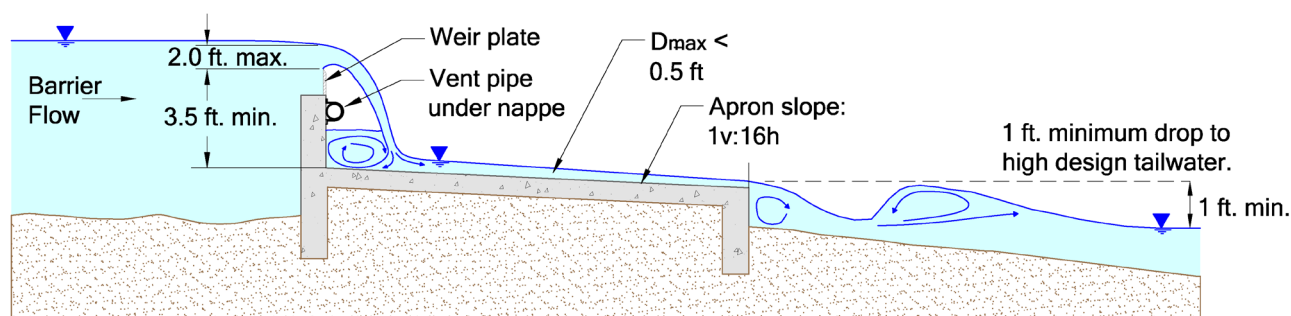


Figure 6-7. Cross section of a combination velocity and vertical drop barrier

6.4.3.2 Specific criteria and guidelines

6.4.3.2.1 Weir height

The minimum weir height relative to the maximum apron elevation is 3.5 feet (Wagner 1967).

This design assumes a straight, uniform, linear weir crest that will create uniform flow conditions on the apron. Labyrinth-style weirs are not allowed since they concentrate flow on the apron and create non-uniform flow conditions downstream.

6.4.3.2.2 Apron length

The minimum apron length (extending downstream from the base of a weir) is 16 feet.

This criterion is based, in part, on results of laboratory studies where adult Chinook salmon and steelhead were blocked by a velocity barrier dam with a 15-foot-long apron under two test conditions: 1) a vertical dam height of 3 feet with 1 foot of head; and 2) a vertical dam height of 4 feet with 2 feet of head (Slatick and Wagner 1989).

6.4.3.2.3 Apron slope

The minimum apron slope in a downstream direction is 1:16 (vertical:horizontal).

6.4.3.2.4 Weir head

The maximum head over the weir crest is 2 feet.

Other combinations of weir height and weir crest head may be approved by NMFS on a site-specific basis.

6.4.3.2.5 Apron elevation

The elevation of the downstream end of the apron should be greater than the tailrace water surface elevation corresponding to the high design flow (BOR 2006). There should be at

least 1 foot of elevation difference between the water surface elevation at the downstream end of the apron and the high design tailwater elevation.

6.4.3.2.6 Flow venting

The flow over the weir should be fully and continuously vented along the entire weir length to allow a fully aerated flow nappe to develop between the weir crest and the apron (BOR 2006).

Full aeration of the flow nappe prevents an increase in water surface behind the nappe, reducing the opportunity for fish to stage and jump the weir.

6.4.3.2.7 Flow depth on the apron

Flow depth on the apron should not exceed 0.5 foot (Wagner 1967).

At sites where a maximum depth of 0.5 foot cannot be maintained, apron velocities of 20 ft/s in association with a sill height (i.e., minimum weir height relative to the maximum apron elevation) of 5.25 feet have been used successfully (Wagner 1967).⁴

6.4.3.2.8 Minimum flow velocity over the apron

A minimum velocity of 16 ft/s is recommended by Wagner (1967).

The recommendation by Wagner (1967) is based on Weaver (1963) who reported that Chinook salmon and steelhead could swim against a 16-ft/s velocity for a distance of at least 85 feet in a test flume.

6.4.4 Vertical Drop Barriers

6.4.4.1 Description and purpose

A vertical drop barrier functions as an exclusion barrier by providing head in excess of the leaping ability of the target fish species (Figure 6-8). Vertical drop barriers can be designed based on a concrete monolith, rubber dam, bottom-hinged leaf gate, or an alternative approved by NMFS.

⁴ Wagner (1967) does not provide any additional information on this particular barrier configuration. If it is assumed that flow on the apron is 8 inches deep at 20 ft/s, the discharge per linear foot is approximately 13.5 ft³/s. This translates to a maximum of 2.5 feet of head over a sharp crested weir. This barrier configuration should be biologically tested before a prototype facility is constructed.

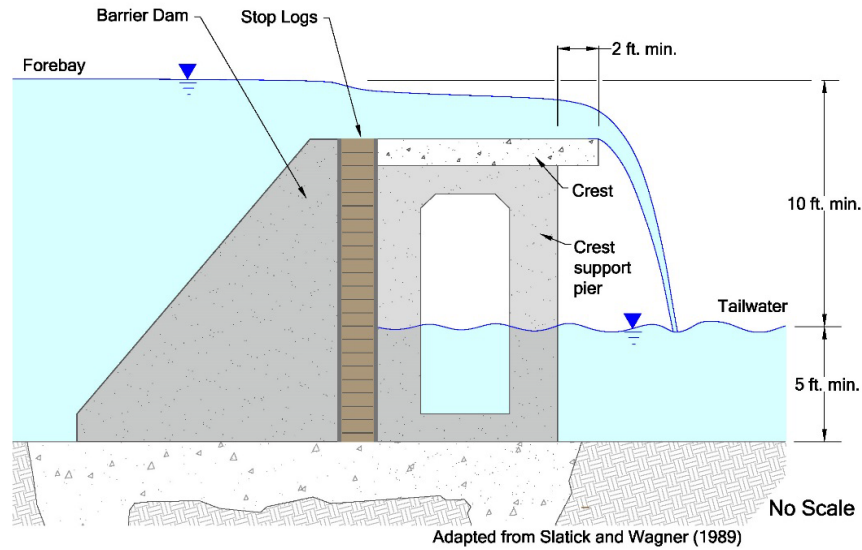


Figure 6-8. Cross section of a vertical drop barrier

6.4.4.2 Specific criteria and guidelines

6.4.4.2.1 Minimum height

The minimum height of a vertical drop structure should be 10 feet relative to the high design flow (Wagner 1967; Bell 1991; Clay 1995). This is measured as the water surface level of the forebay relative to the water surface level of the tailrace.

6.4.4.2.2 Cantilever

If the potential for injury to fish from leaping exists, the downstream crest of the barrier should extend over the tailwater at least 2 feet beyond any structural surfaces.

6.4.4.2.3 Minimum flow depth

Provisions should be made to ensure that fish jumping at flow over the vertical drop structure will land without contacting any solid surface and in a pool that is a minimum of 5 feet deep.

6.4.5 Velocity Barriers

Figure 6-9 shows a cross section of a velocity barrier and its main characteristics that include high water velocity and the long longitudinal length of the barrier over which the design velocity is maintained. The design approach is to provide a combination of water velocity, travel distance, and shallow depth that, taken together, exceed the swimming ability of the target fish.

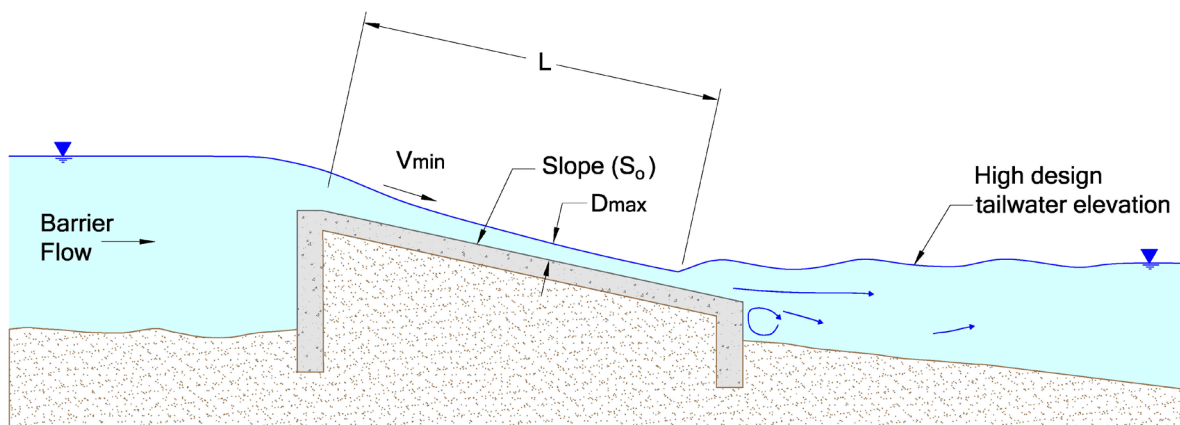


Figure 6-9. Cross section of a velocity barrier

Designing a velocity barrier to prevent the upstream migration of adult salmonids can be challenging due to their strong swimming capabilities. Experience has shown that salmonids will seek flow concentrations or discontinuities in flow (often near the edges of the flow) and use these features to find a route over this style of barrier. In addition to combining high velocity and shallow depth, the design should also create uniform flow conditions across the barrier, which can be difficult to achieve.

NMFS currently does not have criteria or guidelines for a velocity barrier.

NMFS will evaluate a proposed velocity barrier design based upon the hydraulic conditions created by the barrier and by comparing these conditions to the swimming capabilities of the target species. In general, velocity barriers are not recommended by NMFS because fish may spend a long time trying to negotiate the obstacle before seeking an alternate route, which delays the fish and may exhaust them in the process. As discussed in Section 6.3.3.5, barriers should also lead fish to a safe passage route, and NMFS will assess this when reviewing a proposed velocity barrier design.

6.5 Behavioral Barriers

Behavioral types of barriers, such as electric and acoustic fields, have had limited application and were ineffective in most cases (BOR 2006). While electric fields have been used as barriers for decades, persistent problems with early installations limited their widespread use (FERC 1995). These limitations included fish injury and mortality, safety, and effectiveness over a wide range of flow and environmental conditions (Clay 1961). Strobe lights and acoustical systems have been tested in various applications to block juvenile or adult fish from entering water intake systems. These systems were tested in the 1980s and 1990s and seemed promising at first (EPRI 1994) but were found to have limited effectiveness. Thus, electrical fields, strobe lights, acoustical systems, and other behavioral barriers are not widely used within the WCR and are considered experimental. Additional information regarding the various types of behavioral barriers and their performance and limitations may be found in Appendix C. Appendix C also provides information regarding the processes to be followed in order to use experimental devices such as behavioral barriers.

7 Adult Fish Trapping Systems

7.1 Introduction

Chapter 7 presents criteria and guidelines that address the design of new adult fish trapping systems. This chapter also includes criteria and guidelines that may apply to existing trapping programs that are being retrofitted. In both cases, traps should be designed to utilize known or observed fish behaviors to benignly route fish into a holding pool. The holding pool does not include a volitional exit, and once the fish are allowed or encouraged to exit the holding pool, they can be examined for research and management purposes and loaded into transportation tanks for transport to release locations or hatcheries.

*NMFS typically prefers the use of volitional passage for upstream fish passage facilities, as opposed to non-volitional facilities and operations. Volitional passage is defined as the passage of fish under all naturally passable flows, whereby a fish can enter and exit any passage apparatus or structure under its own power, instinct, swimming ability, and migration timing. Non-volitional is defined as the collection, handling, transportation, and release of adult fish from a collection site at or below a barrier to a release point located upstream from the barrier or location.*⁵

For some facilities, fish transportation is not a requirement and fish are trapped, monitored, sorted, and released from the trap to continue their upstream migration. For example, at some trapping facilities hatchery-origin fish are removed to protect wild-origin fish or collect hatchery broodstock. In the Pacific Northwest, certain areas within watersheds are designated as wild fish sanctuaries, and hatchery-origin fish should be collected and removed from traps located below these areas. Also, fish of a specific species or life stage or fish previously tagged for research purposes may also need to be collected and monitored at trap locations and then released.

The operational requirements for a trapping facility and its design are highly interdependent: management objectives for trap operation define the facility's functional design, and the objectives should be identified before trap design development can proceed. NMFS' primary objective is that a fish passage facility be designed and operated in a manner that the facility helps restore the viability of anadromous fish populations, which is why NMFS often prefers that volitional passage be used. Volitional passage facilities can operate 24 hours per day, 7 days per week, year-round.

However, there are instances where passing fish over a barrier using trap and haul techniques may be the only viable passage alternative. For example, thermal stratification can occur in

⁵ An illustration of a trap and haul operation is available at http://www.westcoast.fisheries.noaa.gov/fish_passage/about_dams_and_fish/trap_and_haul.html.

reservoirs at high head dams during summer, resulting in temperature differentials between the fishway entrance and water released below the dam. This can affect how fish utilize volitional passage facilities, and a trap and haul program would provide passage to areas above the thermally stratified reservoir.

The success of collection and transport operations relies on a high degree of engineering, technical, and operational competence. The process is generally composed of the following distinct phases: (1) Collection, (2) Handling, (3) Transportation, and (4) Release. This sequence is sometimes abbreviated by the acronym ‘CHTR’. The essential idea is to engineer effective system components for each phase, and to consistently execute operations to move fish in a safe and timely manner to designated release location(s). This section provides guidance on how to collect, handle and release fish from a collection facility. For all of these steps, careful attention must be given to maintenance of aquatic conditions and water quality to keep fish in good condition. It is very important to properly acclimate fish to any changing aquatic conditions or environmental transitions. Stressors associated with the aquatic environment (as experienced by the fish) must be minimized and carefully managed. All technical details for each phase of the overall process must be properly addressed.

7.2 Types of Traps

There are two types of traps. The first type is where a trap is an integral component of the primary route of fish passage above a barrier. Examples of these traps include the following:

- Traps located directly adjacent to a barrier
- Traps at the upstream end of a fish ladder
- Traps that serve as holding box associated with broodstock collection facilities in tributary streams in conjunction with intermittent barriers

A collection and transport facility located at the upstream end of a fish ladder is the most common application of this type of trap.

The second type of trap is an off-ladder design wherein the trap is situated adjacent to a ladder such that it is not the primary route of passage and does not interfere with the normal operation of the ladder. The ladder provides volitional passage from the tailrace to the forebay of the barrier under normal conditions, but when necessary or desired, all or some fish can be diverted into the trap.

For both types of traps, once fish are in a trap they can be accessed for a variety of purposes, including the following:

- Enumeration
- Evaluation for tags and injuries
- Sampling for genetic identification
- Sorting for various management purposes
- Transportation to various locations
- Tagging to support fisheries management or research

Fish that are enumerated or evaluated can be released back into the ladder or at another location.

7.2.1 General Criteria

Fish ladders should not be designed or retrofitted with in-ladder traps or fish loading facilities. Rather, fish holding and loading facilities should be placed in an adjacent, off-ladder location in order to route fish targeted for trapping purposes.

Fishway ladder pools typically do not meet the requirements of trap holding pools. Therefore, use of fishway ladder pools to site traps can create adverse impacts to the migrating fish. These impacts include elevated stress, delay, injury, or mortality caused by turbulence, jumping at water being supplied to the holding pool, and handling. Locating the trap off-ladder allows the facility to have the operational flexibility to readily switch between volitional ladder passage and trapping modes of operation.

7.3 Design Scoping

7.3.1 Purpose

Proposals to design new facilities or complete major upgrades to existing facilities should address the following issues, or at the very least show how the following issues were considered:

- *Describe the objective of the trapping operation and identify how the fish will be counted, collected (including the expected holding densities), handled, sampled for research or management purposes, transported (how and what frequency), and released.*
- *Identify the number of fish that will be targeted and the total number potentially present. This should include the expected peak number of fish per day, seasonal and daily fish returns, future fish return expectations, expected incidental catch, etc.*
- *Identify the target species, including ESA-listed species.*
- *Identify other species likely to be present at the trap, including ESA-listed species.*
- *Describe the environmental conditions expected to occur during trap operation such as water and air temperature, flow conditions (lows and peaks), and debris load.*
- *Describe the location, duration, frequency, predicted fish numbers, and scale of the trap and haul operations by developing an operations plan for the trap.*
- *Describe the facility's security mechanisms and procedures that will be in place in the operations plan.*
- *Identify when, what and how many fish will be taken to what location and for what purpose for the entire trapping season. (Many times different species or origins have different destinations from the trapping facility. Understanding the fish disposition for each species, run type and origin plays a huge role in the facility design (e.g. number of holding tanks and raceways).)*
- *Describe the maximum duration of delay or holding within the trapping system for target and non-target species and life stages.*
- *If a Hatchery and Genetic Management Plan, ESA Section 4(d) Limit 7 Scientific Research and Take Authorization application, ESA Section 7(a)(2), or ESA Section 10(a)(1)(A) permit application exists, show how one of these documents was used as the basis for design of a*

trapping facility. At least one of these types of documents will have to be developed for most trapping facilities and will be available for designing the facility.

7.4 Fish Handling Criteria

Section 7.4 provides criteria and guidelines that are applicable to handling fish in traps.

7.4.1 Nets

The use of nets to capture or move fish should be minimized or eliminated. If individual adult fish need to be moved, then they should be placed into rubber tubes with one end sealed. The tube should be partially filled with sufficient water to keep the head and gills of the fish submerged. Avoid handling the fish by hand, unless they have been adequately sedated. All fish should be handled with extreme care.

7.4.2 Anesthetization

Fish should be anesthetized before being handled.

The method of anesthetization for ESA-listed anadromous salmonids may be specified by the appropriate ESA permit, which should be in place prior to any directed take of listed species. The type of anesthetic to be used can be selected by agreement with NMFS during the design process and prior to submittal of an ESA permit request. Determination of the method and anesthetic used should be decided early in design, since each has different infrastructure requirements.

Once the anesthesia is selected protocols should be written to guide appropriate application of the chemical to allow for safe handling while minimizing the risk of over-exposure and mortality. The protocol should include details on water temperature and adjustment of dosage based on water temperature. Finally, a water temperature maximum should be set when fish handling will not be done.

7.4.2.1 Recovery

Fish that have undergone anesthetization should be allowed to recover from the effects of the anesthetic before being released (Section 7.5.10).

Fish require time to recover from the effects of anesthesia. The amount of recovery time needed will depend on several variables including the exposure time to the anesthesia, the water temperature (and general water quality conditions), and the individual sensitivity of the fish. Warm water temperatures and prolonged exposure to anesthetic will result in extended recovery times.

Fish should be monitored to ensure they are recovering. Signs of recovery include fish that are consistently upright and oriented, display normal gilling activity, and are responsive to stimuli.

During recovery fish should be protected from risk of impingement or accidental release back to the river (see specific guidance in Section 7.5.10).

7.4.3 Non-Target Fish

New or upgraded trapping facilities should be designed such that non-target fish can bypass the anesthetic tank.

7.4.4 Frequency

Unless otherwise agreed to by NMFS, all fish (i.e., adults and juveniles of all species and sizes) should be removed from the trap holding pool and raceways at least once every 24 hours whenever the trap is in operation. When either environmental (e.g., water temperature extremes, low dissolved oxygen, or high debris load) or biological conditions (e.g., migration peaks or delay) warrant, fish should be removed more frequently to preclude overcrowding or adverse water quality conditions from developing (Section 7.5.5.2).

7.4.5 Personnel

Trap personnel that handle fish should be experienced or trained to ensure that fish are handled safely.

7.5 Trap Design Criteria

Section 7.5 provides criteria and guidelines that apply to trap design.

7.5.1 Trap Components

Trap systems should include the following components:

- *Removable diffusers or gates located within the fish ladder to block passage and guide fish into the trap*
- *A holding pool; a transition channel or port that connects the fish ladder to the holding pool; and a trapping mechanism as described in Section 7.5.4 (attraction flow is discharged via devices described in Section 7.5.4)*
- *A gate to prevent fish from entering the trap area during crowding operations*
- *A fish crowder (and brail if needed) to encourage adult fish to exit the off-ladder holding pool and enter sorting and loading facilities*
- *Separate holding pool inflow supply and outflow facilities*
- *Distribution flume used in conjunction with false weir or steepass systems to enable fish to exit the holding pool*
- *A lock or lift (or hopper) for loading fish onto the transportation truck*
- *A flume, pipe, or ladder to return fish either to the ladder or to the dam forebay where they can continue their upstream migration (when returning fish to the ladder, fish should be allowed to volitionally enter the ladder from a resting pool)*

7.5.2 General

7.5.2.1 Location

The entrance to trap facilities should be located in a hydraulically stable, low-velocity (i.e., approximately 1.5 ft/s), accessible area of the upstream passage facility, similar to the requirements for a counting station (Section 5.6).

This location allows fish to be more easily directed toward the trap entrance without excessive turbulence.

7.5.2.2 Flow

Fish ladders should not experience any significant change in fishway flow volume during trap operations.

Fish ladders are often designed to operate within a narrow range of flows; thus, changing the flow volume during trap operations can often compromise the function of the ladder. Depending on the design, it may be necessary to add or remove flow from the ladder in order to adjust for the operation of the trap.

7.5.2.3 Edges

All trapping components exposed to fish should have all welds and sharp edges ground smooth to the touch to minimize injuries. Additional features, such as neoprene padding covered by UV stabilized rubber, may also be required to minimize fish injuries.

7.5.2.4 Fish safety

Provisions should be included in the facility design to provide guaranteed safety to the fish or a method or manner to release fish back to the river in case of emergency (e.g., power outage or loss of water supply).

Fish safety provisions may include guaranteed water supply, water level and water supply alarms, aeration systems, and backup pumps and generators.

7.5.3 Pickets

Pickets are used to prevent fish from entering a specific area (e.g., AWS) or to guide fish to a particular area (e.g., toward a counting window for enumeration or a trap entrance).

7.5.3.1 Design velocity

The average velocity through pickets should be less than 1 ft/s for all flows (Clay 1995).

The average design velocity is calculated by dividing flow by the total submerged picket area. Non-uniform or excessive velocities through the structure can create false attraction conditions that delay fish and induce upstream migrants to attempt to jump over the pickets, potentially injuring the fish.

7.5.3.2 Material

Pickets should be constructed of non-corrosive materials. Panels may consist of flat bars (where the narrow edge of the bar is aligned with flow) or round columns of steel, aluminum, or durable plastic. All surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.

7.5.3.3 Bar spacing

The maximum clear spacing between picket bars is 1 inch for adult trapping facilities. At sites where lamprey may be present, pickets should have a maximum 0.75-inch clear spacing between bars.

At sites where smaller fish are present, a smaller spacing between bars may be required.

7.5.3.4 Pickets in off-ladder holding pools

Off-ladder holding pools should include intake and exit pickets designed to prevent adult fish from exiting the holding pool. These should conform to the criteria identified in Section 6.3. The design of off-ladder holding pools should also include an adjustable overflow weir located downstream of, or in conjunction with, the entrance pickets to control the water surface elevation in the holding pool.

7.5.3.5 Blocking pickets

Removable pickets installed within the ladder to block fish from ascending further and route them into an off-ladder trapping pool should be angled toward the off-ladder trap entrance and comply with the criteria listed in Sections 5.3.7 and 5.6.3.7. Pickets installed within ladders should be completely removed from the ladder when trapping activities are not occurring.

7.5.4 Trapping Mechanisms

7.5.4.1 Description and purpose

There should be a mechanism that allows fish to enter, but not volitionally exit, a holding pool. The most commonly used mechanisms include finger weirs, Vee trap fykes, or false weirs (Section 7.5.8).

The maximum velocity over finger traps is 8 ft/s. The amount of flow over the top of a finger weir is usually 2 to 6 inches but varies based upon species. The height of a finger weir varies but is usually in range of 6 to 10 inches (Bell 1991). When using finger traps, an escape area should be provided at both ends to prevent fish from being held against the fingers and killed (Bell 1991).

For a Vee trap, Bell (1991) recommends a minimum velocity of 4 ft/s. The opening at the apex is usually around 8 inches but may need to be larger or smaller depending upon the species present. Being able to adjust this opening can be very beneficial.

Figure 7-1 shows a schematic of a finger weir. Figure 7-2 shows a cutaway of a Vee trap.

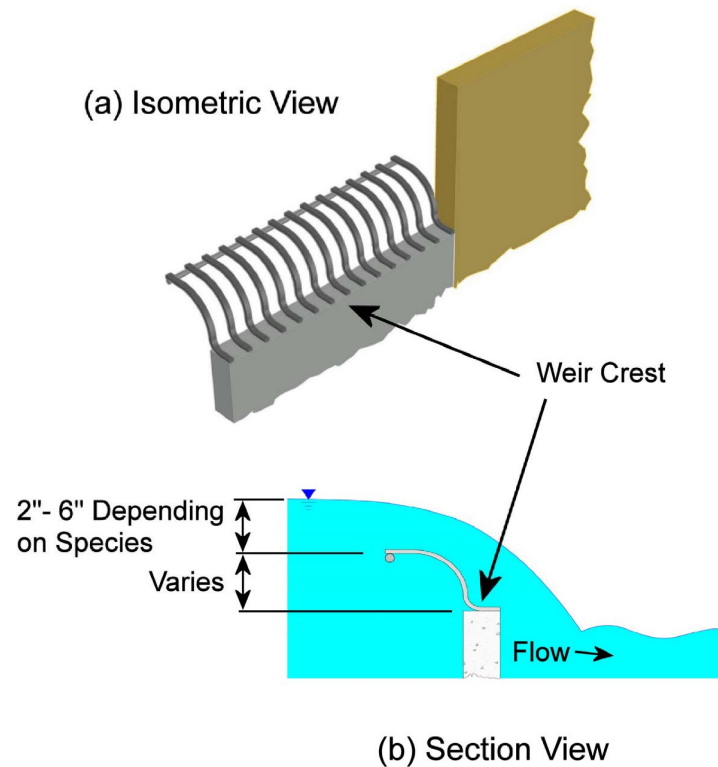


Figure 7-1. Finger weir schematic

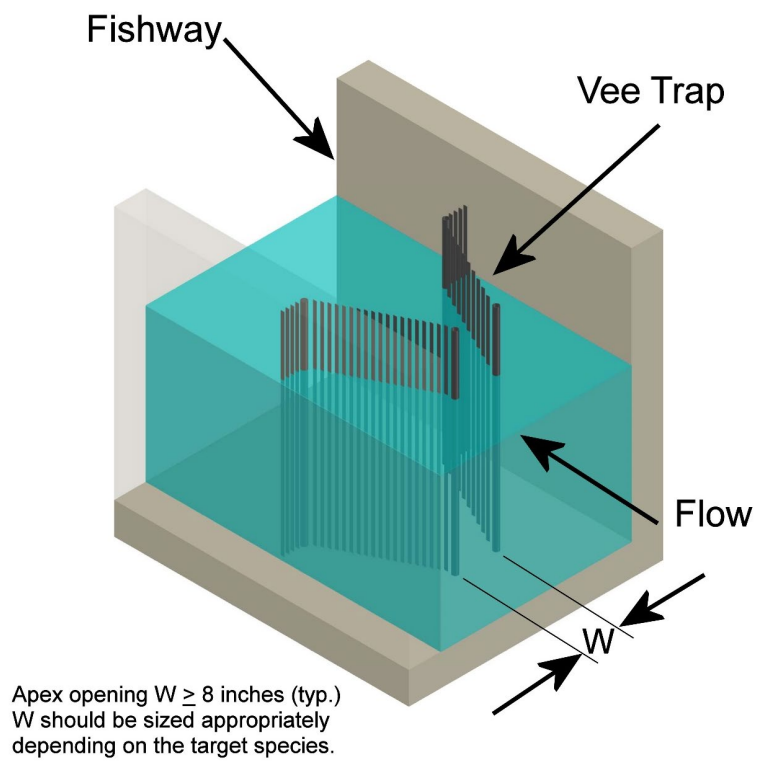


Figure 7-2. Cutaway of a Vee trap

7.5.4.2 Edges

All trapping components exposed to fish should have all welds and sharp edges ground smooth to the touch to minimize injuries. Additional features, such as neoprene padding (covered by UV stabilized rubber), may also be required to minimize fish injuries.

7.5.4.3 Materials and bar spacing

Materials and bar spacing should conform to Sections 7.5.3.2 and 7.5.3.3.

7.5.4.4 Closure

Trapping mechanisms should be able to be closed temporarily to avoid spatial conflict with trail crowding and loading operations. The trapping mechanisms should be designed to safeguard against fish gaining access to unsafe areas such as areas behind a crowder or under a floor trail.

7.5.5 Holding Pools

Holding pools and raceways are used to provide safe areas where fish can be held and accumulated until the facility operators are prepared to process them (for actions such as sorting, evaluation, or transportation).

7.5.5.1 Water quality

Holding pool water quality should be equal to or exceed that of the ambient waters from which fish are trapped.

Key water quality parameters include water temperature, oxygen content, and pH. The purpose of this criterion is to provide fish with a safe, healthy holding environment.

7.5.5.2 Trap holding pool capacity

The following criteria should be followed with regard to trap holding pool capacity:

- *Trap holding pool capacity is based on the number and poundage of fish that can be safely held in a given pool volume for a given time period as well as water quality and quantity.*
- *The number of fish is determined by the maximum daily number of fish passing through the ladder or facility, or by the number of fish expected to be trapped and held prior to being transported.*
- *Fish poundage is determined by multiplying the weight of the average fish targeted for trapping by the maximum number of fish expected to occupy the trap. Note that the poundage calculation may entail calculations for a number of different fish species.*

7.5.5.3 Short-term holding

Trap holding pools should be sized to provide a minimum volume of 0.25 ft³/lb of fish. Trap water supply flow rate should be at least 0.67 gallon per minute (gpm) per adult fish for the predetermined adult fish trap holding capacity.

These criteria apply to conditions when water temperatures are less than 50 degrees Fahrenheit (°F), dissolved oxygen is between 6 and 7 parts per million, and fish are held less than 24 hours (Senn et al. 1984; Bell 1991; Bates 1992). For example, to hold 100 lb of fish for less than 24 hours, the holding pool would need to provide a volume of 25 ft³ (100 lb × 0.25 ft³/lb of fish) at 50°F. These criteria are based on the long-term holding requirements presented by Senn et al. (1984), which have been modified and adapted to short-term holding conditions. (See Section 7.5.5.5 for guidance on when water temperatures exceed 50°F.)

7.5.5.4 Long-term holding

Trap holding pool water volumes and water supply rates should be increased by a factor of 2 (0.5 ft³/lb of fish and at least 1.34 gpm per adult fish, respectively).

For example, to hold 100 lb of fish for more than 24 hours (but less than 96 hours), the holding pool would need to provide a volume of 50 ft³ (100 lb × 0.5 ft³/lb of fish) at 50°F. Long-term holding should not exceed 96 hours. Trap and haul facilities are not intended for the long-term holding of adults (e.g., hatchery broodstock). However, NMFS will consider additional information or research regarding adult fish holding times and densities, if provided. (See Section 7.5.5.5 for guidance on when water temperatures exceed 50°F.)

7.5.5.5 Holding pool capacity when water temperatures are greater than 50°F

If water temperatures are greater than 50°F, the poundage of fish held should be reduced by 5% for each degree above 50°F (Senn et al. 1984). The trap capacity and average weight of targeted fish values to be used in a design are subject to approval by NMFS.

For short term holding (less than 24 hours) at 60°F, to hold 100 lb of fish, the holding pool would need to provide a volume of 50 ft³. For long term holding (greater than 24 hours but less than 96 hours) at 60°F, the holding pool would need to provide a volume of 100 ft³.

Extreme care should be taken when water temperatures are above 68°F during trap operations.

Table 7-1 is provided for reference.

Table 7-1. Holding Pool capacity when water temperature exceeds 50°F

Temp (°F)	Short Term Holding (0.25 lb/ft ³)	Short Term Holding (0.25 ft ³ /lb)	Long Term Holding (0.5 lb/ft ³)	Long Term Holding (0.5 ft ³ /lb)
50	4.00	0.25	2.00	0.50
51	3.80	0.26	1.90	0.53
52	3.60	0.28	1.80	0.56
53	3.40	0.29	1.70	0.59
54	3.20	0.31	1.60	0.63
55	3.00	0.33	1.50	0.67
56	2.80	0.36	1.40	0.71

57	2.60	0.38	1.30	0.77
58	2.40	0.42	1.20	0.83
59	2.20	0.45	1.10	0.91
60	2.00	0.50	1.00	1.00
61	1.80	0.56	0.90	1.11
62	1.60	0.63	0.80	1.25
63	1.40	0.71	0.70	1.43
64	1.20	0.83	0.60	1.67
65	1.00	1.00	0.50	2.00
66	0.80	1.25	0.40	2.50
67	0.60	1.67	0.30	3.33
68	0.40	2.50	0.20	5.00
69	0.20	5.00	0.10	10.00

7.5.5.6 Trap holding pool inflow

The following criteria should be followed with regard to trap holding pool inflow:

- *Inflow should be routed through an upstream diffuser designed in accordance with the criteria identified in Section 5.3.7.*
- *The maximum average velocity through the diffuser that is acceptable is 1 ft/s for vertical diffusers and 0.5 ft/s for horizontal diffusers.*
- *Horizontal diffusers should be used when supplying water directly to fish holding pools to reduce the potential for fish jumping at the diffuser flow (Bell 1991).*
- *For both vertical and horizontal diffusers, baffling and other methods of energy dissipation should be used to prevent excessive turbulence and surging, which may induce adult jumping within the trap.*
- *Flow distribution through the diffuser should not cause fish to crowd into a particular area of the holding pool. However, when fish are being crowded for handling or routing, it is best to take advantage of their natural behavior and concentrate the water supply near the end of the pool where fish are being encouraged to move to as part of the operation.*

7.5.5.7 Shading

Consideration should be given to providing shading for holding pools and raceways.

Shading can reduce stress and jumping in adult fish and can reduce the potential for sun burn (Bell 1991).

7.5.5.8 Holding pool water depth

The minimum depth of water in the holding pool is 5 feet.

This is the same minimum depth criterion as is specified for fish ladder pools.

7.5.5.9 Adult jumping

Trap holding pool designs should include provisions that minimize adult jumping, which may result in fish injury or mortality.

Examples of provisions that reduce jumping include the following (Bell 1991):

- Incorporating a high freeboard on holding pool walls of 5 feet or more (note that Bell [1991] recommends incorporating up to 6 feet of freeboard into the facility design)
- Covering or shading the holding pool to keep fish in a darkened environment
- Providing netting over the pool that is strong enough to prevent adults from breaking through the mesh fabric
- Providing sprinklers above the holding pool water surface to break up the water surface and reduce the ability of fish to detect movement above the trap pool
- Designing the corners of the holding pools to have a minimum radius of 18 inches
- Ensuring that water from distribution flumes and pipes does not drop directly into the holding pool
- Ensuring that there are no areas of strong horizontal light nor dark areas present on the surface of the holding pool

7.5.6 Crowders

Crowders are porous panels that can be deployed into a holding pool and used to move fish horizontally to the end of the pool for collection by a hopper or lift, or to encourage the fish to leave the holding pool. Crowders can be pushed by personnel or mechanically operated.

7.5.6.1 Bar spacing

Holding pool crowders should have a maximum clear opening between bars of 0.875 inch. Gaps around the sides of crowder panels should not exceed 1 inch. The side and bottom seals of the crowder panel should allow the crowder to move without binding and should prevent fish from entering the area behind the crowder panel.

If smolt-sized juvenile salmonids or other small fish are expected to be retained in the adult holding pool, the maximum clear bar spacing of the crowder panel (and brail if present) should be reduced to 0.25 inch, and any gaps around the sides the crowder panels should not exceed 0.375 inch.

Often, smaller-sized fish find their way into and become caught in the adult trap holding pool. Provisions should be incorporated into the trap design to safely remove smaller-sized fish from the holding pool and return them to the river.

7.5.6.2 Material

Crowder panels should be constructed of non-corrosive materials. The use of galvanized material should be avoided if possible, and otherwise minimized. Panels may consist of fish screen material such as profile bar or perforated plate material, flat bars where the narrow edge

of the bar is aligned with flow, or round columns of steel, aluminum, or durable plastic. All edges and surfaces exposed to fish should be rounded or ground smooth to the touch.

The galvanization process uses zinc, which can be toxic to fish (this is why non-corrosive materials for crowder panels should be used). During the crowding process, fish are extremely likely to come into direct contact with the crowder panels. To reduce the potential for fish to be descaled or injured when being crowded, all surfaces and edges that fish can contact need to ground smooth or rounded.

7.5.6.3 Crowding process and crowding speeds

For mechanical crowders, the beginning of the crowding process can be automated, but at the end of the process when fish densities are high the crowder should be manually controlled.

Speeds for horizontally oriented crowders are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools. Maximum crowder speed should not exceed 2 ft/s and should be adjustable.

Crowders are often controlled by a variable frequency drive (VFD). VFDs allow for crowder travel speed to be slowly increased or decreased. This moves the equipment to crowd, but not stress, adult fish in the holding pool. Further, it eliminates erratic (jerking) crowder movement provided with a simple on-off switch. Crowder speeds are also sometimes controlled by a switch to toggle between fast and slow speeds. In all cases, the VFD should be programmed not to increase the crowder or rail speed beyond a maximum level.

7.5.6.4 Coverage

Crowders should be able to cover (crowd) the entire holding pool and should not leave any areas where fish may escape the crowding process.

Being able to crowd the entire holding pool ensures that all fish can be removed from the pool and that no fish spends more time than necessary in the holding pool.

7.5.6.5 Fish entering the holding pool while crowding

If the crowder cannot be removed from the holding pool, it is important that fish do not enter that portion of the holding pool located behind the crowder during crowding operations.

Fish should not be able to access the area behind the crowder where they could become trapped resulting in injury or death.

7.5.7 Brails

Brails are porous panels that can be used to move fish vertically in a holding pool or fish lock. For large holding pools, they are often used in conjunction with a crowder to encourage fish to exit the holding pool.

7.5.7.1 Floor brails

The following criteria should be followed with regard to floor brails:

- *Floor brails should be composed of screen material that is sized according to the life stage and species present to preclude injury or mortality from occurring to target and non-target fish species. Gap openings along the sides of the rail should not exceed 1 inch.*
- *For adult salmonids, brails should have a maximum clear spacing between bars of 0.875 inch. Gaps around the sides of crowder panels should not exceed 1 inch, and seals should be installed that cover all gaps. The side and bottom seals of the crowder panel should allow the crowder to move without binding and prevent fish from moving underneath the rail.*
- *If juvenile salmonids (i.e., smolt-sized fish) or other small fish are expected to be caught in the holding pool, consideration should be given to including a separator system and juvenile sanctuary area as part of the rail system. Also, the maximum clear spacing between bars of the rail should be reduced to 0.25 inch, with side tolerances of no more than 0.375-inch opening or the openings sealed with a brush material.*

7.5.7.2 Material

Rail panels should be constructed of non-corrosive material. The use of galvanized material should be avoided if possible, and otherwise be minimized. Panels may consist of fish screen material such as profile bar or perforated plate material; flat bars where the narrow edge of the bar is aligned with flow; or round columns of steel, aluminum, or durable plastic. All edges and surfaces exposed to fish should be rounded or ground smooth to the touch.

The galvanization process uses zinc, which can be toxic to fish (this is why non-corrosive materials for crowder panels should be used). During the crowding process, fish are extremely likely to come into direct contact with the crowder panels. To reduce the potential for fish to be descaled or injured when being crowded, all surfaces and edges that fish can contact need to ground smooth or rounded.

7.5.7.3 Slope

The sides and the floor of the rail should be sloped toward the holding pool egress point to encourage adult fish to move off the rail.

7.5.7.4 Lifting

The rail should not be used to lift fish out of the water.

7.5.7.5 Rail speed

Rail speeds are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools. Maximum rail speed should not exceed 2 ft/s and should be adjustable. The beginning of the railing process can be automated, but at the end of the process when fish densities are high, the rail should be manually controlled.

7.5.7.6 Fish lock brails

When floor brails are used in association with fish locks (Section 7.6.2), the floor brail hoist should be designed for both manual and automatic operation and should allow the brail to move at a maximum rate of 2.3 ft/s (both upward and downward). Also, the brail should be able to be operated at speeds that match changes in water surface elevation. Automated operation is allowed only when the water depth above the brail is 4 feet or more. At water depths less than 4 feet, operation of the brail should be conducted manually.

These criteria are designed to minimize stressing fish during crowding between the floor brail and the point where water in the lock exits over an egress weir.

7.5.8 False Weirs

A false weir is a specialized floor diffuser used to introduce water at the top of a fishway or entrance to a distribution flume for the purpose of attracting and encouraging fish to voluntarily move into a specific area (Figure 7-3). The device usually creates a strong upwelling flow that simulates flow cascading over a weir. Fish are attracted to the cascading flow and swim through the upwelling into the distribution flume. Care should be taken when locating a false weir to avoid light-to-dark transition at the location of the false weir (shadows) or movement by operator personnel around the false weir. These conditions could cause a fish to reject (not enter) the false weir.

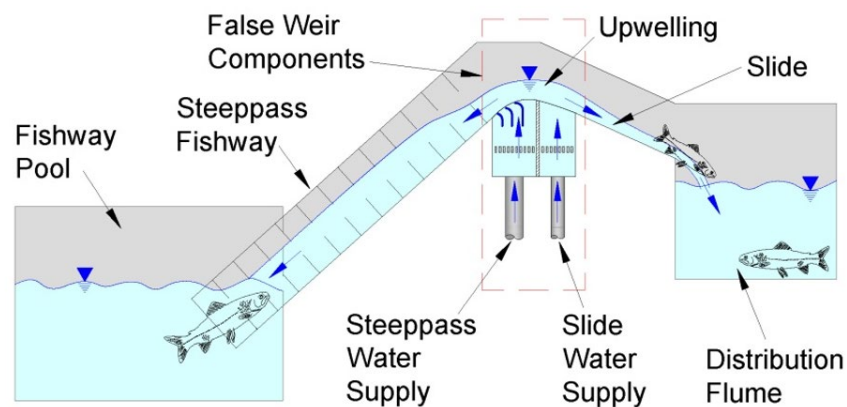


Figure 7-3. Cross section of a false weir

7.5.8.1 Depth

Water depth over the crest of the false weir should be at least 6 inches to facilitate fish egress from the holding pool.

7.5.8.2 Water Supply and Dewatering

The false weir design should include independent water control for both the weir side (steppass water supply side in Figure 7-3) and flume side (slide water supply in Figure 7-3). Additionally, the slide side of the false weir should include a dewatering screen/system to allow the operator to trim the flow down the slide/flume.

Tuning the amount of flow over the false weir to encourage fish movement while having the ability to limit the amount of flow down the flume is very important. Too much flow down the flume, may allow the fish to try to swim against the flow until exhaustion (Section 7.5.9.3). Achieving the balance between sufficient weir flow and reduced flume flows can be impossible with a common water supply. The addition of a drain between the weir supply and the flume supply is very helpful and allows the operator to maximize attraction flow entering the holding pool. Finally, the independent water control and drain allows the operator to continue to supply the flume with flow both before and after the weir is turned on and off, respectively.

7.5.8.3 Adjustability

The false weir and the downstream water level should have enough adjustability to backwater the false weir and create a streaming flow condition, rather than a plunging flow condition over the weir.

Incorporating this adjustability in the design of the false weir allows the operator to adjust conditions at the false weir to allow adult fish to swim through the weir, rather than having to leap at it to pass the weir. Care should be taken when raising the downstream water surface elevation to ensure this does not adversely affect hydraulic conditions in the trap facility further downstream of the false weir.

7.5.8.4 Fish entering a distribution flume

In situations where fish are entering a distribution flume after passing over a false weir, the ability to change the amount of flow coming from the false weir should be rapid and easy to change in order to regulate the movement of fish over the weir.

Oftentimes it is necessary to control (i.e., meter) the number of fish passing through the false weir so operator personnel can identify and sort fish into various holding tanks. Having the ability to rapidly change the amount of flow coming from the false weir allows the operator some control over how many fish enter the false weir at time. Operator-controlled neoprene doors that open and close in front of, or vary the width of, the entrance to the false weir can be used to allow the operator to more efficiently meter fish through the false weir. Care should be taken in providing sufficient freeboard (around, above, through and downstream of the false weir), since very strong leapers (like steelhead) can jump much higher than the water level on the weir crest.

7.5.8.5 Edges

Provisions, such as neoprene padding (covered by UV stabilized rubber), should be installed around a false weir to protect fish that make an inaccurate leap at the weir from being injured.

7.5.8.6 Gravity flow

A gravity flow (i.e., not pumped) water supply should be used for false weirs and steep pass ladders to prevent fish from potentially rejecting the trap component due to the production of noise or vibration from a pump or motor. At sites where it is necessary or

desirable to use a pumped water supply, care should be taken to isolate the pump noise and vibration from affecting the fish.

7.5.9 Distribution Flumes and Pipes

7.5.9.1 General

A distribution flume (or pipe) should be used whenever fish are routed from one area to another.

Distribution flumes are used to convey fish to anesthetic tanks, recovery tanks, pre-transport holding tanks, fish ladders, and project forebays. They are also used to convey fish to various locations after they pass through false weirs.

7.5.9.2 Smoothness

The flume should have smooth joints, sides, and bottom, with no sharp or abrupt edges and no abrupt vertical or horizontal bends.

7.5.9.3 Wetted surfaces, water depth, and velocity

The following criteria should be followed with regard to wetted surfaces, water depth, and velocity:

- *The flume should have continuously wetted surfaces.*
- *For flumes less than 50 feet in length, water depth in the flume should be between 1 and 3 inches, and water velocity should be between 6 and 8 ft/s.*
- *For flumes that are longer than 50 feet, a closed pipe with open channel flow should be used for the entire length of the flume. The water depth in the pipe should be between 2 and 4 inches (a depth of 4 inches is preferred), and water velocity should be greater than 8 ft/s, but less than 15 ft/s.*
- *Site-specific adjustments to these values may be required.*

The combination of low water depth and high velocity is intended to prevent adult fish from holding in the pipe or swimming upstream in the pipe. If the pipe is above ground, observation ports with removable covers should be provided so that conditions in the flume can be observed and the pipe can be accessed for maintenance and debris removal. If the pipe is located belowground, access ports should be provided for inspection and maintenance.

7.5.9.4 Outfalls

When distribution flumes lead to holding tanks or raceways, care should be taken so that adults entering the tank do not hit the walls, floor, or end of the tank or collide (land on top of) with other fish. A dewatering drain should be located immediately upstream of the outfall to eliminate flow from the outfall which can cause false attraction and jumping.

When a distribution flume is used to return adults to the river, the criteria for juvenile outfalls (Section 8.6.4) should be followed (i.e., the bypass flow should not impact the river

bottom or other physical features at any stage of river flow, and the maximum bypass outfall impact velocity should be less than 25 ft/s).

7.5.9.5 Bends

Horizontal and vertical radii of curvature should be at least 5 times the width of the flume to minimize the risk of fish-strike injuries. A removable flume cover should be provided when flumes go through bends greater than 30 degrees in alignment.

Removable covers are necessary to prevent active fish from leaping out of the flume and allow personnel to inspect the flume for debris accumulation in the bend.

7.5.9.6 Size

The minimum inside diameter of the distribution flume should be 15 inches for fish weighing 20 lb or less and 18 inches for fish weighing 20 lb or more.

The minimum sidewall height of a distribution flume is 24 inches.

This height is in addition to the radius of the flume. For example, the minimum total height of a 15-inch diameter flume would be 31.5 inches (24 inches plus half of the diameter at 7.5 inches), as measured from the invert of the flume.

7.5.9.7 Length

Distribution flumes should be as short as possible.

7.5.9.8 Flume structure

Overhead structures that are part of the flume, such as overhead bracing to stiffen the walls of the flume or gate operation arms, should be eliminated if possible, or minimized. If overhead structures are necessary, they should be located above the top of the flume sidewalls or 30 inches above the invert of the flume, whichever is greater.

7.5.10 Anesthetic Recovery Pools

The following criteria should be followed with regard to anesthetic recovery pools:

- *Anesthetized fish should be routed to a recovery pool to allow the fish to be monitored prior to release to ensure they have fully recovered from the anesthesia.*
- *Fish that are recovering from anesthesia should not be routed directly back to the river where unobserved mortality may occur.*
- *Recovery pool inflow should satisfy the water quality guidelines specified in Section 7.5.5.*
- *Recovery pool hydraulic conditions should not result in partially or fully anesthetized fish being impinged on an outflow grating or any other hazardous area.*
- *A recovery pool should allow fully recovered fish to volitionally exit the pool.*
- *The recovery pool should have a brail or crowder system to force fish from the recovery pool if necessary.*

Often, fish require time to recover from effects of anesthetic. Anesthetized fish released directly to an uncontrolled environment (i.e., directly back to the river or into a ladder) often fail to orient themselves upright and sometimes sink to the bottom where they may suffocate or are swept downstream. It is important to provide fish recovering from anesthetic with a safe recovery area where they can be monitored by personnel. Some indications that fish are fully recovered include they are upright and oriented, display normal gilling activity, and are responsive to stimuli. If a fish appears to be struggling to recover or appears distressed, it may be necessary to retrieve the fish and revive it. Revival may involve manually ventilation of the gills by gently moving the fish forward and backward in the water. The ability of a fish to volitionally exit the recovery pool is an indication that the fish has recovered sufficiently from the anesthetic. Fish should not be forced out of the recovery pool for at least 30 minutes after exposure to anesthetic.

7.6 Lifting Devices

Section 7.6 provides criteria and guidelines that apply to fish lifting devices.

7.6.1 Fish Lifts and Hopper Passage Systems

A fish lift is a mechanical system that utilizes a hopper and hoist to allow fish to be trapped at one elevation and raised to a higher elevation. Once raised to the higher elevation, fish can be loaded into a transport tank or truck for release at a remote location, routed to a monitoring and sorting facility, or released above a dam directly into the forebay.

7.6.1.1 Maximum hopper loading densities

The hopper water volumes should be greater than or equal to 0.15 ft³/lb of fish estimated to occur at the maximum fish load. When large fish (fish ranging from 30 to 40 lb in weight) are being transported, the poundage being transported should be reduced by 50% (Bell 1991).

Hopper loading densities are designed to ensure that a sufficient volume of water is available to fish to be raised safely. Normally, the size of the hopper and transport tank loading match, such that a full hopper volume equals a full transport tank volume. The density of fish being held when water temperatures become elevated is a concern that needs to be considered. Bell (1991) recommends that the poundage of fish being transported in tanks be reduced by 10% for each degree of water temperature above 60°F.

7.6.1.2 Hopper freeboard

The distance from the water surface in the hopper to the top of hopper bucket should be greater than the water depth within the hopper.

This is to reduce the risk of fish jumping out of the hopper during lifting operations.

7.6.1.3 Sump

When a trap design includes a hopper sump into which the hopper is lowered during trapping, side clearances between the hopper and sump sidewalls should not exceed 1 inch to

minimize access to the area below the hopper. Flexible side seals or brushes should be used to ensure that fish do not pass below the hopper.

It is very important that the hopper and gates around the sump provide a positive seal and do not allow fish to get into the sump area. If fish do get into this area, they can be very difficult to remove due to the water depth and confined area.

7.6.1.4 Fish hopper egress opening

The fish egress opening from the hopper into the transport tank should have a minimum horizontal cross-sectional area of 3 square feet and a smooth transition to minimize the potential for fish injury.

7.6.1.5 Safeguarding fish

Fail-safe measures should be provided to prevent fish entering the holding pool area from accessing the area occupied by the hopper before the hopper is lowered into position. The interior surfaces of the hopper should be smooth to eliminate fish injuries.

7.6.2 Fish Lock

A fish lock is a mechanical-hydraulic system that utilizes a water chamber or tower to raise fish from one elevation to another. It allows fish that are collected (trapped) at a lower elevation to be raised to a higher elevation by increasing the water level in the chamber or tower until it reaches a predetermined elevation where fish can be released. The fish can be brailed (i.e., crowded) to the higher elevation and then loaded into a transport truck for release at a remote location, routed to a monitoring and sorting facility, or released directly above a dam into the forebay (Clay 1995).

Section 7.6.2.1 outlines the process for routing fish from a holding pool to the forebay or transport vehicle using a fish lock.

7.6.2.1 Holding pool crowding

The following criteria and guidelines should be followed with regard to holding pool crowding:

- *Fish are crowded into the lock; the crowder should meet up with the entrance to the lock so that no fish can become trapped or crushed between the crowder and the lift structure or closure gate.*
- *When the closure gate to the fish lock chamber is shut it should create a uniform surface with the interior of the lock so that the brail can pass the gate without creating excessive gaps that could allow fish to get past the brail.*
 - The closure gate is the gate that seals the lock chamber from the holding pool.
- *Once the closure gate is shut, the crowder should be backed up to reduce the stress on the fish.*

- Crowding, especially the last part of the crowd when fish are forced from the holding pool, can be very stressful to the fish. If there is a break in the crowding operation for some reason (lifting and operating the hopper for example), the crowder should be backed off to reduce the stress on the fish.
- *Flow to fill the lock should be introduced into the lock through floor diffusers below the floor rail.*
 - As the water level rises within the lock, it will ultimately reach an equilibrium elevation with a control weir or false weir.
- *The floor rail should be raised only after the water surface elevation in the lock is at an equilibrium with the control weir or false weir. If the rail is being operated while the fish lock is being filled, the speed of the rail should not exceed the rate of change in water surface elevation. The rail should be greater than 4 feet from the water surface until the water level reaches equilibrium with the control or false weir. The rail should not be used to lift fish out of the water (Section 7.5.7.4).*
 - Speeds for rails (vertically oriented crowders) are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools, but can range up to 2.3 ft/s for vertical fish locks.
- *Fish should exit the lock via a false weir or through the overflow water draining over the control weir.*
- *Fish and water that pass over the control weir or false weir can be routed using a distribution flume to other destinations, including an anesthetic tank, sorting or holding pools, or a transportation vehicle.*
 - Floor dewatering screens in the distribution flume can be used to drain off excess flow just before fish are delivered to anesthetic tanks, holding pools, or transportation vehicles.

7.6.2.2 Lock inflow chamber

The lock inflow chamber located below the lowest-floor rail level should be of sufficient depth and volume (Section 5.5.3.5) to limit turbulence into the fish holding zone when lock inflow is introduced. The inflow sump should be designed so that flow upwells uniformly through add-in floor diffusers (Section 5.3.7; Bell 1991).

Properly designed lock inflow chambers will limit turbulence and unstable hydraulic conditions within the lock that may agitate fish.

7.7 Single Holding Pool Traps

Single pool traps are often used in tandem with intermittent exclusion barriers (Figure 6-5) for broodstock collection from small streams. These trapping systems are used to collect, sort, and load adult fish. Key criteria for single holding pool traps are as follows:

- *The trap holding pool water volume should be designed according to Section 5.5.3.5 to achieve stable interior hydraulic conditions and minimize jumping of trapped fish.*
- *Intakes should conform to Section 5.3.2.*

- *Sidewall freeboard should be a minimum of 4 feet above the trap pool water surface at high design streamflow.*
- *The trap holding pool interior surfaces should be smooth to reduce the potential for fish injury.*
- *A description of the proposed means of removing fish from the trapping pool and loading them onto a transport truck should be submitted to NMFS for approval as part of the ESA incidental take permit application.*

7.8 Upstream Transportation Criteria

Section 7.8 provides criteria and guidelines that are applicable to truck transportation equipment and facilities.

7.8.1 Maximum Transport Tank Loading Densities and Time

Transport tank loading water volumes should be greater than or equal to 0.15 ft³/lb of fish at the maximum fish loading density to provide a sufficient volume of water for fish safety. When large fish (fish ranging from 30 to 40 lb in weight) are being transported, the poundage being transported should be reduced by 50% (Bell 1991). Every effort should be made to reduce the amount of time fish spend in a transport tank.

These loading densities are to ensure that a sufficient volume of water is available in the tank for fish to be transported safely. Normally, the size of the hopper and transport tank loading match, such that a full hopper volume equals a full transport tank volume. The density of fish being held when water temperatures become elevated is a concern that needs to be considered. Bell (1991) recommends that the poundage of fish being transported in tanks be reduced by 10% for each degree of water temperature above 60°F.

Due to the high loading densities in transport tanks and the stress it may create, every effort should be made to minimize the amount of time the fish spend in these tanks. Fish should not be held for long in a transport tank while waiting for other fish to be processed or while waiting for other fish to fill the tank.

7.8.2 Transport Tanks

To minimize handling stress, truck transport tanks should be compatible with the hopper design. If an existing vehicle will be used, the hopper should be designed to be compatible with existing equipment. If the transport tank opening is larger than the tube or hopper opening, a cap or other device should be designed to prevent fish from jumping at the opening. Truck tanks for hauling adults should be closed systems, and the tanks should be kept full to prevent sloshing (Bell 1991).

7.8.2.1 Fish transfer from hopper to tank

The transfer of fish should be made water-to-water. The design of the hopper and transport tanks should allow for hopper water surface control to be transferred to the truck

transport tank during loading so that water and fish do not plunge abruptly from the hopper into the fish transport tank.

7.8.2.2 Transport tank egress

The fish egress opening from the transport tank should have a minimum cross-sectional area of 2 square feet (Clay 1995). The bottom of the transport tank should be sloped (front to back and side to side) toward the release opening and have a smooth transition that minimizes the potential for fish injury.

7.8.2.3 Oxygen and temperature requirements

Depending upon site-specific conditions, the transportation tank should have the capability to maintain dissolved oxygen levels between 6 and 7 parts per million. The transportation tank should also contain water chillers to maintain ambient water temperature if the transport cycle time could result in unhealthy increases in the water temperature in the tank or temperature differential between the tank water temperature and the ambient water temperature where the fish are released exceed the water tempering described in Section 7.8.3.5.

Many existing fish transport trucks do not include water chillers because they are designed for short transport trips during which the water temperature conditions in the tank do not result in temperature changes that exceed the water tempering requirements when the fish are released. Water tempering can be performed using chillers or mixing with cooler or warmer water at loading or release sites.

7.8.3 Release Location

After being transported, fish should be released in a safe location with sufficient depth and good water quality.

The criteria and guidelines in Sections 7.8.3.1 through 7.8.3.6 apply to release locations.

7.8.3.1 Direct release from a transport tank

Fish should not be dropped more than 6 vertical feet during release. The receiving water should be at least 3 feet deep, and fish should not contact the bottom. The impact velocity of fish entering the receiving water should be less than 25 ft/s.

7.8.3.2 Release pipe from a transport tank

For locations where release pipes are required, the minimum diameter for a release pipe is 24 inches (30 inches is preferred). The end of the release pipe should not be submerged. The internal surface of the pipe joints should be smooth to the touch to prevent descaling and injury to fish. The release pipe elevation criteria, receiving water depth, and impact velocity are the same as for fish being released directly from a transport tank (Section 7.8.3.1).

Depending on how fish are released from the transport tank, the entrance to the release pipe may have to be larger (e.g., 36 inches), or a funnel or flume should be created that smoothly

transitions from the release tank outlet to the release pipe. Care should be taken to minimize the possibility of a fish leaping out of the system during transfer from the tank to release pipe.

7.8.3.3 Release water

Water should be supplied to the release pipe prior to fish being released and also used to flush the last fish out of the pipe.

7.8.3.4 Water quality

Water quality (i.e., water temperature and dissolved oxygen) at the release site should be representative of the general water conditions in the river in the vicinity of the release site.

7.8.3.5 Water tempering

Fish should not be subjected to rapid temperature changes. Temperature differentials between the transport tank and release location should be no more than 2 degrees Celsius (°C). If tempering is required to meet this criterion, changes in temperature should not exceed 1°C every 2 minutes or 5°C per hour. Tempering may take longer when temperatures are further away from the optimal temperature for the target species and life stage.

Changes in water temperature that occur too rapidly or are beyond the normal survival range of fish may cause thermal trauma (Post 1987). Mortality associated with rapid temperature changes may occur in the short term from loss of equilibrium (Bell 1991) and increased predation (Groot et al. 1995). Over longer time periods, thermal stress can act as an additive stressor and increase susceptibility to disease (Piper et al. 1982). Fish adapt more rapidly when the temperature change is nearer their thermal optimum than when the change is further away from that temperature (Schreck and Moyle 1990). Rapid changes in temperature have more significant negative effects at the upper end of a fish's temperature tolerance. As temperatures increase, fish are more active and have greater potential for self-inflicted injury, oxygen consumption is higher, and the saturation level of oxygen is lower, which increases the possibility of hypoxia (Murphy and Willis 1996).

7.8.3.6 Release site egress

The release site should provide direct and simple egress for fish into the river for continued migration upstream.

8 Fish Screen and Bypass Facilities

8.1 Introduction

Chapter 8 provides criteria for designing fish screen facilities for hydroelectric, municipal, irrigation, and other water-withdrawal projects that prevent fish (primarily young fish, fish with poor swimming capabilities, and larvae) from being entrained into water diversions. The objectives of these criteria are to develop fish screen facility designs that prevent fish impingement on the outward face of all fish screen material, do not increase predation above background levels, and ensure the structural integrity and longevity of all facility components is maintained. This allows the facility to be operated within its design criteria and protects fisheries resources over the design life of the project.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other than salmonids, NOAA will consider deferring to the more conservative criteria on a case by case basis.

The criteria are to be used when designing new facilities or performing major retrofits to existing facilities. The criteria are also to be used for temporary diversions such as water drafting operations (Section 8.7) and when stream flow is to be routed around a construction site. In addition, information presented in Chapter 1, Introduction; Chapter 3, Design Development; and Chapter 4, Design Flow Range, of this document apply to the design of fish screen and bypass facilities.

8.1.1 100% Flow Screening

All facilities that divert or use water from a body of water should convey 100% of the diverted flow through a fish screen or bypass that is designed, constructed, tested, and operated using the criteria contained herein.

The application of these criteria to existing fish screen facilities is addressed in Section 8.2.

8.1.2 Deviation from These Criteria

The criteria can be adjusted by NMFS as needed to meet the specific requirements of a project. It is the responsibility of the applicant to provide compelling evidence in support of any proposed waiver (Section 1.6) or modification of a criterion to NMFS early in the design process and well in advance of a proposed federal action. Appendix C (Experimental Technologies)

provides additional information on the NMFS approval process for unproven fish passage technologies.

There may be cases where site constraints or extenuating circumstances weigh in favor of a deviation or waiver of these criteria. Extenuating circumstances may include environmental factors that affect a fish's swimming ability or condition such as abnormally warm or cold waters or waters low in dissolved oxygen.

The swimming ability of target fish species and their life stages are primary considerations in designing effective fish screen facilities. The swimming abilities of fish vary with species, age-class, size, and duration (i.e., endurance) and type of swimming activity required (e.g., sustained versus burst swim speed). Bell (1991) provides information on swimming speeds for multiple fish species and age-classes and for different functional speeds (cruising, sustained, and darting). Swimming ability also depends upon a number of biological and physical factors, including the physical condition of individual fish; water quality parameters, such as dissolved oxygen concentration and water temperature; and ambient lighting conditions. For example, swimming effort may be reduced by 60% at oxygen levels that are one-third of saturation, and temperatures above and below the optimum range for any species affect swimming effort (Bell 1991). Adverse temperatures may reduce swimming effort by 50% (Brett et al. 1958).

8.1.3 Experimental Technology

The process to evaluate experimental screening technology is described in Appendix C. Proponents of new, unproven fish passage designs (i.e., designs not meeting the criteria and guidelines contained in this chapter) should provide NMFS with the types of information identified in Section 1.5.

NMFS considers several categories of screen designs that are currently in use to be experimental technologies. These include Eicher screens, modular inclined screens, and Coanda intake screens. Infiltration galleries may be considered an acceptable alternative for excluding fish at water diversions, but these are not considered positive exclusion barriers. Therefore, they are not addressed in this chapter. Information on the design and use of infiltration galleries is presented in Appendix B. The design and use of experimental technologies may be considered on a case-by-case basis through discussions with NMFS and in accordance with the procedures outlined in Appendix C.

8.2 Existing Fish Screens

8.2.1 General

If a fish screen was constructed prior to the date of this document, but in accordance with the NMFS criteria that were established on August 21, 1989, or later, NMFS considers these screens to be compliant provided that all of the following conditions have been met:

- *The entire screen facility functions and is operated as designed.*
- *The entire screen facility has been maintained and is in good working condition.*

- *When screen material wears out, it is replaced with screen material meeting the current criteria stated in this chapter (Section 8.5.8). To comply with this condition, structural modifications may be required to retrofit an existing facility with new screen material.*
- *Mortality, injury, entrainment, impingement, migration delay, or other harm to anadromous fish caused by the facility has not been observed.*
- *Emergent fry are unlikely to be located in the vicinity of the screen, as agreed to by NMFS biologists familiar with the site.*
- *When biological uncertainty exists, access to the diversion site by NMFS is permitted by the owner or operator of the facility for verification that the criteria in this chapter are being met.*

8.3 Project Design Review

The most effective approach to designing fish screening and bypass projects is to have NMFS included in all phases of the design. This can occur by having NMFS participate in a technical advisory team convened for the project or having NMFS review and comment on project designs, or both. While both the preliminary and final designs should be developed in cooperation and interaction with engineering staff from NMFS WCR Environmental Services Branch (Section 3.2), it is especially important that NMFS be involved in the preliminary design phase of a project. This is to ensure that the design parameters needed to produce a functional fish passage project are established early in the design process.

The project design process is most efficient when design criteria are identified and accepted by NMFS while a project is in its infancy. The entire project design development process and information typically required for a preliminary design are discussed in Chapter 3.

8.4 Structure Placement

All screen facilities should be designed to function properly and protect fish from being entrained into the water diversion throughout the full range of hydrologic conditions expected to occur at the location.

For in-stream facilities, the full range of conditions is normally from the minimum stream flow during which water diversions may take place, up to a 100-year flood event. In situations where streambanks will overtop allowing flow into the canal outside of the screen area at flows lower than the 100-year flood event, the screen may be designed to resist overtopping up to the lower flows. NMFS may require the facility operator to capture and relocate fish that become stranded behind a fish screen.

8.4.1 In-Stream Installations

Where it is physically practical and biologically desirable to do so, the fish screen should be constructed at the point of water diversion, and the screen face should be oriented parallel to the streamflow.

Several physical factors may preclude a fish screen from being located and constructed at the water diversion. These include excess channel gradient; the potential for large debris to

damage the screen facility; access for personnel and equipment to conduct facility maintenance, operations, and repair; unsuitable soils for constructing a fish screen facility at the point of diversion; and the potential for heavy sediment accumulations.

Depending on site-specific conditions, in-stream screens may be subject to increased damage by debris. However, they typically offer the following advantages:

- They do not require a formal bypass system.
- They keep migrating fish in the streamflow.
- They may reduce fish proximity to the screen face.

8.4.1.1 Bankline screens

For screens constructed at the edge of a stream (Figures 8-1 through 8-3), the screen face should be aligned with the adjacent bankline, and the transition between the native streambank and the fish screen face should be shaped to minimize turbulence and eddying in front, upstream, and downstream of the screen. For inclined, flat plate screen designs, the screen angle should not be greater than 45 degrees from vertical, and the top of the screen should be submerged a minimum of 1 foot at low stream design flow. The design should also minimize any adverse alteration of riverine and riparian habitat.



Figure 8-1. Aerial view of the Garden City-Lowden 2 water diversion on Walla Walla River near Touchet, Washington (Notes: River flow is from left to right. The bankline screen is located at the head end of the canal, just upstream of the spillway and adult ladder exit.)



Figure 8-2 Bankline screens at the Garden City-Lowden 2 diversion on the Walla Walla River near Touchet, Washington, under construction



Figure 8-3 Bankline vertical flat plate fish screen sized for 3,000 ft³/s (Glenn-Colusa Irrigation District) along the Sacramento River in California (Note: the screen is shown in operation (left) and during construction (right).)

8.4.2 In-Canal Installations

All screen facilities installed within canals should include an effective fish bypass system (Section 8.6) to collect and transport screened fish safely back to the river with minimum delay (Figure 8-4). In instances where the returned bypass flow represents a substantial proportion of the remaining instream flow downstream from the water diversion, the bypass outfall should be placed as close to the point of diversion as practicable to minimize the length of the dewatered stream channel.

Where installation of fish screens at a diversion entrance is not desirable or is deemed impractical, the screens may be installed at a suitable location in the canal downstream of the water diversion. Locating the bypass outfall as close to the point of diversion as possible reduces the length of dewatered stream channel.

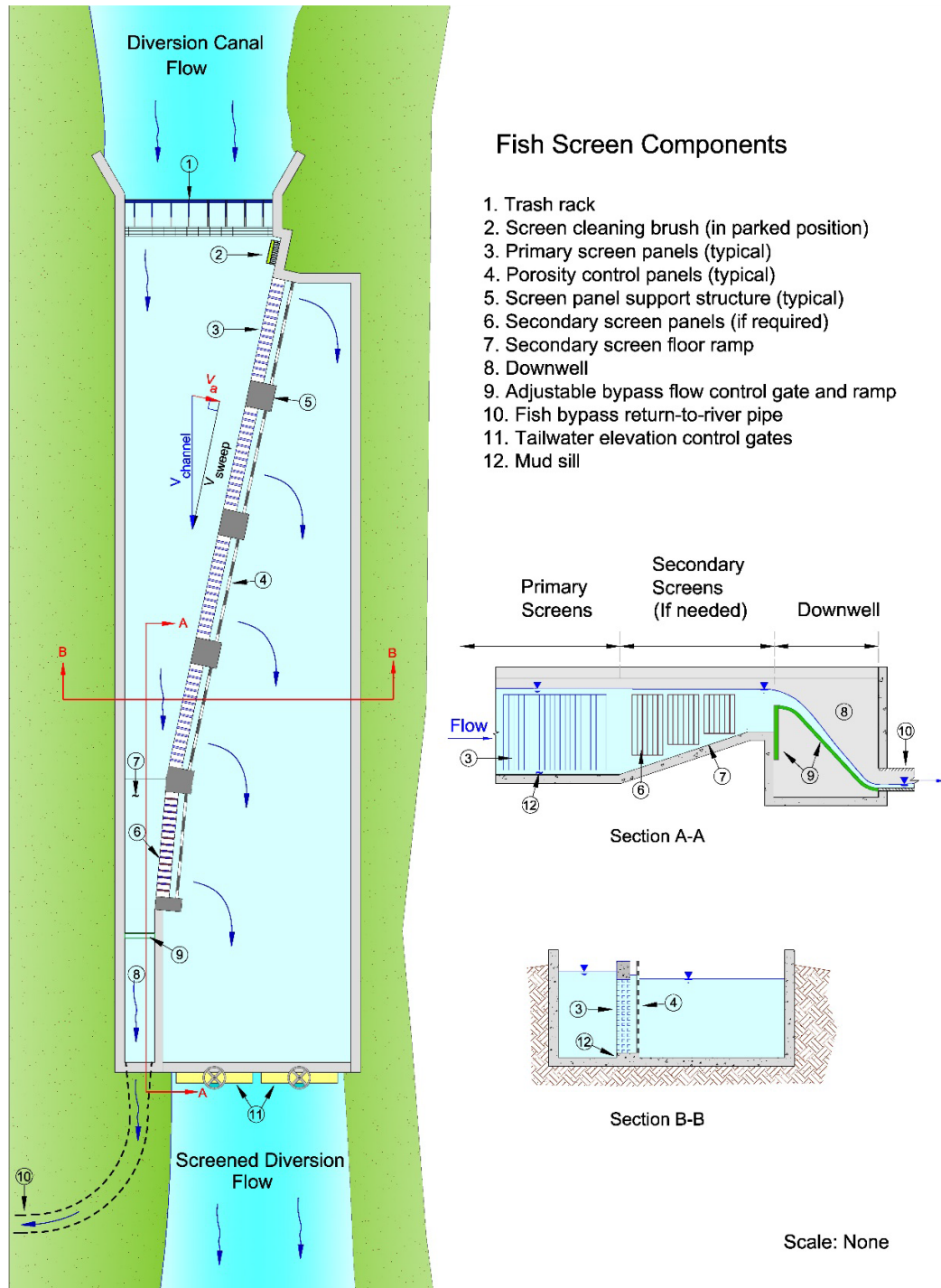


Figure 8-4 Schematic of a typical in-canal fish screen system layout and components at water diversions



Figure 8-5 Vertical plate screen facility under construction in a diversion canal located on the Santiam River near Stayton, Oregon

8.4.2.1 Headworks Control Gates

Canal flow should be controlled with gates located downstream from the screen (Figure 8-4, tailwater control gates). If headworks gates must be used to throttle flow, they should not create a head differential greater than 12 inches. Submerged headworks control gates should be operated fully closed or open at least 12 vertical inches.

Fish can be injured if forced to pass through a small opening created by a partially open headgate. Head drops greater than one foot through gates can prevent bidirectional movement of fish. Higher heads can create high water velocities and pressure differentials that may injure fish from shear stresses or impacts with hard surfaces.

8.4.2.2 Headworks trash rack

All in-canal screens should have a trash rack at the canal headworks to minimize the amount of debris that will reach the fish screen structure (Bell 1991). Trash racks should have openings that are at least 10 inches wide for Chinook salmon passage and 8 inches wide for all other salmonid species.

Additional trash rack design criteria are provided in Section 5.8 of this document. Bell (1991) recommends that openings be 12 inches wide for large salmon.

8.4.3 Lakes, Reservoirs, and Tidal Areas

Intakes in lakes, reservoirs, and tidal areas should be located offshore where feasible to minimize shoreline-oriented fish from coming into contact with the facility. When possible, intakes should be located in areas with sufficient ambient velocity to minimize sediment

accumulation in or around the screen. Intakes in reservoirs should be at an appropriate depth to reduce the number of juvenile salmonids that encounter the intake.

The appropriate depth for intakes in lakes, reservoirs, and tidal areas will be determined on a case-by-case basis. One factor that will be considered when locating these intakes is that although juvenile salmonids are surface oriented, they may congregate in colder water located at depth if surface waters are too warm.

8.4.3.1 Required submergence

For facilities in lakes, reservoirs, and tidal areas, the facility should be placed such that the screen area is adequately submerged to meet the design approach velocity criterion at the historical low water conditions (Section 8.5.7).

8.5 Screen Design Specifications

8.5.1 Approach Velocity

The design approach velocity for active screens should not exceed 0.4 ft/s for fish screens where exposure time is limited to less than 60 seconds, or 0.33 ft/s where exposure time is greater than 60 seconds (Smith and Carpenter 1987; Clay 1995). The design approach velocity for passive screens, as described in Section 8.5.6, should not exceed 0.2 ft/s (Cech et al. 2001).

For the purposes of this document, approach velocity, “ V_a ” in Figure 8-4, is defined as the water velocity component normal (perpendicular) to the screen surface. The minimum amount of screen area required is calculated by dividing the maximum diversion rate (in ft^3/s) by the design approach velocity (in ft/s). The porosity of the screen is not considered in the calculation of approach velocity. The operating approach velocity for any fish screen at any diversion rate may be calculated by dividing the current diversion flow rate by the effective screen area (Section 8.5.2).

Exposure time is defined as the time it takes a particle to traverse the length of the fish screen when moving at the speed of the sweeping velocity (Section 8.5.3). The design approach velocity criteria have been shown to minimize juvenile fish contact with, and impingement on, screen materials. This includes the impingement of emergent fry under cold water temperature conditions. (Appendix E provides a discussion of how to measure approach velocity.)

Note that these criteria apply to salmonids. Other species may require different approach velocity standards. For example, in California, the U.S. Fish and Wildlife Service requires that a design approach velocity of 0.2 ft/s be used at locations where Delta smelt (*Hypomesus transpacificus*) are present.

8.5.2 Effective Screen Area

The effective screen area is defined as the total wetted screen area minus the area occluded by major structural elements. The minimum effective screen area required is defined as the maximum screen flow divided by the allowable approach velocity. For rotary drum screens,

the effective screen area is defined as the vertical projection of the wetted screen area minus the vertical projections of the area occluded by major structural elements.

When calculating effective screen area, components (bars and rods) that make up the screen material are not considered to be “major structural elements” as long as the screen porosity remains greater than 27% when considering those structural elements. Major structural elements are elements of the facility that support the screen panels or cylinders.

8.5.3 Sweeping Velocity

The design sweeping velocities should never be less than the design approach velocity and should not decrease along the length of the screen.

Sweeping velocity is defined as the water velocity component parallel to the face of a fish screen (Figure 8-4). A swift sweeping velocity may help move fish and debris past the fish screen and reduce the chance of impingement of juvenile salmonids on the screen material (Cech et al. 2001). Based on laboratory studies, (Cech et al. 2001) a high sweeping velocity (2 ft/s) minimized juvenile Chinook salmon contacts with screens during daylight conditions and maximized downstream passage during day and night conditions. Sweeping velocities between 0.8 and 3 ft/s are generally considered to be optimal. Higher sweeping velocities may be desired to prevent fish from swimming upstream out of the fish screen forebay.

8.5.3.1 In-canal screens

In-canal screens should be angled across the canal to provide a sweeping velocity within the optimal range for the entire range of design conditions (Clay 1995). For screens shorter than 6 feet in length, the screen may be arranged perpendicular to canal flow. The sweeping velocity should remain constant or increase, but may not accelerate faster than 0.2 feet per second per foot (ft/s/ft) toward the bypass entrance.

Studies show juvenile salmonids may resist entering a bypass system when encountering a sudden acceleration in water velocity (Haro et al. 1998). The acceleration criterion is designed to gradually guide fish toward and into the bypass entrance.

In some situations, angling of the screen for sweeping velocity optimization may best be accomplished using a vee-shaped arrangement, as shown in figure 8-5.

Brett and Alderdice (1953), as referenced in Clay (1995), recommend a uniform acceleration rate of no more than 0.1 ft/s/ft of length.

8.5.3.2 On-river screens

Designers have less control over sweeping flow for screens built in a river or on the bank of a river; however, designers should make every attempt to ensure that sweeping velocity does not decrease along the length of the screen. This is to encourage fish to move past the facility and reduce the chance that sediment will deposit along the length of the screen.

8.5.3.3 Quiescent and tidal areas

To mitigate for a lack of sweeping velocity in quiescent and tidal areas, designers should use a design approach velocity not greater than 0.33 ft/s when calculating the effective screen area.

Fish screens in lakes and tidal areas usually cannot meet the sweeping velocity criteria for in-canal or on-river screens. A lower approach velocity is required for these types of screens to allow fish to volitionally swim away from the screen face.

8.5.4 Flow Distribution

The screen design should provide for nearly uniform flow distribution over the screen surface, thereby minimizing approach velocity over the entire screen face. The designer should demonstrate how a uniform flow distribution will be achieved. The maximum deviation from the target design approach velocity is 10%.

Achieving a uniform flow distribution eliminates localized areas of high velocity that have the potential to impinge fish and debris. Methods that could be used to achieve uniform flow distribution include incorporating porosity control features on the downstream side of screens that can be adjusted and training walls to direct flow into the design. Large facilities may require hydraulic modeling to identify areas of flow distribution that are of concern to NMFS.

8.5.4.1 Porosity controls

To ensure uniform flow distribution, most screens should be equipped with some form of tunable porosity controls (i.e. baffles) placed immediately behind the screen. Screen porosity controls should be tuned to achieve approach velocity criteria at the earliest opportunity available. For screens greater than 10 feet tall, NMFS may require that the baffles be capable of controlling flow through the lower parts of screen panels independently of the upper parts. The use of louver-style porosity control baffles should be limited to flat plate screens 6 feet in height or shorter.

A fish screen facility equipped with adjustable baffles to distribute flow uniformly over all wetted screen area is not considered complete until it undergoes a hydraulic evaluation to adjust the baffles. NMFS will determine one or more operating scenarios under which the hydraulic evaluation should take place. For most facilities, hydraulic evaluations should take place at or near the maximum diversion rate but there are cases where a lower diversion rate may be justified. In rare cases, a hydraulic evaluation may be required at two or more operating scenarios to account for various operating conditions such as, but not limited to, the following examples:

- A possible worst-case scenario for a fish screen may be when head waters are too low to submerge all screen area. In such cases, the fish screen hydraulics may need to be studied at a low water condition under a reduced diversion rate.
- At a high-water condition under the full diversion rate.
- At a low water condition under the full diversion rate.

The most common porosity control devices used to date have been louvers, where the angle of the louver can be varied to control the quantity of water flowing through the screen in front of the louver. However, it has been shown that it can be difficult to achieve uniform flow when using louver baffles (e.g., AECOM 2009). A newer method provides a more effective means of tuning screen velocity and flow distribution. It consists of sliding, overlapping porosity plates that are in contact with each other (Figure 8-6). As the moveable plate (vertically adjustable slotted plate; Figure 8-6) is adjusted, it obscures a progressively larger percentage of the perforations of the fixed plate (the stationary slotted plate; Figure 8-6). These panels (baffles) are typically installed in sections no greater than 2 feet wide, which provides fine-scale porosity adjustments for the screen as a whole. Porosity plates with square or slotted openings provide linear adjustability unlike porosity plates with circular openings (i.e., the change in porosity is linearly proportional to the distance the adjustable plate is moved). The adjustable and stationary slotted plates (parts 2 and 3, respectively, in Figure 8-6) should be of the same material or of different materials with similar coefficients of thermal expansion to maintain relative positioning over a range of temperatures. Ultra-high-molecular-weight (UHMW) polyethylene has a high coefficient of thermal expansion and should not be paired with aluminum or steel for this purpose. Using UHMW for both panels works well as the two sheets will slide easily and prevent leakage between sheets, but both panels should be manufactured under identical conditions to ensure holes align well. Metal panels may warp during fabrication which may prevent the panels from mating well.

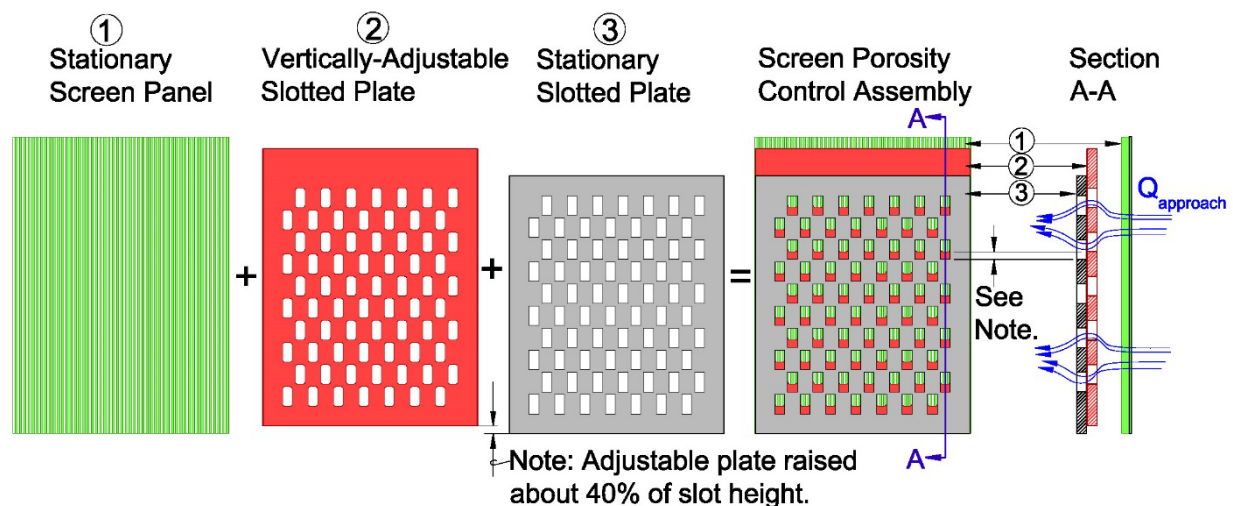


Figure 8-6 Schematic diagram of sliding, overlapping porosity plates used to control porosity and achieve uniform flow conditions through fish screens

8.5.5 Active Screen Cleaning Systems (Active Screens)

All new fish screens should incorporate an automated cleaning system unless the project meets the requirements for passive screens listed in Section 8.5.6.

8.5.5.1 Screen cleaning systems (in-canal or on-river screens)

Screen cleaners should be capable of removing debris from the entire screen surface at least once every 5 minutes and should be operated as required to prevent debris accumulation. Cleaning systems should be designed to operate continuously or on an adjustable timer. On larger screens, the cleaning system should also be triggered whenever the head differential across the screen exceeds 0.3 foot over the clean screen condition. The cleaning system and operations protocol should be effective, reliable, and satisfactory to NMFS. Physical cleaning systems that use a travelling brush or wiper should provide a means for the brush to move away from the screen face at the downstream end of brush travel to allow for the release of accumulated debris.

Fish screens operate most efficiently when they are clean and free of impinged material and attached growth such as algae or sponges (Bell 1991). Fish screen material with a porosity of about 50% will result in negligible head loss at the design approach velocity values identified in Section 8.5.1. Head loss across a screen due to impinged debris increases with the loss of screen open area at a geometric rate (BOR 2006). With increasing head loss, the force impinging debris (or fish) on the screen material also increases, making cleaning the screen more difficult. A screen experiencing 0.3 foot of head loss under an operating approach velocity of 0.4 ft/s may have less than 10% open area due to debris impingement. Under this condition, any weak-swimming fish coming in contact with the screen would experience injury or death due to the excessive forces acting on its body. Additionally, the water diversion would begin to experience significant reduction in diversion rate, and the facility could experience structural damage. Systems to monitor head differential across a screen should be designed to distinguish head loss due to debris impingement from loss caused by wave action or other transient disturbances.

Automated screen cleaning systems are generally categorized as physical, hydraulic, or pneumatic. Physical cleaning systems use a brush or other wiper device to physically remove impinged debris and attached growth and have a long history of successful deployments. NMFS recommends the use of a physical cleaning system for most screen applications; however, there are instances when a hydraulic or pneumatic cleaning system may be more practical.

Hydraulic cleaning systems use high-pressure water jets to remove debris from the screen face and rely on a current (or trash removal systems in the case of traveling belt screens) to remove debris from the vicinity of the screen facility. However, hydraulic cleaning systems do not remove attached growth as effectively as physical cleaning systems and may stimulate the growth of some types of algae.

Pneumatic cleaning systems use compressed air to lift debris from the screen face and rely on a current to remove debris from the vicinity of the screen facility. Pneumatic cleaning systems provide a cleaning force by displacing water primarily in the upwards direction; therefore, air burst cleaning systems in horizontal cylindrical screens may not remove debris impinged on the bottom of those screens. Pneumatic cleaning systems cannot completely remove attached growth and may stimulate the growth of some types of algae. If a screen material were to become occluded with attached growth, the compressed air can impart tremendous buoyant forces on the screen material and the facility overall. Screens employing a pneumatic cleaning system should consider the buoyancy force of trapped air when designing facility foundation and

structural components. An additional problem faced by pneumatic cleaning systems is that they are frequently undersized and cannot provide the required volume of air to clean the entire screen face. This is exacerbated by the tendency for the air bubbles to take the path of least resistance, which can often be the clean portions of the screen. Because pneumatic cleaning systems only lift debris from a screen, adequate sweeping flow should be present to move debris downstream away from the water intake.

8.5.5.2 Screen cleaning systems for screens in quiescent and tidal areas

At locations that do not have sufficient sweeping velocity, fish screens should be equipped with an automated cleaning system that is capable of removing debris from the body of water, rather than one that may merely push debris to one side or the other.

Effective cleaning systems rely on the sweeping flow, sometimes combined with the mechanical action of the cleaner, to carry the debris downstream and away from the screen face. Cleaning systems that merely push debris to the side of the screen face are inappropriate for low-velocity locations. This is because without a means to collect and remove debris, the debris lifted from the screen face is likely to become impinged again on the screen face. Additional measures are recommended in these situations to keep floating debris away from the face of a fish screen. Cleaning systems that push debris to the side of a screen are best suited for situations where sweeping flow is present that will carry any debris away from the screen.

8.5.6 Passive Screens

A passive screen, meaning a screen without an automated cleaning system, may only be used when all of the following criteria are met:

- *The combined rate of flow at the diversion site is less than 3 ft³/s.*
- *Sufficient ambient river velocity exists to carry debris away from the screen face.*
- *The site is not suitable for an active screen.*
- *Uniform approach velocity conditions exist at the screen face, as demonstrated by laboratory analysis or field verification.*
- *The debris load is low.*
- *A maintenance program exists that is approved by NMFS and implemented by the water user.*
- *The screen is frequently inspected, and debris accumulations are removed as site conditions dictate.*
- *For cylindrical screens, sufficient stream depth exists at the site to provide a water column of at least 1 screen radius around the screen surface.*
- *The screen is designed to be easily removed for maintenance and to protect it from flood events.*

8.5.7 Screen Submergence and Clearance

Fish screens should be submerged sufficiently to maintain adequate wetted screen area to meet the approach velocity design criterion whenever the diversion is in operation; additional submergence is required in some circumstances.

Effective screen area will be reduced if screen area becomes exposed due to a drop in the water surface. (Section 8.5.2) Under this condition the diversion rate should be adjusted and maintained such that the operating approach velocity does not exceed the design approach velocity criteria at any given time.

8.5.7.1 Vertical flat plate screens

Fish screen facilities with flat, vertical screen panels, or panels inclined less than 20 degrees from vertical, should be designed to remain fully submerged over the entire range of expected water surface elevations. Facility designs may allow for vertical screen panels, or panels inclined less than 20 degrees from vertical, to become partially exposed when water surface elevation is lowered so long as the operating approach velocity does not exceed the design approach velocity.

8.5.7.2 Inclined flat plate screens

Fish screen facilities with flat plate screens installed at an incline of more than 20 degrees but less than 45 degrees from vertical should be designed to remain fully submerged over the entire range of expected water surface elevations. The top of the screen should be submerged a minimum of 1 foot at low stream design flow.

The tops of inclined flat plate screens need to be sufficiently submerged at low stream design flow to prevent hydraulic conditions from forming at the interface between the screen and the water surface that could trap and impinge debris and fish.

8.5.7.3 Rotary drum screens

For rotary drum screens, the design submergence should be between 65% and 85% of the drum diameter. In many cases, stop logs may need to be installed downstream of the drum screens to achieve the design submergence criteria. The stop logs should be located at least two drum diameters downstream from the back of the drum.

Submergence levels greater than 85% of the drum diameter increase the possibility of entrainment over the top of the screen, fish impingement on the screen, and the subsequent entrainment of any fish impinged on the narrow screen area above the 85% submergence level due to the almost horizontal angle of impact of surface-oriented fish. Submergence levels that are less than 65% may reduce the self-cleaning capability of the screen due to the inability of material to temporarily adhere to the screen face and be carried over the top of the screen. Clay (1995) recommends that submergence be between 66% and 75% of the screen diameter. Examples of rotary drum screens are shown in Figures 8-7, 8-8, and 8-9.



Figure 8-7 Large-sized rotary drum screen at the Sunnyside Canal located on the Yakima River near Yakima, Washington

(Note: The person standing upstream of a drum and an intermediate bypass entrance. Water flow direction is from the foreground to the background of the photograph.)



Figure 8-8 Medium-sized rotary drum screen at the Burlingame Diversion located on the Walla Walla River near Walla Walla, Washington



Figure 8-9 Rotary drum screens installed in a water diversion canal and operated (i.e., powered) by paddle wheels

8.5.7.4 Cylindrical screens

Cylindrical screens (other than rotary drum screens) should be submerged to a depth of at least 1 screen radius below the minimum water surface and have a minimum of 1 screen radius clearance between the screen surfaces and natural or constructed features.

These clearances provide escape routes for fish to avoid the draw of water passing through the screen material.

8.5.7.5 End-of-pipe screen submergence and clearance

All end-of-pipe screens should have adequate submergence below the water surface and adequate clearance from the streambed and any structure to provide an escape route for fish approaching the screen. For cylindrical-shaped screens, 1 screen radius or 6 inches, whichever is greater, is normally adequate submergence and clearance.

Submergence and clearance requirements for screens with other shapes will be determined by NMFS on a case-by-case basis. An example of an end-of-pipe screen is shown in Figure 8-10.



Figure 8-10 Typical end-of-pipe screen equipped with “wagon wheels” to elevate the screen off the stream bottom

8.5.7.6 End-of-pipe screen design

All end-of-pipe screens should meet the approach velocity criteria described in Section 8.5.1 and should be located in areas with sweeping velocities great enough to aid in moving fish and debris away from the intake. All end-of-pipe screens should be oriented to take maximum advantage of sweeping velocity in moving fish and debris away from the screen face.

For the purposes of this document, an end-of-pipe screen is defined as a fish screen of any shape that may be attached to the end of a pipe or hose.

8.5.7.7 Horizontal flat plate screens

Design criteria specific to horizontal screens are provided in Section 8.8.

8.5.7.8 Conical screens

Design criteria specific to cone screens are provided in Section 8.9.

8.5.8 Screen Material

Screen materials should be corrosion-resistant and sufficiently durable so as to maintain a smooth, uniform surface over the course of long-term use. Perforated plate surfaces should be smooth to the touch, with the openings punched through in the same direction as the water flow.

Screen materials commonly used include stainless steel, aluminum, plastic, and antifouling alloys containing copper and other metals.

8.5.8.1 Opening size

The maximum screen opening allowed is based on the shape of the opening:

- *Circular screen face openings should not exceed 3/32 inch in diameter (Neitzel et al. 1990a).*
- *Slotted screen face openings should not exceed 0.069 inch (1.75 millimeters [mm]) in the narrow direction (Mueller et al. 1995).*
- *Square screen face openings should not exceed 3/32 inch as measured on a diagonal (Neitzel et al. 1990b).*

8.5.8.2 Open area

The percent open area (porosity) for any screen material should be at least 27%.

8.5.8.3 Gaps

Screens and associated civil works that are exposed to fish should be constructed such that there are no gaps greater than 0.069 inch (1.75 mm). For traveling belt screens or other screens with moving screen material, screen seals should be sufficient to prevent gaps larger than 0.069 inch (1.75 mm) from opening during screen operations.

Clay (1995) notes that care is required in the construction, adjustment, and operation of rotary drum screens. The drum should be fitted carefully in the box to eliminate spaces around the edges that are larger than the openings in the screen mesh.

8.5.9 Civil Works and Structural Features

8.5.9.1 Smoothness

All concrete and steel surfaces, including edges and corners, in areas fish have access to should be smooth to the touch and free from burrs and sharp edges. These can injure fish or people that come in contact with the structure.

8.5.9.2 Pressure differential protection

Larger fish screen structures should be equipped with fail-safe systems that protect the structure from large pressure differentials across the screen face, should the screen become plugged. If a fail-safe system is tripped, the diversion operation should cease until the system can be reset and protection from entrainment into the diversion is restored.

The fail-safe systems installed so that the structural integrity of the facility is never compromised may include governors that reduce the water diversion rate when the pressure differential exceeds a given value. Fused blow-out panels, slide gates, and pressure relief valves may also be acceptable solutions for preventing excessive pressure differentials that can result in screen facility failure.

8.5.9.3 Placement of screen surfaces

The face of all screen surfaces should be placed flush with any adjacent screen bay, pier noses, and walls to the greatest extent possible.

This is needed to allow fish to have unimpeded movement parallel to the screen face and unobstructed access to bypass entrances and routes.

8.5.9.4 Structural features

Structural features should be provided to protect the integrity of fish screens from large debris and to protect the facility (Bell 1991).

A trash rack, log boom, sediment sluice, and other measures may be required to protect the structural integrity of a fish screen, especially for on-river screens.

8.5.9.5 Civil works

The civil works should be designed in a manner that prevents undesirable hydraulic effects, such as eddies and stagnant flow zones, that may delay or injure fish or provide predator habitat or openings that allow predators to access the facility.

8.5.9.6 Canal dewatering and fish salvage

For in-canal screens, the floor of the screen civil works should be designed to allow fish to be routed back to the river safely when the canal is dewatered. An acceptable fish salvage plan should be developed in consultation with NMFS and included in the O&M plan.

Canal dewatering and fish salvage may be accomplished via the bypass system or by using a small gate and drain pipe, or similar provisions, to drain all flow and fish back to the river. The operations and maintenance plan should address the rate at which water can be drained back to the river to allow fish to move volitionally to the river to minimize stress. Trained personnel should be on site to rescue stranded fish. A rescue plan may need to consider collect lamprey larvae (ammocoetes) that may be living in sediments deposited in a diversion canal, and possibly even in sediments behind a fish screen.

8.6 Bypass Systems

Bypass systems are required for in-canal screens to provide a safe and efficient means of routing fish from the area in front of in-canal screens to the stream from which they were diverted.

8.6.1 Bypass Design

Bypass systems should work in tandem with the fish screens to move all fish present (target and non-target species and all life stages) from the area in front of the screens and return them back to the stream or river (or to a holding pool, in the case of collection and transport facilities) with a minimum of injury and delay (Clay 1995).

8.6.2 Bypass Entrance

The bypass entrance should be located at the downstream terminus of the fish screens and should be designed to allow downstream migrants to easily locate and enter the bypass (Clay 1995). The screen and any guidewalls should naturally funnel downstream migrants and flow to the bypass entrance. For screens that are less than 6 feet in length and are constructed perpendicular to canal flow, the bypass entrance(s) may be located at either end (or both ends) of the screen.

8.6.2.1 Flow control

Each bypass entrance should be capable of controlling the flow rate through that entrance. If an orifice plate is used, the opening should have smooth, rounded-over edges and the opening should be large enough to safely pass the largest fish that may be entrained into the diversion canal. For steelhead kelts, the opening should be at least 8 inches in the smallest dimension.

Typically, an overflow weir is used to regulate flow through the entrance. Orifice plates are discouraged from being used because they may hinder fish from moving into the bypass and they are more likely to clog with debris.

8.6.2.2 Minimum velocity

The minimum bypass entrance flow velocity should be greater than 110% of the maximum canal velocity upstream from the bypass entrance. At no point may flow decelerate along the screen face or in the bypass channel. Bypass flow amounts should be of sufficient quantity to ensure these hydraulic conditions are achieved whenever downstream passage is required.

8.6.2.3 Lighting

Lighting conditions upstream of a bypass entrance should be ambient and extend downstream to the structure or device controlling bypass flow. In situations where transitions from light to dark conditions or vice versa cannot be avoided, they should be gradual or occur at a point in the bypass system where fish cannot escape the bypass and return to the canal (i.e., at a location where bypass flow velocity exceeds fish swimming ability).

8.6.2.4 Dimensions

For diversions greater than 3 ft³/s, the bypass entrance should extend from the floor of the canal to the water surface and be at least 18 inches wide (Ruggles and Ryan [1964] as cited in Clay [1995]). For diversions of 3 ft³/s or less, the bypass entrance should be a minimum of 12 inches wide. The bypass entrance should be sized to accommodate the entire range of bypass flow, utilizing the criteria listed in Section 8.6.

8.6.2.5 Weirs

For diversions greater than 25 ft³/s and where weirs are incorporated into the bypass entrance, the minimum water depth over the weir is 1 foot; however, a depth of 1.5 feet over a weir is preferred. Similarly, weir width should be a minimum of 1.5 feet; greater widths are preferred.

Juvenile outmigrating salmonids appear to be less reluctant to go over a weir when water depth over the weir is greater than 1 foot (Manning et al. 2005). As a general rule and based on field observations, NMFS believes that water depth over a weir should be at least 1 foot, but if additional flow is available, a depth of 1.5 feet or even 2 feet is preferred. Manning et al. (2005) reported significantly faster travel times for steelhead moving through a dam forebay when the crest of an inflatable spillway was deformed and water depth and velocity over the spillway were increased. Water depth increased from 0.13 foot to 2.4 or 3 feet, and water velocity increased from 0.2 ft/s to 3.9 or 4.6 ft/s during test replicates. Also, wider passageways are preferred; the recommended minimum width is 1.5 feet.

8.6.2.6 Intermediate bypass entrances

The fish screen design should include intermediate bypass entrances if the design approach velocity is greater than 0.33 ft/s and the sweeping velocity may not convey fish to a terminal bypass entrance within 60 seconds, assuming that fish are transported along the length of the screen face at a rate equal to the sweeping velocity.

Clay (1995) notes that if the screen is extremely long, it may be advisable to place bypass entrances at intervals across the face.

8.6.2.7 Training walls

All intermediate bypass entrances should have a training wall to guide fish into the bypass system.

8.6.2.8 Flow acceleration

All bypass entrances should be designed to gradually accelerate flow into the bypass entrance and between the entrance and the flow control device at a rate not to exceed 0.2 ft/s per linear foot.

Juvenile salmonids have been observed to resist moving with water flow that accelerates too quickly (Haro et al. 1998). Brett and Alderdice (1953), as referenced in Clay (1995), recommend a uniform acceleration rate of no more than 0.1 ft/s per linear foot.

8.6.2.9 Secondary dewatering screens

Secondary dewatering screens should meet all design criteria (e.g., approach velocity, sweeping velocity, cleaning, and screening material) of the primary screens.

Secondary dewatering screens may be used within the bypass system to reduce bypass flow.

8.6.3 Bypass Conduit and System Design

8.6.3.1 Bypass conduit

Depending on the site-specific conditions, the bypass conduit can be either U-shaped flume or round pipe.

8.6.3.2 Surface smoothness

The interior surfaces and joints of bypass flumes or pipes should be smooth to the touch to provide conditions that minimize turbulence, the risk of catching debris, and the potential for fish injury.

Pipe joints may be subject to inspection and approval by NMFS prior to completion of the bypass. Every effort should be made to minimize the length of the bypass pipe while meeting the hydraulic criteria listed in Sections 8.6.3.4 through 8.6.3.6.

8.6.3.3 Bypass pipe diameter

The minimum bypass pipe diameter is 10 inches.

The bypass flume or pipe diameter is a function of the bypass flow and slope, and the diameter incorporated into the bypass pipe design should achieve the velocity and depth criteria identified in Sections 8.6.3.5 and 8.6.3.6. Bypass flume or pipe hydraulic characteristics should be calculated to determine a suitable pipe diameter.

8.6.3.4 Bypass flow rate

The minimum design bypass flow is 5% of the total diverted flow rate unless otherwise approved by NMFS.

While the minimum bypass flow is 5% of the total diverted, larger bypass flow proportions will aid in cleaning the fish screen and will guide fish toward the bypass system more quickly.

8.6.3.5 Bypass velocity

Water velocity in the bypass conduit should be between 6 and 12 ft/s for the entire operational range of bypass flow, and should always be greater than 2 ft/s. If higher velocities are approved by NMFS, special attention to pipe and joint smoothness should be demonstrated by the design.

Bypass systems with velocities that are less than 2 ft/s can accumulate sediment deposits within the bypass system.

8.6.3.6 Water depth

The design minimum depth of free surface flow in a bypass pipe should be at least 40% of the bypass pipe diameter unless otherwise approved by NMFS.

8.6.3.7 Closure valves

Closure valves cannot be used within the bypass system unless specifically accepted by NMFS.

8.6.3.8 Pumps

Fish should transition through bypass system components via gravity flow and never be pumped. Use of a pump would only be acceptable if NMFS required the installation of a bypass where insufficient head was available to support gravity flow.

8.6.3.9 Downwells and flow transitions

Downwells should be sized based on an EDF between 8 to 10 ft-lb/ft³/s. Fish should never free-fall within a bypass system pipe or enclosed conduit. Downwells should be designed to produce a free water surface when turbulence, geometry, and alignment aspects of the design are considered.

Equation 8-1 should be used to calculate downwell volume.

$$V = \frac{(\gamma)(Q_{bypass})(H)}{EDF} \quad (8-1)$$

where:

- V = pool volume (ft³)
- γ = unit weight of water (62.4 lb/ft³)
- Q_{bypass} = bypass flow, in ft³/s
- H = height of drop between water surfaces, in feet
- EDF = energy dissipation factor, from 8 to 10 ft-lb/ft³/s

8.6.3.10 Pressurized flow

Flow in all types of fish conveyance structures should be open channel (i.e., not pressurized). Bypass systems should be vented or open to the atmosphere. If a pressurized bypass conveyance is required by site constraints, pressures in the bypass pipe should remain equal to or above atmospheric pressures. Transitions from pressurized to non-pressurized conditions within a bypass pipe, and vice versa, should be avoided.

8.6.3.11 Bends

The ratio of bypass pipe center-line radius of curvature (R) to pipe diameter (D), or R/D, should be greater than or equal to 5. If mitered pipe fittings are used to change conveyance direction, the maximum miter angle allowed is 15 degrees (11.25 degrees is preferred). If multiple miter joints are used to change the direction of the conveyance more than 15 degrees,

each miter joint should be separated by length(s) of pipe that are sufficiently long to achieve the required ratio of R/D for the bend assembly as a whole.

In situations that involve super-critical flow velocities, R/D ratios greater than 5 may be required. Bends should be minimized in the layout of bypass systems due to their potential to facilitate debris clogging and produce turbulence.

8.6.3.12 Debris management

Bypass pipes or open channels should be designed to minimize debris clogging, sediment deposition, and facilitate their inspection and cleaning as necessary.

8.6.3.13 Access for maintenance

Access for maintenance inspections and debris removal should be provided at locations in the bypass system where debris accumulations may occur. Bypass systems greater than 150 feet in length should include access ports at appropriate spacing to allow for the detection and removal of debris.

Alternate means of providing for bypass pipe inspection and debris removal may be considered by NMFS.

8.6.3.14 Natural channels and fishways

Natural channels and fishways may be used as a bypass transit channel under limited circumstances and only upon approval by NMFS.

Use of natural channels and fishways as juvenile fish bypasses expose fish to increased delay and predation (compared to a typical bypass system). Use of a natural channel will require that adequate water depth and velocity, flow volume, protection from predation, and good water quality conditions can be provided. The potential for increased predation is typically extremely high for natural channels due to the high concentration of fish in a small amount of flow in the bypass system and area. Additionally, sufficient flow would be required to mitigate for any seepage occurring within the bypass system while maintaining adequate water depth and velocity. If a natural channel is to be used, special consideration needs to be given to where the bypass channel connects to the river.

8.6.3.15 Sampling facilities

Sampling facilities installed in the bypass conduit should not impair the operation of the facility during non-sampling periods in any manner.

Refer to Appendix F for additional information on the design of juvenile fish sampling facilities.

8.6.3.16 Hydraulic jumps

There should be no hydraulic jump(s) within a bypass system.

8.6.4 Bypass Outfalls

8.6.4.1 Location

Bypass outfall locations should meet the following conditions:

- *Bypass outfalls should be located to minimize predation by selecting an outfall location that is free of eddies and reverse flow and does not place bypassed fish into an area of known predator habitat (Bell 1991).*
- *The point of impact for bypass outfalls should be located where ambient river velocities are greater than 4 ft/s when in operation (Shively et al. 1996).*
- *Bypass outfall locations should provide good egress conditions for juvenile fish exiting the bypass and re-entering the stream channel (Bell 1991).*
- *The bypass flow should not impact the river bottom or other physical features at any stage of river flow. Bypass outfalls should be located where the receiving water is of sufficient depth to ensure that fish injuries are avoided at all river and bypass flows.*
- *The bypass outfall should not release fish into areas where conditions downstream from the bypass discharge point will pose a risk of injury, predation, or stranding (Bell 1991). For example, bypass outfalls should avoid discharging fish into areas from which they can enter reaches where flows run subsurface. Also, bypass outfalls should not discharge in the vicinity of any unscreened water diversion or near eddies that may be habitat for predator fish.*

8.6.4.2 Impact velocity

Maximum bypass outfall impact velocity (i.e., the velocity of the bypass flow as it enters the receiving water) should be less than 25 ft/s, including both the vertical and horizontal velocity components (Bell 1991).

Impact velocity may be greater for very large bypass flows that discharge a confined jet that plunges deep into the receiving waters and results in fish deceleration occurring over a longer distance compared to a broader jet not plunging far into the receiving water. For example, Johnson et al. (2003) reported no injuries to juvenile Chinook salmon that were returned to the Columbia River in bypass flow greater than 1,000 ft³/s and when impact velocities ranged up to 50 ft/s.

8.6.4.3 Predation prevention

Predator control systems may be required in areas with a high potential for avian predation.

Predation suppression systems include bird wires (thin wires) strung over the bypass outfall area to prevent predatory birds from flying near the outfall or diving at fish exiting the outfall and high-pressure water spray nozzles over the outfall area to deter birds.

8.6.4.4 Adult fish attraction to bypass discharge

Bypass outfall discharge into the receiving water should be designed to avoid attracting adult fish to the discharge. If the potential exists that adult salmonids may be attracted to and

jump at the bypass outfall discharge, the design of the bypass outfall should include a provision for adult fish to land safely in a zone or location after jumping.

8.7 Water Drafting

Water drafting is the practice of pumping water for short durations from streams or impoundments at low pumping rates to fill water trucks or tanks, often for dust suppression or wildfire management. Water drafting may also be used to dewater a construction site or temporarily divert water around a construction site. When dewatering a construction site an approved dewatering plan should be followed to rescue and relocate stranded fish.

The specifications below are primarily for the protection of juvenile anadromous salmonids in waters where they are known to exist. However, they may also be applied to protect a host of other aquatic organisms.

8.7.1 Water Drafting Operating Guidelines

When engaged in water drafting operations, the following restrictions apply:

- *Operations are restricted to 1 hour after sunrise to 1 hour before sunset.*
- *The pumping rate should not exceed the lesser of 350 gpm or 10% of the streamflow. The operator should measure streamflow prior to initiating pumping to ensure the pumping rate will not exceed 10% of streamflow.*
- *Pumping should be restricted to locations where the water is deep and flowing; pumping from isolated pools should be avoided.*
- *Pumping should not result in a drawdown of the water surface elevation by more than 10% in the area where pumping is taking place nor in any riffles downstream.*
- *Pumping should be terminated when the water truck or tank is full.*
- *An operator should be present during pumping operations and observe stream conditions during pumping to ensure the above restrictions are being met.*
- *A fish screen should be used when pumping. Fish screens should meet guidelines for end-of-pipe screens of this document (Section 8.5.7.5). The operator should be capable of cleaning debris from the fish screen when needed and possess the equipment necessary to do so.*
- *Water drafting truck parked on streambeds, floodplains, or within a riparian corridor should use drip pans or other devices such as absorbent blankets, sheet barriers or other materials as needed to prevent soil and water contamination from motor oil or hydraulic fluid leaks*

8.7.2 Fish Screens for Water Drafting

Design and operation criteria and guidelines for use of fish screens required during pumping operations for water drafting are described in Section 8.7.2.1 through 8.7.2.6.

8.7.2.1 Design

Fish screens for water drafting may be off-the-shelf designs or custom fabricated. The fish screen should be sturdy enough to not compromise the integrity of the screen during pumping when the screen becomes clogged with debris.

The screens may be cylindrical or rectangular in shape as long as the other screen criteria are met.

8.7.2.2 Cleaning

Fish screens for water drafting do not need to have an automated cleaning system; however, an operator should regularly clean the screen during the pumping operation to maintain the minimum amount of screen area that is required to not be occluded with debris.

8.7.2.3 Approach velocity

The design approach velocity should not exceed 0.33 ft/s.

Based on a pumping rate of 350 gpm, the screen for this flow rate should have at least 2.4 ft² of surface area.

8.7.2.4 Uniform flow

Screens should be designed to draw water relatively uniformly over the entire screen area.

Screens may require internal baffles to achieve this criterion.

8.7.2.5 Screen porosity and openings

The screen material should have a porosity of at least 27% and have openings consistent with criteria provided in Section 8.5.8.1. The screen surface should be smooth to the touch.

The size of screen openings depends on the shape of the openings.

8.7.2.6 Screen support and submergence

Fish screens should be supported off the stream bottom by at least 6 inches and be submerged by at least 6 inches (Figure 8-10).

8.8 Special Case: Horizontal Screens

Horizontal flat plate screens operate fundamentally differently than conventional cylindrical and vertically oriented screens. This fundamental difference relates directly to fish safety. When inadequate flow depth exists with vertically oriented screens, the bypass will usually remain operational, and there is only a slight increase in the potential for fish to become impinged on the surface of the screen. In contrast, when the water level on horizontal screens drops and most or all diverted flow goes through the screens, the bypass flow is greatly reduced or ceases completely and there is a high likelihood that fish will become impinged and expire on the screen surface.

8.8.1 NMFS Engineer Involvement

Since site-specific design considerations are required, NMFS should be consulted throughout the development of a horizontal screen design.

NMFS considers horizontal screens to be biologically equivalent to conventional screens if the design and operation of a horizontal screen meets the criteria and conditions listed in Section 8.8.

8.8.2 Design Process

The horizontal screen design process should include an analysis to verify that sufficient hydrologic and hydraulic conditions exist within the stream so as not to exacerbate a passage impediment in the stream channel or in the off-stream conveyance (including the screen facility and bypass system). This analysis should conclude that all of the following criteria can be achieved for the entire fish passage season, as defined in Chapter 2. If the criteria listed here in Section 8.8 cannot be maintained per this design analysis, a horizontal screen design should not be used at the site. If this analysis concludes that the removal of the bypass flow required for a horizontal screen from the stream channel results in inadequate passage conditions or unacceptable loss of riparian habitat, other screen design styles should be considered for the site and installed at the site if the other screen styles will reduce the adverse effects to passage or riparian habitat.

8.8.3 General Criteria

The screen and bypass criteria specified in Chapter 8 apply to horizontal screens. The exceptions to these general criteria are noted in Section 8.8.4.

8.8.4 Specific Criteria

As described in Section 8.8, horizontal flat plate screens are fundamentally different than conventional cylindrical and vertically oriented screens. Specific criteria and guidelines that apply only to horizontal screens are described in Sections 8.8.4.1 through 8.8.4.13.

8.8.4.1 Site limitation

Horizontal screens should be installed in an off-river canal.

Due to the need for very precise hydraulic controls, horizontal screens are not suitable for in-river or in-stream installations.

8.8.4.2 Flow regulation

For a horizontal screen facility to function properly, the site should provide a headgate facility that maintains a water diversion rate that is sufficient and consistent enough to allow the fish screen and bypass system to meet the criteria listed in this section (Section 8.8.4).

8.8.4.3 Channel alignment

Horizontal screens should be installed such that the approaching conveyance channel is parallel to, and in line with, the screen channel (i.e., there is no skew), and uniform flow conditions exist across the upstream edge of the screen. A straight channel should exist for at least 20 feet upstream of the leading edge of the screen, or for a distance of up to two screen channel lengths if warranted by approach flow conditions in the conveyance channel. Horizontal screens should be installed such that a smooth hydraulic transition occurs from the approach channel to the screen channel and there are no areas of abrupt flow expansion, contraction, or separation.

Flow conditions that require a longer approach channel include turbulent flow, supercritical hydraulic conditions, or uneven hydraulic conditions in a channel cross section.

8.8.4.4 Bypass flow depth

The bypass flow should pass over the downstream end of the screen at a depth of at least 1 foot.

8.8.4.5 Bypass flow amount

Bypass flow amounts should be sufficient to continuously provide the hydraulic conditions specified in this section and those specified in Section 8.6. In general, for diversion rates of less than 100 ft³/s, approximately 15% of the total diverted flow should be used as bypass flow. For diversion rates greater than 100 ft³/s, approximately 10% of the total diverted flow should be used for bypass flow. Small horizontal screens may require up to 50% of the total diverted flow be dedicated for bypass flow. The amount of bypass flow should be approved by NMFS.

Bypass flow is used for transporting fish and debris across the plane of the screen and through the bypass conveyance back to the stream.

8.8.4.6 Diversion shut-off

If hydrologic analysis demonstrates that the diverted flow rate could drop below the flow rate required to satisfy the diversion and supply the bypass with its full design flow rate, the horizontal screen design should include a means to automatically shut off the diversion flow or a means to route all diverted flow back to the originating stream.

8.8.4.7 Sediment removal

The horizontal screen design should include a means to simply and directly remove sediment that accumulates under the screen without compromising the integrity of the screen while water is being diverted.

8.8.4.8 Screen approach velocity

Screen approach velocity should be less than 0.25 ft/s and uniform over the entire screen surface area. If the horizontal screen is equipped with an automated mechanical screen cleaning system, screen approach velocity should be less than 0.4 ft/s and uniform over the entire screen surface area.

The best available science regarding horizontal screens is evolving. Therefore, NMFS may require a lower approach velocity or may specify a minimum ratio of sweeping velocity to approach velocity. Recent prototype development has demonstrated that better self-cleaning of a horizontal screen is achieved when the ratio of sweeping velocity and approach velocity exceeds 20:1, and approach velocities are less than 0.1 ft/s.

8.8.4.9 Screen sweeping velocity

Sweeping velocity should be maintained or gradually increase for the entire length of screen. Sweeping velocity should never be less than 2.5 ft/s or an alternate minimum velocity approved by NMFS that is based on an assessment of sediment load in the water diversion system.

Higher sweeping velocities may be required to achieve reliable debris removal and to keep sediment mobilized.

8.8.4.10 Post-construction inspection and testing

Upon completion of screen construction and watering up of the system, velocity testing should be performed to ensure that approach velocity is uniform over the entire screen area. For the purpose of this test, uniform is defined as all test velocities falling between 90% and 110% of the nominal screen approach velocity. Sweeping velocity should also be verified to be in a uniformly downstream direction to ensure that fish and debris are bypassed rapidly.

8.8.4.11 Monitoring and maintenance

Daily inspection and maintenance (if required) should occur on the screen and bypass system to maintain operations consistent with these criteria.

8.8.4.12 Post-construction monitoring

Post-construction physical and operational monitoring of all components of new horizontal screen facilities should occur for at least the first year of operation and cover all periods of operation.

8.8.4.13 Inspection log

An inspection log should be kept for each horizontal screen. A copy of the inspection log should be provided annually to the NMFS design reviewer upon request, who will review the inspection log and may make recommendations for the next year of operation. The inspection log should include:

- *Inspection dates, times, and the observer's name*
- *Water depth at downstream end of the screen (i.e., the entrance to the bypass)*
- *Debris present on the screen, including any sediment retained in the screen openings*
- *Fish observed on or passing over the screen surface*
- *Operational adjustments and maintenance performed on the facility*

8.9 Special Case: Conical Screens

Conical (or cone) screens were developed for small water diversions in shallow tidal areas. They have been installed on pumped and gravity diversions since 1996. The conical shape provides a large amount of screen area in a small footprint (Figure 8-11). The screen units sit on a constructed steel or concrete platform connected to a diversion pipe. They have rotating brush cleaning systems that are driven by hydraulic or electric motors, some of which run off batteries charged by solar panels. Turbine-driven units, where the cleaning system is driven by a propeller installed in the conveyance pipe and mechanically connected to the cleaning system through a large gear reducer, have been used successfully in a few cases. For turbine-driven units, screen cleaning does not occur unless water is being diverted. A turbine-driven cleaning system may not be appropriate for seasonal use unless the units are removed seasonally.



Figure 8-11 Conical screen

Conical screens were designed for use on inverted siphons in tidal areas where the screen units would be partially exposed at lower tides. Because they were used only on siphons, as the source water stage decreased on an ebb tide and screen area became exposed, the rate of diversion decreased proportionally so the operational approach velocity never exceeded the design approach velocity. As a side benefit, the daily exposure to air and sunlight helped keep the screen surface free of algal growth.

8.9.1 Locations

Conical screens should be sited in locations where fish have a clear escape route past a screen. They should not be installed in enclosed vaults or in close proximity to a structure that prevents fish from freely moving away from the screen.

8.9.1.1 Maximum ambient velocity

Conical screens are acceptable for use in lakes, reservoirs, backwater channels, and tidal areas where the ambient velocity does not exceed 1 ft/s. They may be used where the current is greater than 1 ft/s if other (i.e., superior) screening alternatives are not available, an appropriate flow distribution baffle system is used, and the design is acceptable to NMFS.

8.9.2 Approach Velocity

The maximum design approach velocity for conical screens is 0.33 ft/s.

The minimum effective screen area required for an installation may be determined by dividing the maximum diversion rate in ft³/s by 0.33 ft/s.

8.9.3 Flow Uniformity

Conical screens have been equipped with two types of baffle systems to distribute flow over all screen area. Early screens used an inverted cone design that divided the interior space into upper and lower areas. That design performed well in quiescent water with a narrow plenum, but field testing in a live stream showed that the inverted cone baffle did not balance flows well when flow was moving past the screen. In fact, the approach velocity on the leading edge of the screen unit could exceed the design value even when not diverting water because stream flow could enter the upstream side and exit the downstream side. To solve this problem, a new baffle design was developed.

The BOR's Technical Service Center near Denver, Colorado, developed a relatively complex baffle system with vertical dividers and a central flow balancing cylinder to distribute intake flow more evenly into four hydraulically-isolated quadrants (Hanna 2011). The vertical dividers prevented stream flow from passing completely through the screen unit. The manufacturer routinely includes a simplified internal baffle based on the USBR design in all of their conical screens.

BOR also tested an external baffle system to control how water approaches and passes into a conical screen (Hanna 2013). The external baffle concept created more uniform flow into the screen but debris could accumulate on the baffles in a riverine setting; therefore, NMFS recommends the use of an internal baffle system to allow stream flow to move debris and fish away from the diversion intake.

8.9.4 Effective Screen Area

All screen area submerged greater than 6 inches may be considered as effective screen area (Figure 8-12). If conical screens become exposed to air, the rate of diversion should be reduced to meet the design approach velocity criterion (Section 8.9.2) due to the reduced effective screen area.

When conical screens become exposed to air in tidal or backwater environments, the top 6 inches of screen material below the water surface may become occluded by debris.

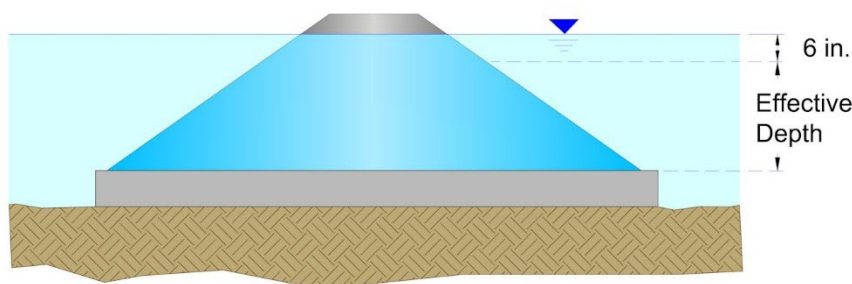


Figure 8-12 Elevation view of a conical fish screen showing the effective depth

8.9.5 Submergence

Conical screens may be operated while partially exposed above water but should be designed such that the screen is sufficiently submerged to maintain adequate effective screen area for the rate of diversion at any given moment.

The definition of effective screen area is provided in Section 8.5.2.

8.10 Project Inspections and Evaluations

8.10.1 General

Inspections and evaluations should be performed at each appropriate phase of a project. This includes during construction, when the project is substantially complete but not yet operating, and after construction.

Inspections of project details and evaluations of project systems are necessary to ensure that a fish screen project functions as intended.

8.10.2 Quality Assurance and Quality Control

An on-site project engineer or inspector should be assigned to every project. The inspector should provide notice to NMFS of key milestones in the construction process and access to the site for inspections.

The inspector is responsible for ensuring construction specifications and tolerances are met and for testing all project systems. NMFS should be allowed to witness testing of project systems.

8.10.3 Inspection

8.10.3.1 During construction

During the course of construction, activities may preclude various facets of screen and bypass construction from being inspected. In instances where these facets of construction may pose a risk of injury or mortality to fish later on during normal operations, the on-site engineer or inspector should inspect these items prior to construction continuing. In some instances, NMFS may require that a NMFS inspector be given the opportunity to inspect these items prior to construction continuing. If this is the case, NMFS will provide the project proponent with a list of screen and bypass elements that will require NMFS inspection during the course of construction. These may include (but are not limited to) the following:

- *Bypass pipe joints, either welded or mechanical*
- *Bypass downwells*
- *Bypass outfalls, if protected during construction by a cofferdam*
- *Any components that convey water that may contain fish*

8.10.3.2 Facilities near completion

Nearly completed fish screen and bypass facilities should be made available to NMFS staff for inspection prior to watering up to verify that the screen is operable in a manner consistent with the design criteria. NMFS staff may inspect construction quality, pipe joints, fit, and finish of components exposed to fish.

8.10.3.3 Evaluations

At some sites, screen and bypass facilities may need to be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved and debris removal systems are effective. At the discretion of NMFS, this may entail a complete biological evaluation, especially if waivers to screen and bypass criteria are granted, or merely a visual inspection of the screen in operation if the screen is relatively simple and designed and constructed to the standard criteria listed throughout the chapters of this document.

8.10.3.4 Mechanical and electrical systems evaluations

Testing of mechanical and electrical systems should be performed before initiating operations.

This should include testing of any alarm systems, including audible alarms, pagers, and other warning systems; data recording equipment, emergency shut-off systems, cleaning systems, actuators, and solenoids; backup systems; and other mechanical and electrical systems. These evaluations should be included in a list of final items to be completed by the contractor and carried out prior to contractor demobilization and should be written into the construction contract.

8.10.3.5 Automatic cleaning systems evaluations

Cleaning systems and their components should be tested in the dry, when possible, and again when screen facilities are operable, but prior to initiating normal operations.

Using O&M documentation of the cleaning systems provided by the designer or fabricator, all cleaning systems should be tested in automatic and manual operating modes. These evaluations should be included in a list of final items to be completed by the contractor and carried out prior to contractor demobilization and should be written into the construction contract.

8.10.3.6 Biological evaluations

Depending on the size of a project, any variances from established criteria, and the complexity and uniqueness of the project design, NMFS may require that biological evaluations be conducted on a fish screen facility. The biological evaluations may involve monitoring fish that naturally inhabit the site or releasing test fish obtained from another source such as a hatchery. If biological evaluations are required, the applicant must submit a biological evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. Biological evaluations must be performed by qualified personnel using established methods.

The biological evaluations could include monitoring to assess the number of fish being injured or delayed, entrained behind the fish screen, impinged on the fish screen and evidence of fish predation associated with the water intake structure. The biological evaluation study plans should describe the source of fish, test equipment, and methods that will be used; the statistical analysis that will be conducted and associated precision of any tests; and the proposed frequency, timing, and duration of any monitoring and testing.

8.10.3.7 Juvenile fish bypass systems

Hydraulic testing of juvenile fish bypass systems is required to create rating curves for gate openings needed to achieve prescribed flow rates, and to ensure that the bypass system hydraulics conform to hydraulic design criteria.

Biological testing of juvenile bypass systems may be required to ensure that juvenile fish are being returned safely to the main river channel. If biological evaluations are required, the applicant must submit a biological evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. Biological evaluations should be performed by qualified personnel using established methods.

The study plan should consider the complexity of the bypass system and the size and number of juvenile fish likely to be present during water diversion operations.

8.10.3.8 Fish screen hydraulic evaluations

The hydraulic evaluations described in this section are required for fish screen facilities. Appendix E (Performing Hydraulic Evaluations) provides information on how to conduct hydraulic evaluations.

Hydraulic evaluations are required on all screens equipped with adjustable flow tuning baffles designed to distribute flow evenly over all wetted screen areas, and where confirmation of hydraulic conditions at a fish screen is necessary. The applicant should submit a hydraulic evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. The final hydraulic evaluation should be conducted under the high design (diversion) flow unless otherwise agreed to by NMFS.

Hydraulic evaluations involve taking water velocity measurements at locations that are oriented both perpendicular (i.e., the approach velocity) and parallel (i.e., the sweeping velocity) to the screen face. Hydraulic evaluations are used on screen facilities with flow-balancing baffles to adjust the baffles to achieve uniform approach velocities across all wetted screen surfaces. Baffle systems should be adjusted in this manner prior to initiating normal water diversion operations. The hydraulic evaluation plan should include the proposed equipment, methods, and time schedule that will be used when conducting the hydraulic evaluations.

In the event that hydraulic conditions are found by NMFS to be unacceptable and the existing baffle system is incapable of adjusting flows to meet the hydraulic criteria, physical modifications to the facility may be required along with follow-up hydraulic evaluations of the modified hydraulic conditions.

Hydraulic evaluations should be carried out as soon as practical to ensure the facility is operating as near to design criteria as practical using the guidelines described in Appendix E. If the facility cannot be operated at an optimal diversion rate for the hydraulic evaluation within the first year of operation, the facility owner should seek to extend the deadline for carrying out the hydraulic evaluation from NMFS.

Hydraulic evaluations should be performed by qualified personnel using established methods.

A final hydraulic evaluation report should be provided to NMFS that includes the following:

- *A description of site and environmental conditions at the time of testing*
- *A list of technicians performing tests*
- *The materials and methods employed in the test, including locations of all velocity measurements in the final iteration of baffle adjustments, including justification of the number of points at which velocity measurements were taken*
- *A description of the final baffle settings*
- *The approach and sweep velocity data for all measured points in the final iteration of baffle adjustments presented in a table format*
- *The approach and sweeping velocity values for all measured points in the final iteration of baffle adjustments presented in a graphical format*

- *An objective evaluation of hydraulics at the site and anticipated screen performance*

8.11 Operations and Maintenance Plans

8.11.1 General

All fish screen projects should have an approved O&M plan. The plan should include procedures deemed acceptable by NMFS for operating the screen facility under a variety of environmental conditions, the full range of water diversion operations, and the procedures for periodic inspections and maintenance required to achieve fish screening effectiveness over the design life of the facility.

The purpose of an O&M plan is to ensure that the facility performs as designed and is providing effective fish screening over the life of the project. The O&M plan is the manual that describes exactly how the fish screen facility will be operated and maintained as well as procedures and personnel to contact in the event of emergencies. The following guidelines provide a template that can be used to prepare an O&M plan.

8.11.2 Operations

The O&M plan should include procedures that will ensure the fish screen meets all previously agreed to criteria. In addition to normal operation conditions, the plan should include information, procedures (including fish salvage plans), and personnel contact information in case of emergencies.

The O&M plan should include the seasonal maximum diversion rates agreed to in the design process, other criteria identified in the project description, project mitigation measures, and any applicable permit conditions or ESA Biological Opinion requirements. Additionally, the plan should address specific criteria on pump use at pumped diversions and gate use at gravity diversions that are required to achieve uniform approach velocities across screen surfaces.

8.11.2.1 Posting

A list of operating procedures that is easy to follow should be posted in a highly visible location at the water diversion site.

The list should include specific operating procedures needed to achieve uniform approach velocities across the screen face at various diversion rates. Emergency power cut-off switches, pressure relief valves, instructions for operating any auxiliary equipment, and emergency shutdown procedures should also be placed in locations that are easily found.

8.11.3 Maintenance

The diversion owner should incorporate maintenance procedures recommended by the designers, contractors, and suppliers into the O&M plan.

The maintenance section of the O&M plan should specify the frequency and interval for performing each maintenance procedure. The project owner is responsible for obtaining

documentation (including specifications and maintenance requirements) from suppliers of off-the-shelf and custom systems and equipment and ensuring that all necessary maintenance equipment, tools, and component parts are readily available and on-hand for the maintenance. The O&M manual should identify activities that need to be carried out on a periodic basis (e.g., daily, weekly, monthly, quarterly, annually, or another periodic schedule).

8.11.4 Maintenance Records

The facility owner should maintain a log of O&M activities, which should be made available upon request of appropriate federal and state agencies. The logbook should include the following:

- *One copy of the operating procedures list discussed above (Section 8.11.2)*
- *One copy of the periodic maintenance schedule discussed above (Section 8.11.3)*
- *Records of regularly scheduled and unscheduled maintenance procedures performed*

8.11.5 Periodic Visual Inspections

The project owner, or their agent, should perform visual inspections of the screens on an annual basis or more frequently if required to ensure design criteria are being met. Inspectors should examine cleaning system performance, structural integrity of the screen area, fish-exclusion integrity of seals and transition areas, and other factors affecting screen facility performance. Inspectors should determine if the current maintenance procedures are sufficient to ensure that screen performance will continue to meet the facility's design criteria into the future.

Guidelines for conducting periodic inspections are as follows:

- Auditing maintenance records:
 - Review the O&M logbook to identify any recurring problems.
 - Compare logged records with the O&M plan to ensure the plan is under compliance and note any areas that need troubleshooting.
- Inspecting underwater components:
 - Check for gaps at joints and seams that could compromise screen efficiency.
 - Note any accumulation of debris.
 - Inspect screen material for damage and material integrity.
 - Check screens and structural members for corrosion, wear, or other deterioration.
 - Check sacrificial anodes and replace if necessary.
 - Check screen hold-down plates and other protrusions from the screen face for damage and debris accumulation.
- Witness cleaning system operations:
 - Intentionally foul the fish screen with locally available materials if possible and view the efficiency of the screen cleaning system.
 - Inspect spray orifices for fouling and erosion and whether the water or air spray systems need to be enlarged.

- Inspect screen faces for undulations in the screen material that may reduce cleaning efficiency (i.e., for traveling brush systems).
 - Inspect screen cleaning brushes for wear and deterioration (e.g., for traveling brush systems).
 - Inspect seals for wear and deterioration.
 - Assess the overall efficiency of the cleaning system and identify any recommended solutions in the inspection report.
 - Inspect underwater moving parts for corrosion and damage.
- Inspect the morphology of the stream channel in the immediate vicinity of the project for debris, erosion, and sedimentation that may potentially damage screens and their supporting structures or adversely affect screen operation and effectiveness.
- If warranted, measure water velocities perpendicular to the screen face to determine flow uniformity over all screen surfaces. Above normal debris accumulation in small areas may indicate approach velocities exceed the design criteria in those locations. Excessively high approach velocities can result in debris accumulation. If the accumulation is not addressed in a timely manner it may result in less efficient water withdrawal and eventual damage to the screen material or its structure.
- Test backup systems and alarms that could include the following:
 - Pump shut-off controls
 - Blow out panels
 - Mechanical brush shut-off system controls
 - Screen cleaning system failure alarms

9 Operations and Maintenance

9.1 Introduction

The design criteria and guidance provided in this document were developed to produce a high level of effectiveness and reliability at installed fish passage and protection facilities. Achieving this requires that these facilities be operated and maintained properly to optimize their performance in accordance with the design objectives of the facility. Failure to do so is a key concern of NMFS. This is because insufficient attention to the operational and maintenance aspects of a facility can compromise its fish passage effectiveness and result in fish injury and mortality.

This chapter addresses O&M issues in general and describes the components needed in a facility O&M plan. Where necessary, other chapters of this document will also address O&M issues that apply specifically to the topics covered in those chapters (e.g., Chapters 5 and 8).

9.2 General Criteria

Passage and screening facilities at barriers, diversions, water intakes, traps, and collection facilities should be operated and maintained in accordance with the O&M plan over the entire life of the project. This is needed to meet the mechanical design and biological objectives of the facility and the goal of providing optimal conditions for fish that result in successful passage (i.e., no mortality and minimal injury and delay).

NMFS requires that facility owners and operators commit to accepting responsibility for installing and properly operating, maintaining, and repairing the fish passage facilities described in the Guidelines. This is to ensure that: 1) fish affected by the facility are protected in a manner that is consistent with the intended performance of the facility based on its design; and 2) fish protection is provided on a sustained basis. For example, the proper function and operation of a fish passage facility would need to be restored immediately after damage from flooding and prior to the arrival of migratory fish, including repairing damaged structures and removing accumulated gravel and sediment.

Where facilities are inadequately operated or maintained, and the injury or mortality of listed fish can be documented, the responsible party is liable to enforcement measures as described in Section 9 of the ESA.

9.3 Specific Criteria – Staff Gages

Staff gages should be installed and maintained at critical locations throughout the facility.

Staff gages allow personnel to quickly determine if the facility is being operated within the established design criteria. Staff gage locations will be identified in the O&M plan.

9.4 The Operations and Maintenance Plan

This section describes how O&M plans are developed and approved and their contents.

9.4.1 O&M Plan Development and Approval

The O&M plan for a facility should be submitted to and accepted by NMFS prior to initiating project construction. The design of facilities should be made in consideration of O&M requirements and vice versa. Therefore, O&M plans need to be developed during the planning and design processes and must be reviewed and approved by NMFS at this time, along with project design documents.

For new facilities, it is recommended that a description of intended operations be obtained from the designer and then incorporated into the O&M plan. Such a description is often referred to as the “designer’s intent.”

The complexity of the O&M plan should reflect the complexity of the facility it addresses. For example, a facility with complex components, narrow operating requirements, and sophisticated water control systems will require a detailed plan that addresses all of the components, systems, and operational scenarios. This should include potential emergency scenarios, including the identification of spare parts for essential components that need to be on hand in case of failure.

9.4.2 Group O&M Plans

Comprehensive O&M plans for a group of projects will satisfy the requirement for an O&M plan for each project in the group as long as NMFS is in agreement with the O&M of the passage facilities.

Examples of group projects include road maintenance plans for culverts and small screen facilities within a network of water diversions.

9.4.3 General

The O&M plan should include the following criteria, procedures, and staffing requirements.

9.4.3.1 Facility operating criteria

The O&M plan should list the facility operating criteria. This includes (but is not limited to) criteria for water levels at critical locations, gate operations, gate settings, how the system is adjusted to accommodate changes in forebay and tailwater levels, and inspection procedures and frequency (e.g., daily, monthly, and annually).

9.4.3.2 Procedures

The O&M plan should include a description of routine O&M procedures. In addition, the O&M plan should include procedures for dewatering the facility, salvaging fish during a dewatering event, sediment and debris removal, and emergency operations.

Procedures, such as dewatering plans, fish salvage plans, and emergency operations, can have a direct impact on the survival of fish in the facility. It is important that these procedures be incorporated into O&M plans and operators are familiar with them in order to minimize any adverse impacts.

9.4.3.3 Staffing requirements

The O&M plan should discuss the staffing requirements needed to support the O&M plan, including the hours staff are required to be on site to monitor and operate the facility. The staffing requirement component of the plan should incorporate automatic controls and telemetry into the O&M plan and facility that notify operators of problems to increase overall reliability of the facility.

9.4.4 Posting the O&M Plan

The O&M plan should be posted at the facility or otherwise made available to the facility operator. Operators should be familiar with and understand the O&M plan and operate the facility accordingly.

It is important that the O&M plan be available and easily accessed by the facility operator should questions or emergency situations arise.

9.4.5 Periodic Review of O&M Plans by NMFS

Operations and maintenance documents should be reviewed and revised (with NMFS involvement) annually for the first 3 years of operation and then periodically after that as conditions and operations dictate.

NMFS intends that O&M plans be “living” documents. O&M documents should be revised periodically as the owner and operator develop more experience with a new facility. This is important because over time, experience will be gained as to how the facility performs under various hydrologic and environmental conditions, and ideas on how to improve the O&M of the facility will develop. For example, it is important that facility owners and operators note areas in the O&M plan that are deficient or need revision.

10 References

- AECOM (AECOM, Inc.). 2009. Upper Baker Floating Surface Collector Field Verification Testing – Spring 2009. Draft report prepared for Puget Sound Energy, Bellevue, Washington, dated May 2009. Document No.:05570-053-0410.
- Barnard, R. J., J. Johnson, P. Brooks, K. M. Bates, B. Heiner, J. P. Klavas, D.C. Ponder, P.D. Smith, and P. D. Powers. 2013. Water Crossings Design Guidelines, Washington Department of Fish and Wildlife, Olympia, Washington.
- Bates, K. 1992. Fishway Design Guidelines for Pacific Salmon. Washington Department of Fish and Wildlife, Olympia, Washington.
- Bell, M.C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fish Passage and Development Evaluation Program, U.S. Army Corps of Engineers, Portland, Oregon.
- Blackett, R. 1987. Development and Performance of an Alaska Steeppass Fishway for Sockeye Salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Science 44:66-76.
- BOR (U.S. Bureau of Reclamation). 2006. Fish Protection at Water Diversions: A Guide for Planning and Designing Fish Exclusion Facilities. Water Resources Technical Publication U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.
- Bottom, D., K. Jones, C. Simenstad, and C. Smith. 2011. Reconnecting Societal and Ecological Resilience in Salmon Ecosystems. Oregon Sea Grant Report ORESO-B-11-001. In Pathways to Resilience; Sustaining Salmon Ecosystems in a Changing World Ecology and Society 14(1):5.
- Brett, J., and D. Alderdice. 1953. Research on Guiding Young Salmon at Two British Columbia Field Stations. Bulletin No. 117, Fisheries Research Board of Canada.
- Brett, J.R., M. Hollands, and D.F. Alderdice. 1958. The effects of temperature on the cruising speed of young sockeye and coho salmon. Journal of the Fisheries Research Board of Canada 15:587-605.
- Brownell, P., S. McDermott, A. Haro, F. Rohde, J. Johnson, A. Blott, B. Rizzo, Undated. Diadromous Fish Passage: A Primer on Technology, Planning, and Design for the Atlantic and Gulf Coasts. Available from NOAA National Marine Fisheries Service Southeast Region, Habitat Conservation Division.
- Castro, J.M. and P.L. Jackson, 2001. Bankfull Discharge Recurrence Intervals and Regional Hydraulic Geometry Relationships: Patterns in the Pacific Northwest, USA. Journal of the American Water Resources Association 37(5):1249-1262, doi: 10.1111/j.1752-1688.2001.tb03636.x.
- CDFG (California Department of Fish and Game). 2002. Culvert Criteria for Fish Passage, California Department of Fish and Game, May 2002.
- Cech, J., P. Young, C. Swanson, M. Levent Kavvas, Z. Chen, and H. Bandeh. 2001. Fish Treadmill-Developed Fish Screen Criteria for Native Sacramento-San Joaquin Watershed Fishes, Final Report, CALFED Bay/Delta Program, CALFED Project 99-N02.

- Clay, C.H. 1961. Design of Fishways and Other Fish Facilities. Department of Fisheries of Canada, Queen's Printer, Ottawa, Canada.
- Clay, C.H. 1995. Design of Fishways and Other Fish Facilities. Second Edition. Boca Raton: CRC Press.
- Collins, G.B. 1976. Effects of Dams on Pacific Salmon and Steelhead Trout. *Marine Fisheries Review* 38(11):39-45.
- Cooper, R.M. 2005. Estimation of Peak Discharges for rural, Unregulated Streams in Western Oregon: U.S. Geological Survey Scientific Investigations Report 2005-5116, 134 p.
- DOI (U.S. Department of Interior). 1987. Design of Small Dams. 3rd Edition. Water Resources Technical Publications, Washington D.C.
- EPRI (Electric Power Research Institute). 1994. Fish Protection/Passage Technologies Evaluated by EPRI and Guidelines for Their Application. EPRI TR-104120s.
- FERC (Federal Energy Regulatory Commission). 1995. Impacts of Hydroelectric Plant Tailraces on Fish Passage: A Report on Effects of Tailraces on Migratory Fish and Use of Barriers, Modified Project Operations, and Spills for Reducing Impacts. Paper No. DPR-9. Office of Hydropower Licensing, Washington, D.C.
- Gauley, J., C. Weaver, and C. Thompson. 1966. Research on Fishway Problems May 1960 to April 1965. Third Progress Report on Fisheries Engineering Research Program, North Pacific Division. U.S. Army Corps of Engineers, Portland, Oregon.
- Gotvald, A.J., N.A. Barth, A.G. Veilleux, and C. Parrett. 2012. Methods for Determining Magnitude and Frequency of Floods in California, Based on Data Though Water Year 2006. U.S. Geological Survey Scientific Investigations Report 2012-5113. Available online only at <http://pubs.usgs.gov/sir/2012/5113/>.
- Hanna, L. 2011. ISI Cone Screen Performance in a Riverine Environment, PAP-1037. U.S. Department of Interior, Bureau of Reclamation, Technical Service Center, Hydraulic Investigations & Laboratory Services, Denver, Colorado. PAP-1037.
- Hanna, 2013. ISI Cone Screen Riverine Performance with an External Baffle. U.S. Department of Interior, Bureau of Reclamation, Technical Service Center, Hydraulic Investigations & Laboratory Services, Denver, Colorado. PAP-1081.
- Hanski, I. 1998. Metapopulation dynamics. *Nature* 396:41-49.
- Haro, A., M. Odeh, J. Noreika, and T. Castro-Santos. 1998. Effect of water acceleration on downstream migratory behavior and passage of Atlantic salmon smolts and juvenile American shad at surface bypasses. *Trans. Am. Fish. Soc.* 127:118-127.
- Hevlin, W., and S. Rainey. 1993. Considerations in the Use of Adult Fish Barriers and Traps in Tributaries to Achieve Management Objectives. Pages 33-40 in K. Bates, compiler. *Fish Passage Policy and Technology*. Bioengineering Section, American Fisheries Society, Bethesda, Maryland.
- Hilborn, R., T.P. Quinn, D.E. Schindler, and D.E. Rogers. 2003. Biocomplexity and fisheries sustainability. *Proc. Nat. Acad. Sci.* 100:6564-6568.
- HSRG (Hatchery Scientific Review Group). 2009. Report to Congress on Columbia River Basin Hatchery Reform.

- Johnson, G., B. Ebberts, D. Dauble, A. Giorgi, P. Heisey, R. Mueller, and D. Neitzel. 2003. Effects of jet entry at high-flow outfalls on juvenile Pacific salmon. *North American Journal of Fisheries Management* 23:441-449.
- Katopodis, C. 1992. *Introduction to Fishway Design*. Freshwater Institute, Central and Arctic Regions, Department of Fisheries and Oceans, Winnipeg, Manitoba, Canada.
- Lang, M., and M. Love. 2014. Comparing Fish Passage Opportunity Using Different Fish Passage Design Flow Criteria in Three West Coast Climate Zones. Contract Report for National Marine Fisheries Service. Humboldt State University and Michael Love & Associates, Inc., Arcata, California, August 2014.
- Larinier, M., F. Travade, and J. Porcher. 2002. Fishways: biological basis, design criteria and monitoring. *Bulletin Français de la Pêche et de la Pisciculture* 364 suppl.:135-146.
- Larinier, M., and F. Travade. 2002. The design of fishways for shad. *Bulletin Français de la Pêche et de la Pisciculture* 2002 364 suppl.:135-146.
- Lindley, S.T., R.S. Schick, E. Mora, P.B. Adams, J.J. Anderson, S. Greene, C. Hanson, B. May, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2007. Framework for Assessing the Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. *San Francisco Estuary and Watershed Sciences* 5:1. Available at <http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art4>.
- Love, M., and K. Bates. 2009. Part XII: Fish Passage Design and Implementation. *California Salmonid Stream Habitat Restoration Manual*. California Dept. of Fish and Game. 188 pages.
- Manning, D., J. Mann, R. Benkert, S. Chase, and S. White. 2005. Steelhead emigration in a seasonal impoundment created by an inflatable rubber dam. *North American Journal of Fisheries Management* 25:1239-1255.
- McClure, M., T. Cooney, and M. Marvier. 2001. Assessing the role of dams in salmon recovery. *Hydro. Rev.* 20:36-45.
- McElhany, P., M. Ruckelshaus, M. Ford, T. Wainwright, and E. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. NOAA Technical Memorandum NMFS-NWFSC-42. Available online at <http://www.nwfsc.noaa.gov/publications/>.
- McLaughlin, R., A. Hallett, T. C. Pratt, L.M. O'Connor, and D.G. McDonald. 2007. Research to guide use of barriers, traps, and fishways to control sea lamprey. *J. Great Lakes Res.* 33:27-19.
- Mooney, D., C. Holmquist-Johnson, and E. Holburn. 2007. Reclamation Managing Water in the West: Qualitative Evaluation of Rock Weir Field Performance and Failure Mechanisms. U.S. Bureau of Reclamation, Technical Service Center, Denver, Colorado.
- Mueller, R., D. Neitzel, and C. Abernethy. 1995. Fisheries Evaluation of the Dryden Fish Screening Facility. Project No. 1985-06200, Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon. BPA report DOE/BP-00029-2.
- Neitzel, D., C. Abernethy, and E. Lusty. 1990a. A Fisheries Evaluation of the Westside Ditch and Wapato Canal Fish Screening Facilities, Spring 1989. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

- Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1990b. A Fisheries Evaluation of the Wapato, Sunnyside, and Toppenish Creek Canal Fish Screening Facilities, Spring 1988. Prepared by Pacific Northwest Laboratory, Richland, Washington, for U.S. Department of Energy, Bonneville Power Administration, Yakima, Washington.
- NMFS (National Marine Fisheries Service). 2001. Guidelines for Salmonid Passage at Stream Crossings. National Marine Fisheries Service Southwest Region. September 2001. Available at: http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_at_stream_crossings_guidance.pdf.
- NMFS. 2006. Comments, Recommended Terms and Conditions, and Prescription for Santa Felicia Hydroelectric Project, FERC Project No. 2153-012. Letter of R.R. McInnis, to M.R. Salas, Federal Energy Regulatory Commission, Washington, D.C., December 14, 2006.
- NMFS. 2014. Public Final Recovery Plan for the Evolutionary Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Sacramento Protected Resources Division, Sacramento, California.
- Northcote, T.G. 1998. Migratory Behavior of Fish and Its Significance to Movement through Riverine Fish Passage Facilities. Fish Migration and Fish Bypasses. In: Fish Migration and Fish Bypasses. Blackwell Science Ltd. Publishers, Oxford, U.K.
- NRC (National Research Council). 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press, Washington, D.C.
- NRCS (Natural Resources Conservation Service). 2007. Technical Supplement 14A. Part 654 National Engineering Handbook. Soil Properties and Special Geotechnical Problems Related to Stream Stabilization Projects. Available online at: <http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17810.wba>.
- Peterson, D., and P. Mohanty. 1960. Flume Studies of Flow in Steep, Rough Channels. Journal of the Hydraulic Division. Proceedings of the American Society of Civil Engineers Vol. 86:55-76.
- Powers, P., and J. Orsborn. 1985. New Concepts in Fish Ladder Design: Analysis of Barriers to Upstream Fish Migration, Volume IV of IV. Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. Project No. 198201400, BPA Report DOE/BP-36523-1.
- Quinn, T.P. 2005. The Behavior and Ecology of Pacific Salmon and Trout. Seattle: University of Washington Press.
- Rajaratnam, N., and C. Katopodis. 1984. Hydraulics of Denil Fishways. J. Hydraul. Eng. 110(9):1219-1233.
- Rideout, S., L. Thorpe, and L. Cameron. 1985. Passage of American Shad in an Ice Harbor style fish Ladder after Flow Pattern Modifications. Proceedings of the Symposium on Small Hydropower and Fisheries, pages 251-256. F. Olsen, R. White, and R. Hamre, editors. Published by the American Fisheries Society, Bethesda, Maryland.
- Roff, D.A. 1992. The Evolution of Life Histories: Theory and Analysis. New York: Chapman and Hall.

- Ruckelshaus, M.H., P.S. Levin, J.B. Johnson, and P. Kareiva. 2002. The Pacific salmon wars: what science brings to the challenge of recovering species. *Annual Review of Ecology and Systematics* 33:665-706.
- Ruggles, C.P., and P. Ryan. 1964. An Investigation of Louvers as a Method for Guiding Juvenile Pacific Salmon. Department of Fisheries Canada, Vancouver, British Columbia.
- Sayre, W., and M. Albertson. 1963. Roughness spacing in rigid open channels. *Transactions of the American Society of Civil Engineers* 128(1):343-371.
- Schindler, D.E., R. Hilborn, B. Chasco, C.P. Boatright, T.P. Quinn, L.A. Rogers, and M.S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. *Nature* 465:609-613.
- Senn, H., J. Mack, and L. Rothfus. 1984. Compendium of Low-cost Pacific Salmon and Steelhead Production Facilities and Practices in the Pacific Northwest. Project No. 83-353. Report to the Bonneville Power Administration, Portland, Oregon.
- Shively, R.P., T.P. Poe, and M.B. Sheer. 1996. Criteria for reducing predation by northern squawfish near juvenile salmonid bypass outfalls at Columbia River dams. *Regulated Rivers: Research and Management* 12:493-500.
- Slatick, E. 1975. Laboratory evaluation of a Denil-type steep pass fishway with various entrance and exit conditions for passage of adult salmonids and shad. *Marine Fisheries Review* 37(9):17-26.
- Slatick, E., and C. Wagner. 1989. Criteria for a Velocity-Barrier Dam for Migrating Adult Salmonids. Northwest and Alaska Fisheries Center, Seattle, Washington.
- Smith, L., and L. Carpenter. 1987. Salmonid Fry Swimming Stamina Data for Diversion Screen Criteria. Final Report, Fisheries Research Institute, University of Washington, Seattle, Washington.
- Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A General Protocol for Restoration of Regulated Rivers. *Regulated Rivers: Research & Management* 12(4-5):391-413.
- Stewart, R. 2003. Techniques for Installing a Resistance Board Fish Weir. Regional Information Report No. 3A03-26. Alaska Dept. of Fish and Game, Anchorage, Alaska.
- Taylor, E.B. 1991. A review of local adaptation in Salmonidae, with particular reference to Pacific and Atlantic salmon. *Aquaculture* 98:185-207.
- Thompson, C., W. Davis, and E. Slatick. 1967. Response of Migrating Adult Salmonids to Vertical and Horizontal Rectangular Orifices at Two Depths. U.S. Fish and Wildlife Service Special Scientific Report No. 547.
- Tobin, J. 1994. Construction and Performance of a Portable Resistance Board Weir for Counting Migrating Adult Salmon in Rivers. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 22.
- USFWS (U.S. Fish and Wildlife Service). 1960.
- USFWS. 2017. *Pacific Lamprey Technical Workgroup*. Practical guidelines for incorporating adult Pacific lamprey passage at fishways. June 2017. White Paper. Appendix.
- Wagner, C. 1967. Fish Barrier Dams: Fish Facilities Section Memo Dated August 23, 1967. Columbia Fisheries Program Office, Bureau of Commercial Fisheries, Portland, Oregon.

- Waples, R.S. 1991. Definition of "species" under the Endangered Species Act: Application to Pacific Salmon. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum. NMFS F/NWC-194.
- Ward, J., and J. Stanford. 1979. The Ecology of Regulated Streams. New York: Plenum Press.
- WDFW (Washington Department of Fish and Wildlife). 2000. Fishway Guidelines for Washington State. Draft Report dated April 25, 2000. Washington Department of Fish and Wildlife, Olympia, Washington.
- Weaver, C., C. Thompson, and E. Slatick. 1976. Fish Passage Research at the Fisheries-Engineering Research Laboratory May 1965 to September 1970. Report No. 32 In: Fourth Progress Report On Fisheries Engineering Research Program, 1966-1972. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.
- Weaver, C. 1963. Influence of water velocity upon orientation and performance of adult migrating salmonids. U.S. Fish and Wildlife Service. Fish. Bull. 63:97-121.
- World Commission on Dams. 2000. Dams and Development: and New Framework for Decision-making. London: Earthscan Publications.
- Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle. 1996. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In: Sierra Nevada Ecosystem Project: Final Report to Congress, Volume III. Centers for Water and Wildland Resources, University of California, Davis. Davis, California, pp. 309-361.
- Ziemer, G. 1962. Steeppass Fishway Development. Information Leaflet 12. Alaska Department of Fish and Game.
- Zimmerman, C.E., and L.M. Zabkar. 2007. Weirs, Chapter 6 in Salmonid Field Protocols Handbook, pp 385-398. American Fisheries Society, Bethesda, Maryland.

Appendix K

Forest Matrix

Permit Area - Landscape - Acres by Age Class - HCP Scenario (run 3.1) - 2020-08-05

MGT	year	0-30	31-60	61-90	91-120	121-150	151-180	>180	NA
Inside HCAs	2023	30635	66097	133950	20282	10379	3714	1463	8114
	2033	30516	40161	114875	61837	11878	4989	2264	8114
	2043	21791	40414	76061	103894	13560	6986	3814	8114
	2053	21900	30323	55674	123703	19485	10258	5176	8114
	2063	14600	30484	35681	105492	61375	11635	7253	8114
	2073	7300	21791	38748	71712	102748	13421	10800	8114
	2083	0	21900	30323	55674	123703	19485	15435	8114
	2093	0	14600	30484	35681	105492	61375	18888	8114
Outside HCAs	2023	73713	115567	149426	10862	1413	238	11	12883
	2033	120654	66663	142039	20023	1732	85	34	12883
	2043	139085	76824	91787	40341	2769	394	31	12883
	2053	167840	71253	52595	55134	3601	747	61	12883
	2063	150614	110329	20130	60364	8429	1280	84	12883
	2073	134445	121840	22990	44487	24851	2219	398	12883
	2083	131581	127779	16645	28940	42237	3251	796	12883
	2093	135693	93007	46073	10764	56559	7780	1353	12883

Appendix L
TerrainWorks Papers

Modeling In-stream Wood Recruitment in Western Oregon

**Daniel Miller, Kevin Andras and Lee Benda
Terrainworks**

October, 2021

1.0 Introduction

As of 2021, three Habitat Conservation Plan (HCP) efforts are underway in Oregon: the Elliott State Forest, the Western Oregon State Forests, and the Oregon Statewide Private Forest Accord. Together, these HCPs involve over 50,000 km² of forest lands. Effects of forest management on in-stream wood recruitment and consequences for fish habitats are important issues in all three. Management prescriptions for riparian buffers are being developed by planning teams who must determine where and to what extent timber harvest should be limited to minimize adverse impacts to aquatic habitats.

The methods and analysis presented below apply generally to each of the HCPs, but more specifically to the Western Oregon State Forests. This report presents a summary of modeling in-stream wood recruitment by forest mortality and landslides and debris flows. It is an abbreviated version of a paper that is in preparation.

There are three sources of wood to fish-bearing streams: (1) Trees that fall directly into fish-bearing streams. Wood from these trees accumulates over time with loss to decay and (2) Debris-flow delivery (traversal of non-fish streams by debris flows that travel to fish streams). Bank erosion (including channel migration and avulsion) is an important wood recruitment process but it is not included in the present analysis. The model can predict with wood pieces or wood volume, of all pieces ≤ 10 cm in diameter and > 1 m in length. Pieces can include that portion outside of the channel banks. Conifer and deciduous trees are included.

The objectives of the analysis include: (1) Quantify effect of proposed riparian buffer extent on wood recruitment to channels and (2) Quantify proportion of wood supplied to fish-bearing streams by upslope landslides and by debris-flows through non-fish-bearing streams.

This requires the application of four models:

1. Stand growth (Forest Vegetation Simulator). The model predicts the number and sizes of trees available for recruitment to channels by mortality.
2. Mortality tree fall. Using either random fall or preferential trajectories, this model predicts the number and size of wood pieces that can fall into streams.
3. Landslide initiation. Identifies potential source areas for landslides (Miller and Burnett, 2007).
4. Landslide and debris-flow runout. Identifies those locations potentially traversed by landslides or debris flows triggered upslope that continue downslope to deposit in fish-bearing channels (Miller and Burnett, 2008).

2.0 Study Area

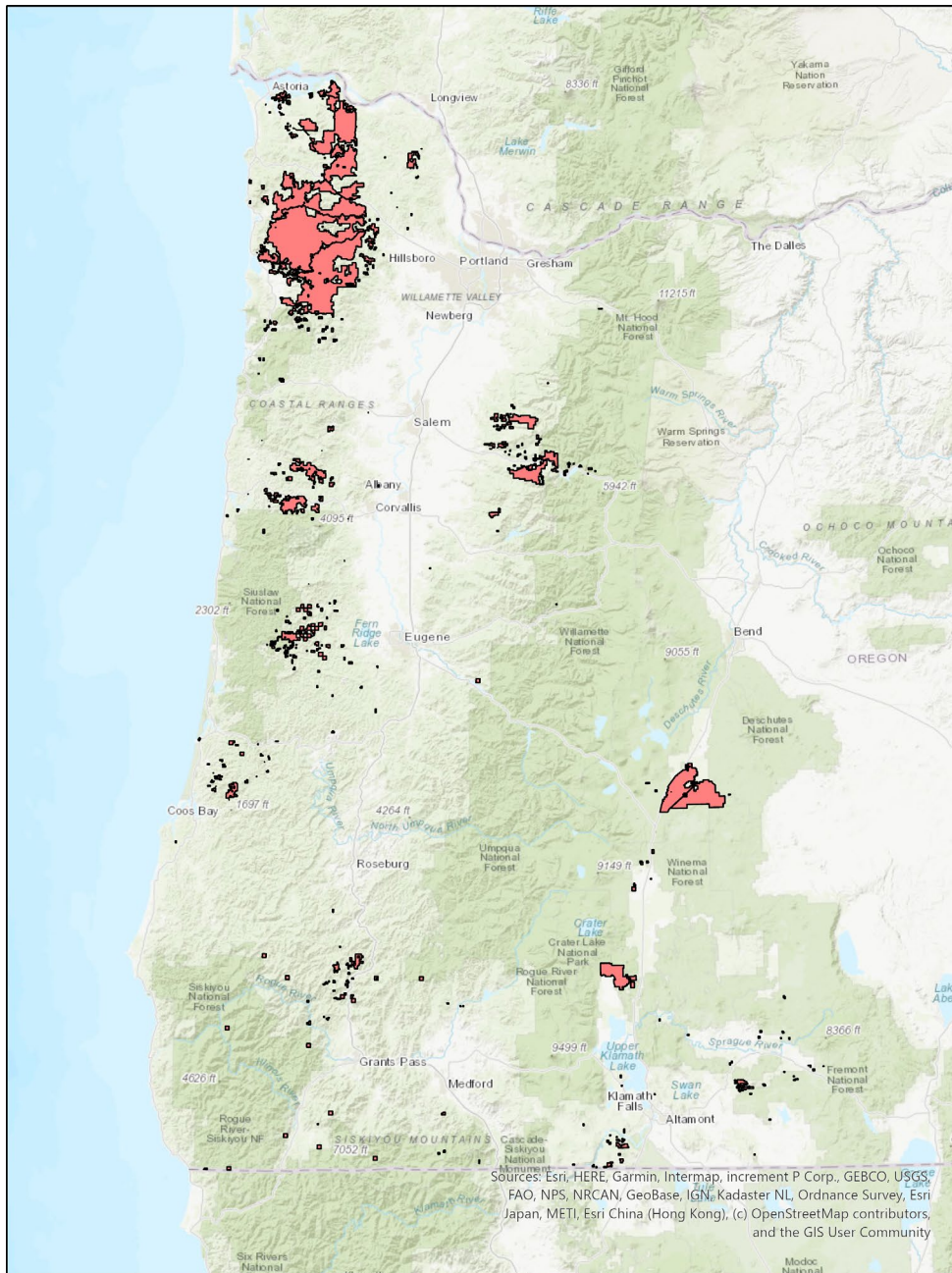


Figure 1. The study area encompasses approximately 2,500 km² of state forest lands in western Oregon.

3.0 Methods

3.1 Synthetic channel network

The first step is to delineate synthetic stream networks using digital elevation models. The analysis includes:

- Synthetic digital network traced from 1/3-arc-second (10m) NED DEM (or 1m LiDAR).
- Enforced to ODF stream layer for fish-bearing and perennial streams.
- Fish presence/absence, perennial/seasonal, size (small, medium, large) conflated from ODF stream layer.
- Channel geometry from regional regression equations to contributing area and mean annual precipitation.
- Gradient and valley width from DEM.

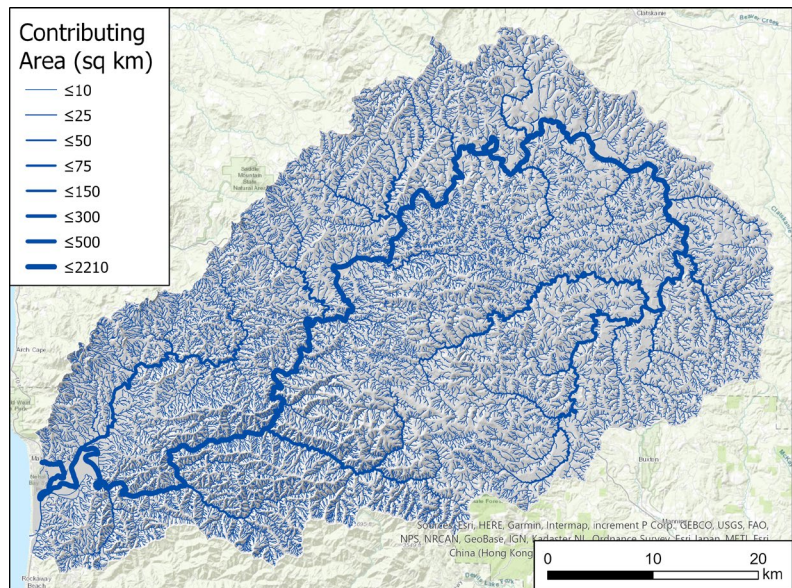


Figure 2. A delineated channel network in the Oregon Coast Range.

References: Miller et al. 2015;
Clarke et al. 2008; Benda et al.
2011; Barquin et al. 2015;
Benda et al. 2015.

Channels are classified into the types used in the State Forest HCP. This is done by conflating the ODF stream types to the digital synthetic network.

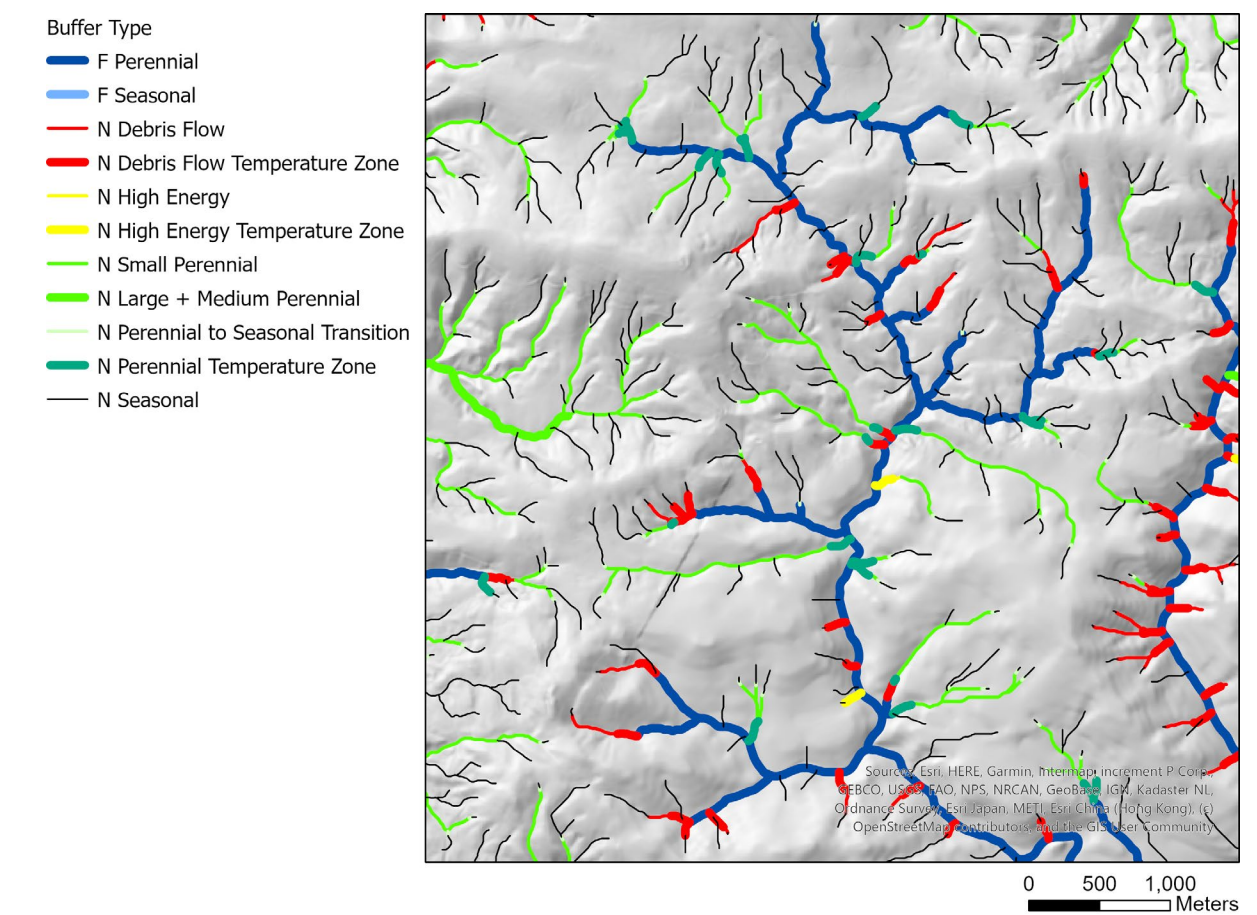


Figure 3. A classified channel network using ODF stream types.

Here is an example set of riparian buffers.

Table 1. Average buffer widths for all type F and large and medium type N streams. All values represent average horizontal distance in feet over the length of stream receiving the buffer.

Stream Size	Type F	Type N
Large	120	120
Medium	120	120
Small	120	See Table 2
Seasonal	50	See Table 2

¹ See Figure 2a

Table 2. Average buffers widths for small perennial and seasonal type N streams.

Stream Type	Within Temperature Zone	Above Temperature Zone
Perennial Small Type N ¹	50	35
Potential debris flow track (Seasonal Type N) ²	50	35
High energy (Seasonal Type N) ²	50	35
Seasonal other (Type N) ³	0 ⁴	0 ⁴

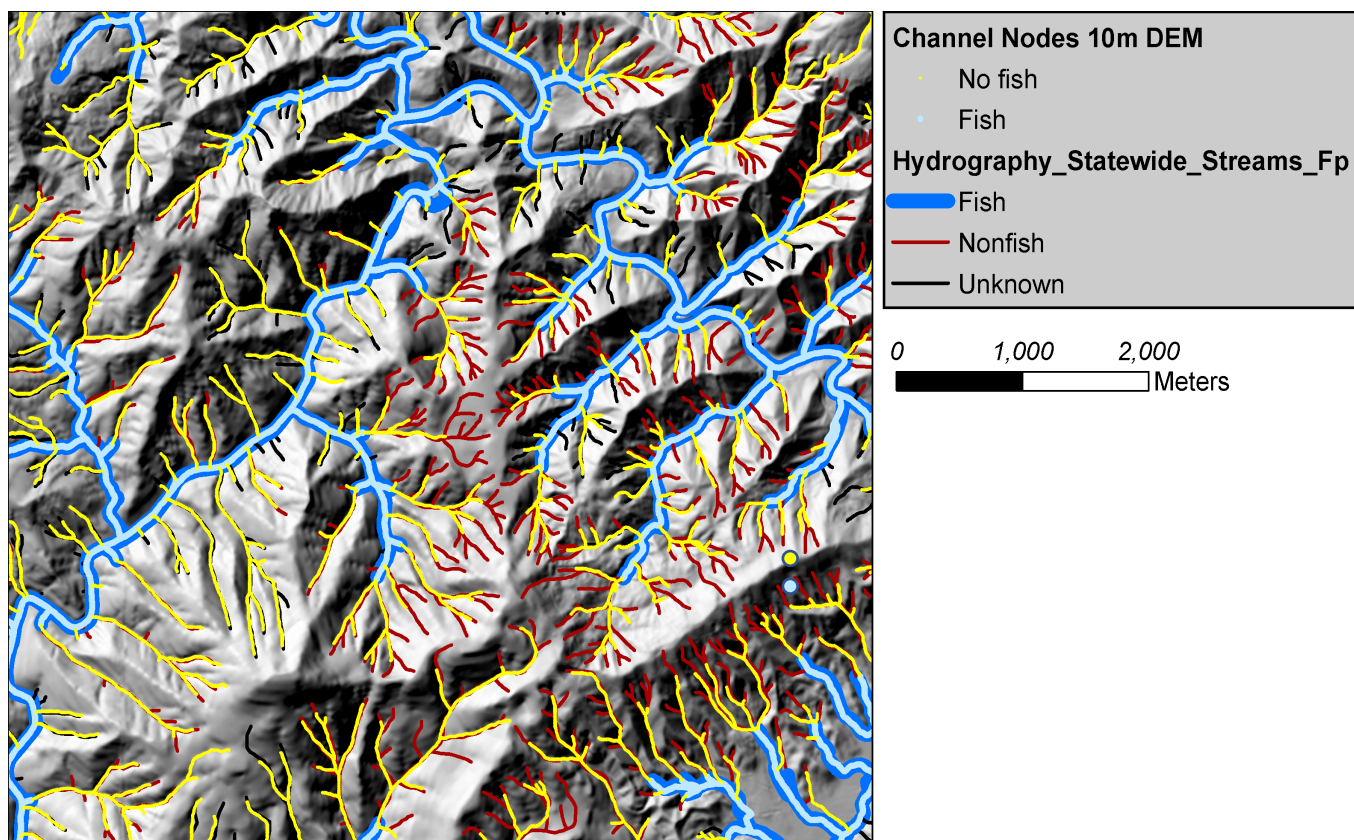


Figure 4. A channel network identifying fish and non-fish channels created by the match between the DEM-traced channel network and the extent of fish presence indicated by state hydrography.

3.2 Forest mortality recruitment

Model of in-stream wood recruitment summary.

1. An unmanaged baseline forest wood recruitment is specified using a uniform forest stand of a specified tree height.
2. All specified buffers are composed of uniform stands of a given height and an average tree-fall rate (mortality rates) within all stands is spatially and temporally uniform.
3. The recruitment rate varies with distance from the channel because the probability that a falling tree hits the channel decreases with distance of the tree from the channel. To be counted, a tree must intersect the channel edge.
4. Wood that falls into a non-fish channels accumulates over time. The accumulated wood decays over time. The total volume of wood found per unit non-fish channel length at any time is proportional to the recruitment rate, decay rate, and accumulation time (time between debris flows, given by the debris flow recurrence interval).
5. Wood that accumulates in a non-fish channel may be carried to a fish-bearing channel by a debris flow. Within any channel, the frequency of debris flows that carry the accumulated wood downstream to a fish-bearing channel is a function of the upslope topography, which determines the number of potential debris-flow sources, and the topography along the channel, which determines the potential for a debris flow to travel all the way to a fish-bearing channel. This frequency can be expressed as an average recurrence interval, which we equate to the average time for wood to accumulate within a channel between debris flows.
6. The wood delivered to the valley floor by a debris flow is partitioned between two portions:
 - a) that deposited in the fish-bearing channel or becomes available to the channel over time and
 - b) that deposited in fans and terraces that eventually decays away and never affects the channel.The proportion that is available to the fish-bearing channel is referred to as the delivery efficiency.

To estimate wood recruitment to channels from riparian zones, a spatially distributed tree-fall model is used. A map of stand types is overlain on a DEM. Tree lists for each stand (from FVS modeling) provide estimates of tree height and stem density by DBH size and species classes.

For each DEM grid point, we identify all channel-edge segments within a maximum tree height.

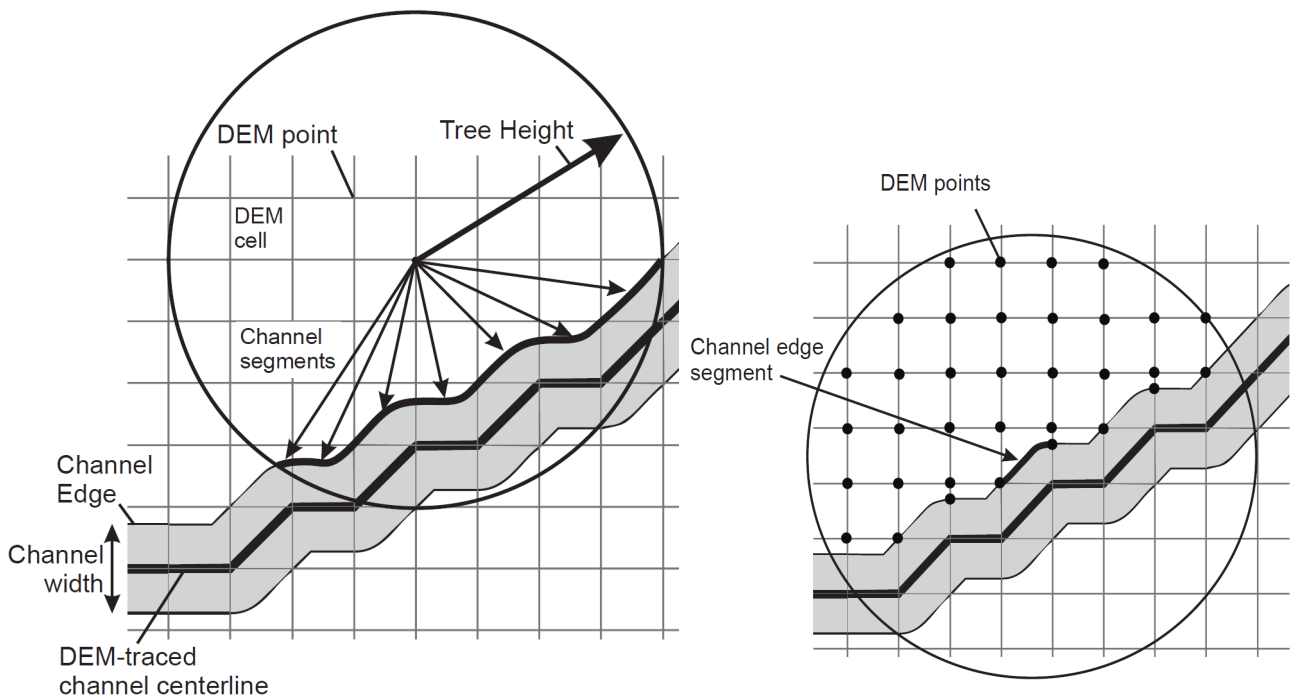


Figure 5. A schematic illustrating the tree-fall model within a DEM. The depicted geometry is used to calculate the probability of tree fall into each channel-edge segment within a distance of one height of a DEM point. A channel-edge segment is defined as the trace of the channel edge through a DEM cell.

Probability of tree fall from each DEM point is calculated for each channel-edge segment. The number of trees, by size and species classes, available to fall from each cell is estimated from mortality estimates in the stand tables. Probability that a falling tree intersects a channel-edge segment is integrated over each cell to estimate the fractional number of trees falling from each DEM cell to each channel-edge segment. Size of recruited pieces is dependent on slope distance from the DEM cell corners to the channel-edge segment and on the height and DBH of the tree. These calculations are iterated over all tree size and species classes and for all DEM cells and channel-edge segments.

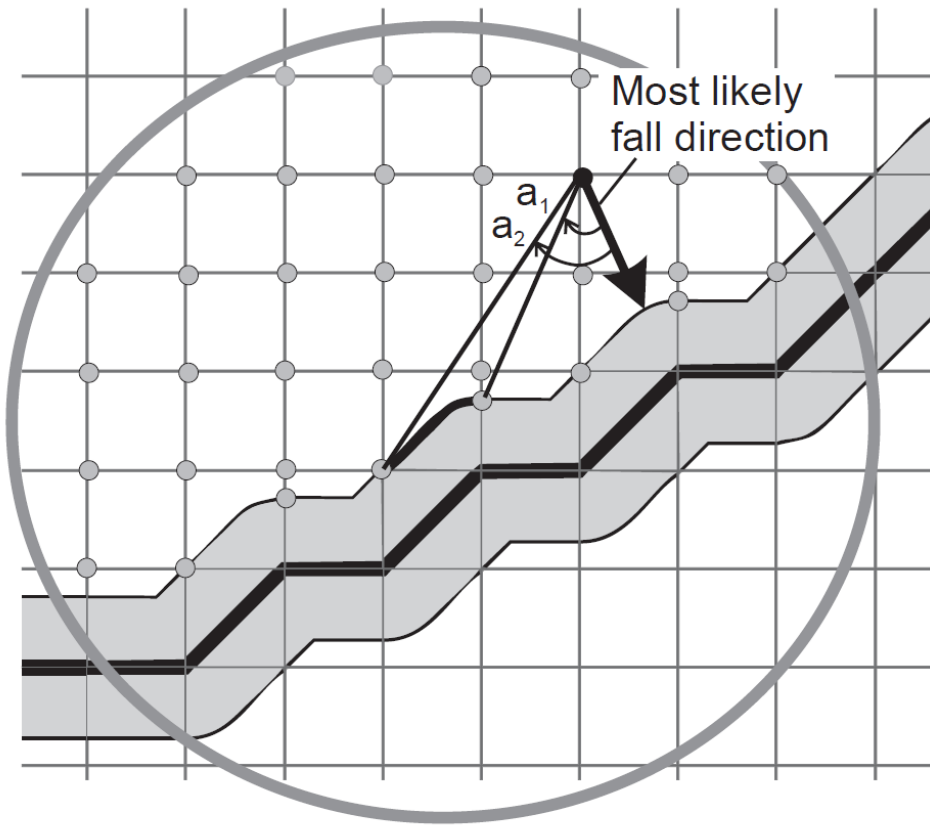
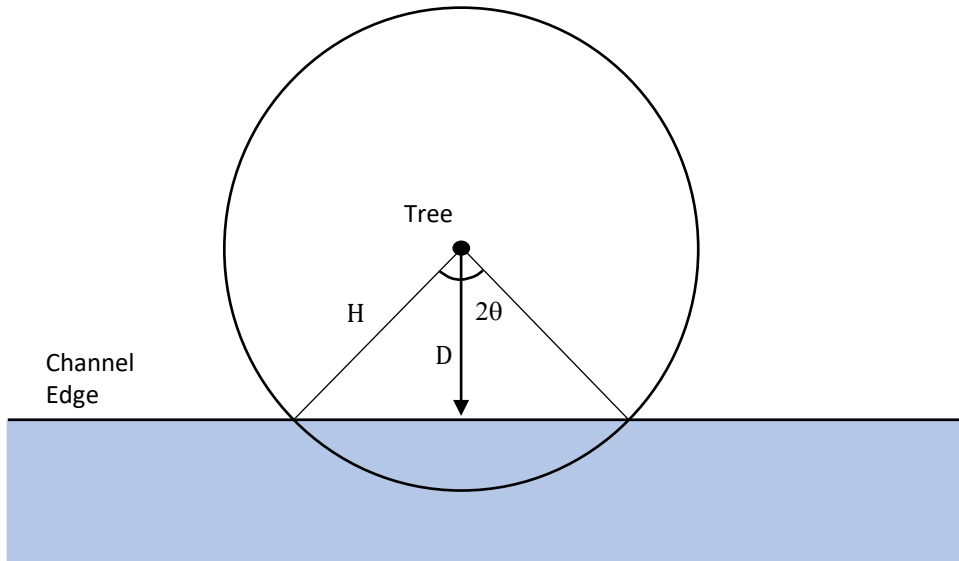


Figure 6. Tree-fall directions are estimated for each DEM cell.



H = Tree Height

D = Distance to Stream

2θ = angle subtended by fall directions for which tree hits channel.

$$\theta = \arccos\left(\frac{D}{H}\right)$$

P = probability that falling tree hits channel.

If fall direction is equally probable in any direction, $P = \theta/\pi$

Figure 7. Probability that a falling tree hits a channel if the fall direction is equally probable in any direction based on random fall. Other fall trajectories can be used, including preferential towards the channel.

The relative recruitment rate is based on the number of trees that fall and the proportional area subtended by the fall directions that intersect the channel. That proportion varies from 50% at the channel edge to zero when $D = H$. The volume of trees falling is the volume density r (stems per unit area times volume per stem) times the tree-fall rate M .

$$\text{Recruitment per unit channel length} = \frac{MH\rho}{\pi} \int_0^1 \arccos\left(\frac{D}{H}\right) d\left(\frac{D}{H}\right) = \frac{MH\rho}{\pi}. \quad \text{Eq. 1}$$

That's for one side of the channel. Both sides gives $2MH\rho/\pi$.

From the tree-fall model, the source-distance curve for average annual recruited wood volume is calculated for each channel node.

Buffer width is intersected with the curve to get volume from within the buffer.

Conifers are represented in the model as a single straight bole specified DBH and total height. For this model, bole taper was modeled as linear.

Deciduous trees are represented as a single bole to one-third the tree height, then with branches that increase in number to two-thirds tree height, and decrease back to one at the top.

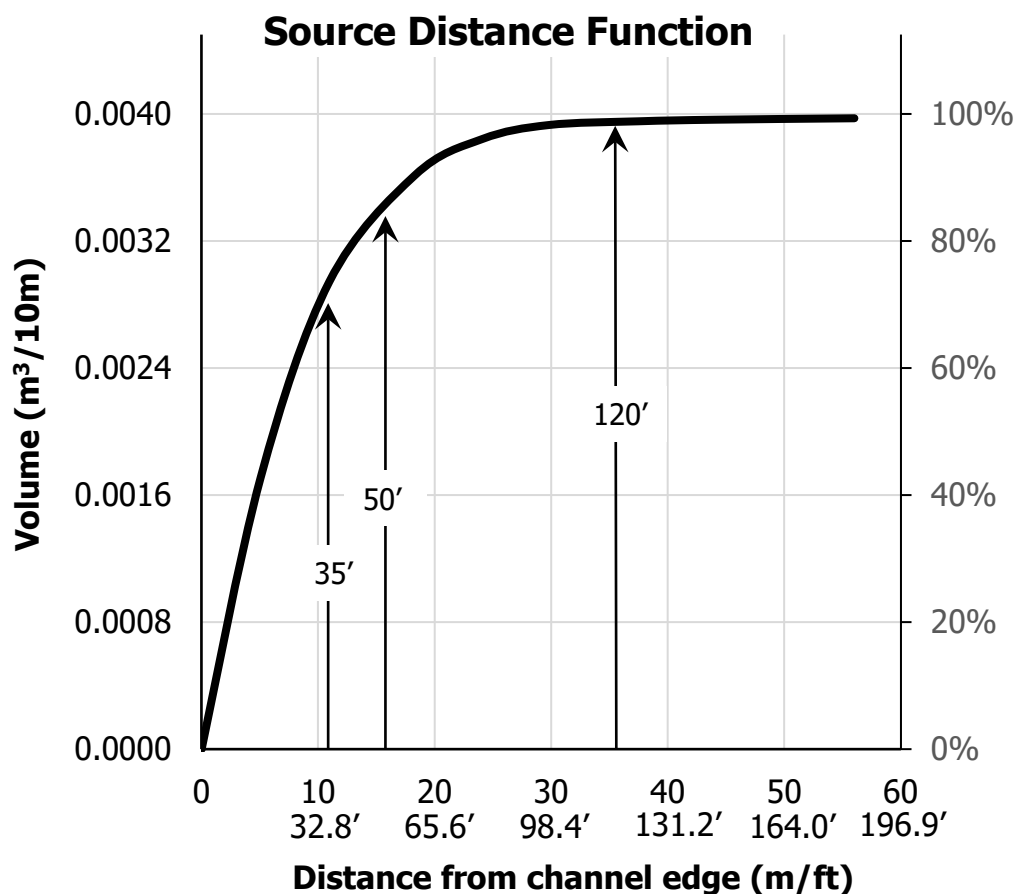


Figure 8. The tree-fall model determines a source distance curve for average annual recruited wood volume for each channel node. Buffer width is intersected with the curve to obtain volume from within the buffer. Conifers are represented as a single straight bole of specified DBH and height. Bole taper is linear. Deciduous trees are represented as a single bole to 1/3 height, then with branches that increase in number to 2/3 tree height, and decrease back to one at the top.

Wood volume in fish streams accumulates over time as trees fall and diminishes over time as the down wood decays. The volume accumulated over a time t is estimated as:

$$\frac{r}{k} * (1 - e^{-kt}) \quad \text{Eq. 2}$$

where r = average annual recruited volume from source-distance curve; k = decay rate (proportion lost per year); and t = time period (years, e.g., 70-year rotation)

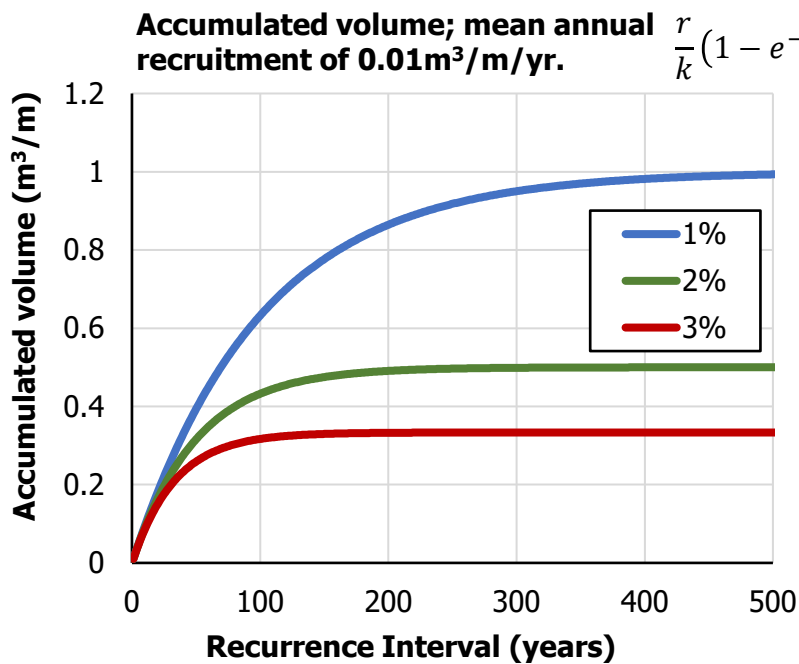


Figure 9. Accumulated wood volume in non-fish streams varies in the model according to estimated recurrence interval of debris flows and by the assigned wood decay rate.

The total volume available for debris-flow-recruitment per year to fish-bearing channels from non-fish channels is, on average, the integral $\int V_A dl$ over all non-fish channels. To approximate this integral, we divide the channel network into tiny segments (each about the length of one DEM cell), calculate V_A for each segment, and sum over all non-fish segments. The total average annual available wood in non-fish channels is then

$$(2MHR/p) \sum_i \left(\frac{1-e^{-kR_i}}{kR_i} \right) l_i, \quad \text{Eq. 3}$$

where R_i = recurrence interval for the i^{th} segment and l_i is the length of the i^{th} segment.

We assume that some portion of this wood is deposited in fans and terraces where it eventually decays away and never affects the channel. The proportion available to affect the channel is given by the “delivery efficiency” E , which we assume to be around 40%.

FVS stand-growth modeling provides estimates of number, size, and species of trees available for recruitment within the ODF management area every year over the modeling term.

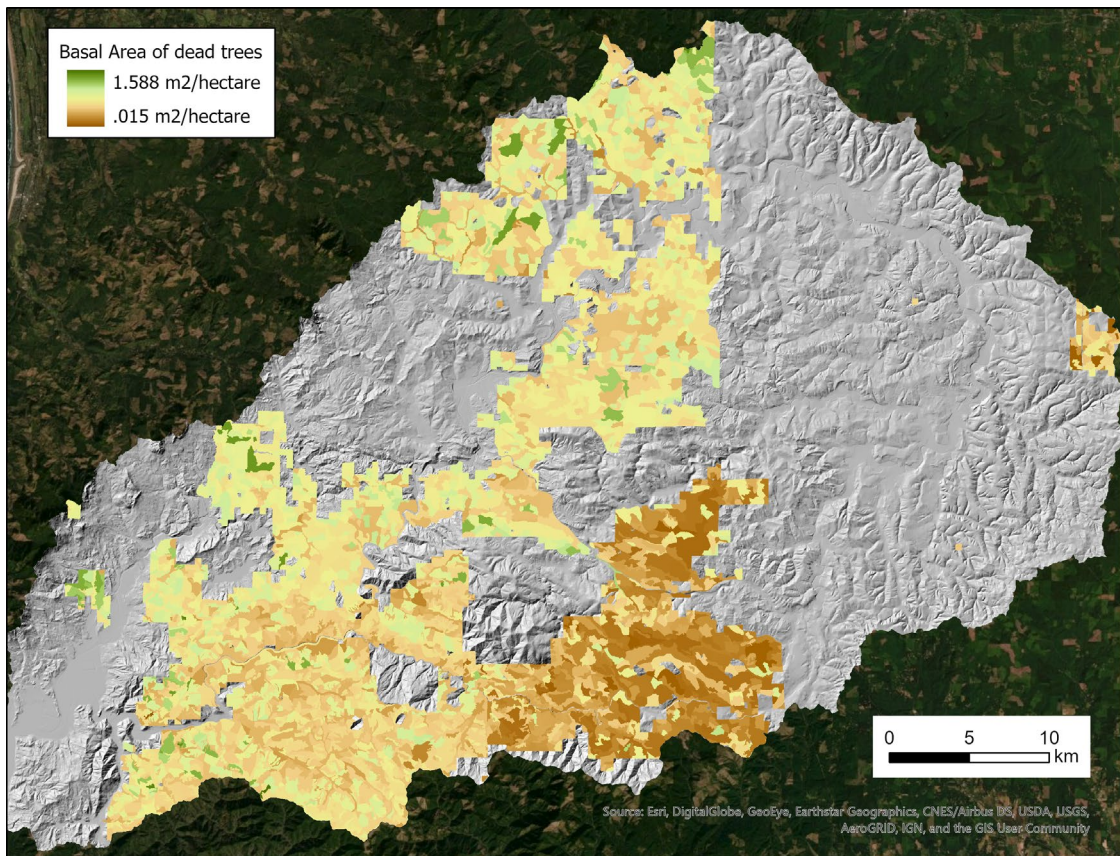


Figure 10. FVS predictions of the volume of dead trees across state forest lands in an Oregon Coast Range watershed.

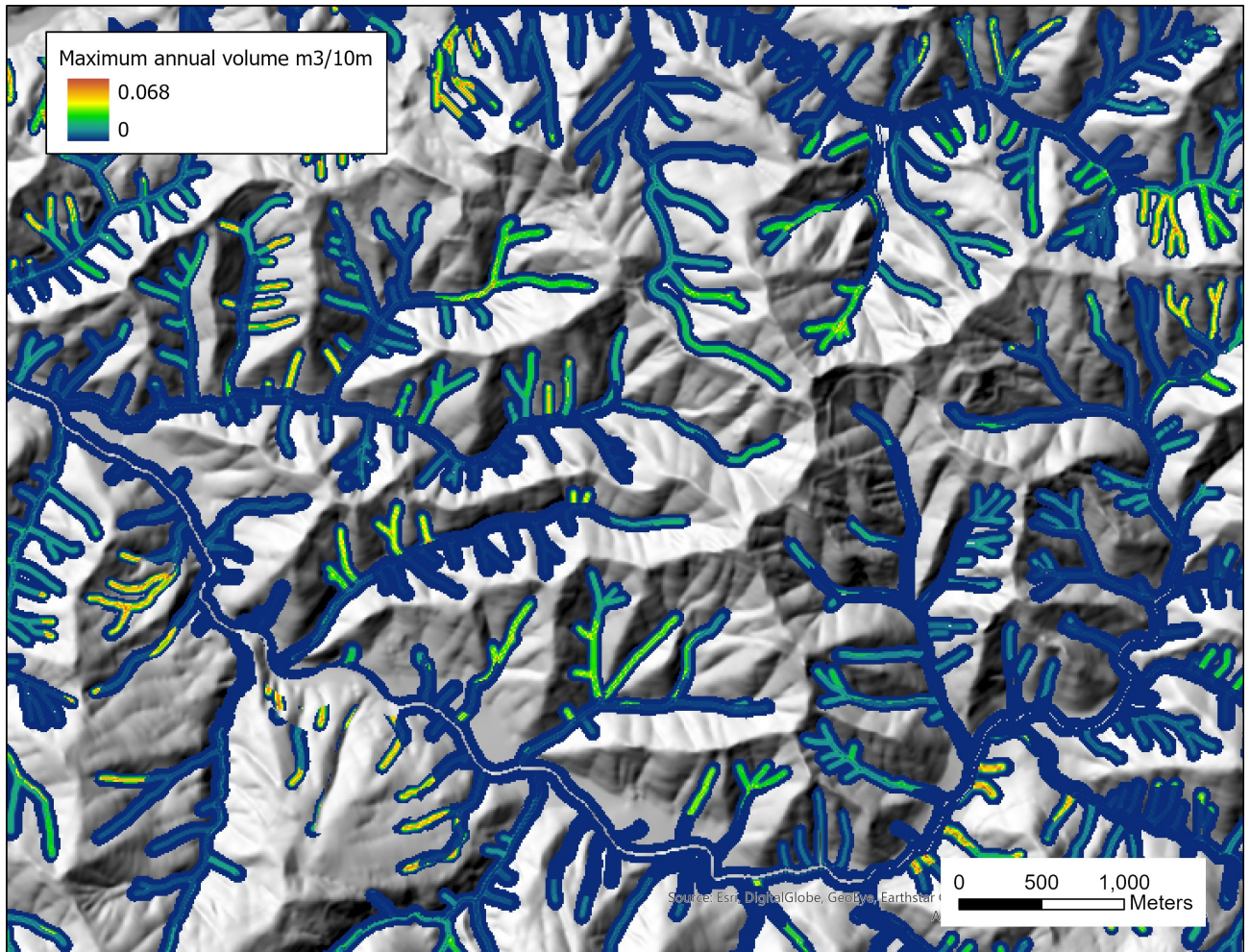


Figure 11. Each delineated channel segment receives an estimated average annual recruitment from each 100 m² DEM cell. Modeled recruitment rates vary with stand type and model year.

3.3 Recruitment by landslide and debris flows to fish streams

Upslope sources of wood include: (1) trees that fall directly into non-fish-bearing channels. Wood from these trees accumulates over time, with loss to decay, until picked up by a debris flow and carried downslope. (2) Trees deposited into non-fish channels by landslides from adjacent slopes. Wood from these trees also accumulates over time, with loss to decay, until picked up by a debris flow. (3) Standing trees knocked over and carried downslope by a debris flow. (4) A portion of debris-flow-carried wood is deposited onto fans and terraces and never accessed by the fish-bearing stream. (5) Direct landslide delivery. Standing trees knocked over and carried downslope by a landslide.

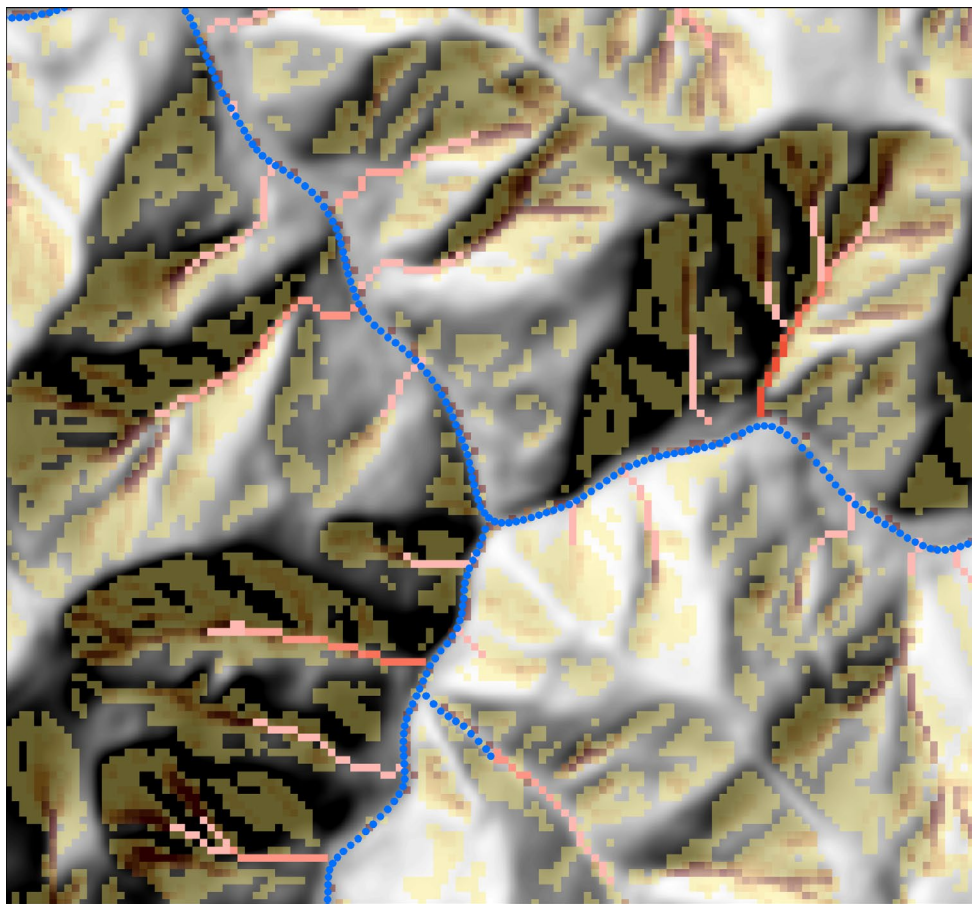
Debris-flow runout length correlates with deposit volume – larger debris flows travel further. Debris flows tend to scour material and bulk up when traversing steep, confined channels, and to lose material to deposition when traversing lower-gradient, unconfined channels and when they change direction at channel junctions. The probability that a debris flow will reach any point downslope decreases with distance, and the rate of decrease is a function of these attributes – gradient, confinement, changes in direction – integrated along the flow path.

From each DEM cell, the flow path can be traced downslope to a stream channel of interest (e.g., any channel, or only fish bearing) or until the probability goes to zero. If the probability is greater than zero at a channel of interest, that probability can be assigned to the originating DEM cell. This gives a map giving the probability of debris-flow delivery to the portion of the channel network of interest.

Initiation and delivery probabilities can be translated to probability that any DEM cell is traversed by a debris flow triggered upslope that continues to a fish-bearing stream.

Traversal probability
increases with:

- Higher upslope landslide initiation potential.
- Increasing number of upslope landslide initiation sites.
- Steeper, more confined transport corridors.



0 100 200
Meters

Figure 12. An illustration of predicted landslide density ($\#/km^2$) and debris flow traversal probability using the model of Miller and Burnett (2007, 2008).

Recurrence interval of debris flows.

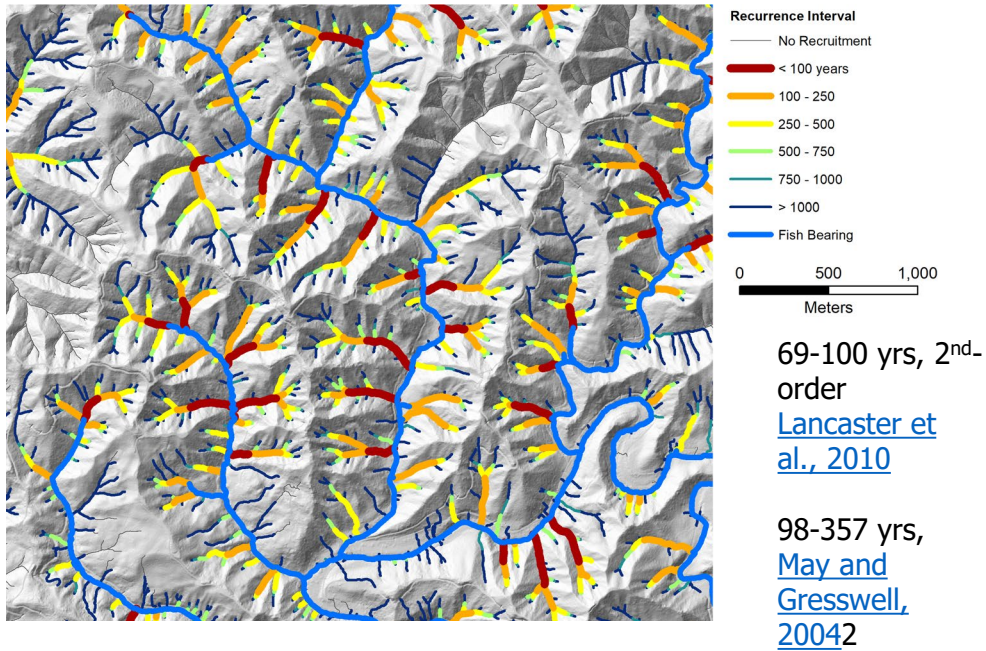
The empirical landslide susceptibility and debris-flow-delivery models (Miller and Burnett, 2007, 2008) provide a method for calculating the probability that any point in a channel network was traversed by a debris flow that traveled to a fish-bearing channel. The model was calibrated using landslide and debris-flow field surveys from basins in the Tyee sandstone following large storms in 1996, so the probability represents debris-flow events in that area from those storms.

We assume that the traversal probability is proportional to the frequency of debris flows; that is, the type of channel more likely to have been traversed by a debris flow in 1996 is also more likely to experience a debris flow over some future period. We express this proportionality as:

$$R = s/P_T, \quad \text{Eq. 4}$$

where s is a scaling factor and P_T is the modeled probability that a point in a channel was traversed by a debris flow from upslope that continued to a fish-bearing stream.

To set a value for the scaling factor s , we took the traversal probability value at the mouth of every non-fish-channel confluence with a fish-bearing stream, grouped these by non-fish channel Strahler stream order, calculated a recurrence interval for each for a specified scaling factor, and plotted cumulative frequency distributions of the resulting recurrence intervals. We then adjusted the scaling factor to give a median recurrence interval for each stream order consistent with estimates from other studies.



$$\text{Recurrence Interval} = I/P(t)$$

where I = empirical factor

$P(t)$ = probability of traversal by debris flow that travels to fish-bearing stream

Calibrated I for 3rd-order confluences

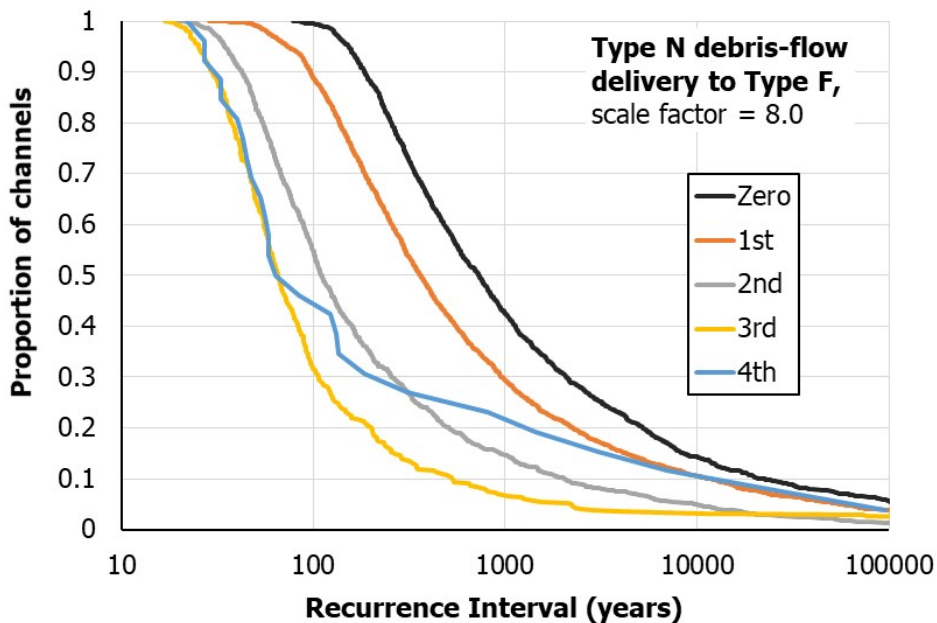


Figure 13. (upper) The predicted recurrence intervals of debris flows in non-fish streams, including extending up to landslide initiation sites (the latter with $Ris > \sim 500$ -years). (lower) Proportion of channels with the predicted recurrence intervals.

The average probability for debris-flow delivery of the accumulated volume of wood to a fish-bearing channel is one over the recurrence interval ($1/T$). Some proportion of the wood in a debris-flow deposit ends up stored on fans and terraces where it never interacts with the channel. Based on field observations in the Coast Range, the proportion that eventually interacts with the channel is estimated as 40% (Benda and Dunne, 1997; May and Gresswell, 2003), which is called the deposition efficiency E .

We translate the accumulation of wood to an average annual recruitment rate to fish-bearing streams as:

$$\frac{Er}{kT} (1 - e^{-kT}) \quad \text{Eq. 5}$$

where E is deposition efficiency, r is annual recruited volume to non-fish streams, k is decay rate (proportion per year) and T is recurrence interval (years).

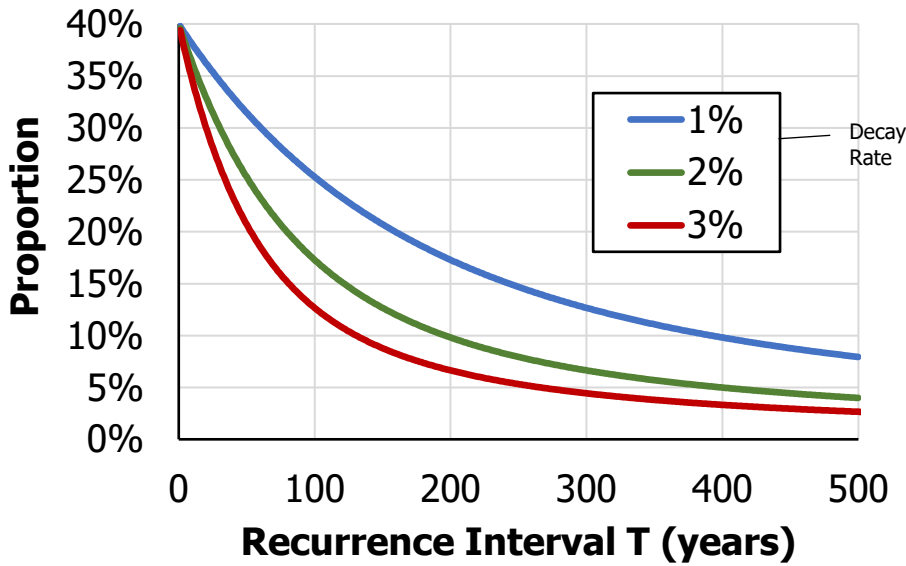


Figure 14. The relationship between relative recruitment rate per unit channel length and recurrence interval.

Wood falls into streams at an average annual rate of $2MH\rho/\pi$. Wood is lost to decay at a rate proportional to the total accumulated volume. Accounting for inputs from tree fall and loss to decay, the accumulated volume over time $t = R$ is $\left(\frac{2MH\rho}{\pi}\right)\left(\frac{1-e^{-kR}}{k}\right)$ per unit channel length. Eq. 6

Assuming all accumulated wood is carried by debris flow after time $t = R$ and that a proportion E of that wood is deposited in sites eventually available to a fish-bearing channel gives an average annual recruitment rate to fish-bearing streams per unit non-fish channel length of

$$\frac{E}{R} \left(\frac{2MH\rho}{\pi}\right) \left(\frac{1-e^{-kR}}{k}\right). \quad \text{Eq. 7}$$

The average annual recruitment rate to a fish-bearing stream is $2MH\rho/\pi$, so the relative recruitment rate of wood from non-fish to fish-bearing streams is $\frac{E}{kR} (1 - e^{-kR})$. Eq. 8

Debris flows also knock over and carry standing trees. To estimate the number of standing trees carried to a fish-bearing stream we multiply standing stem density (number per unit area) by the area of a debris-flow track minus the area of the channel it is traversing. Stem density within a stand varies with tree size, so we sum over all 4-in DBH size classes (the output from FVS) along the potential debris-flow track.

$$\#Trees = \int \rho(w_{DF} - w_C)dl \quad \text{Eq. 9}$$

where ρ is stem density, w_{DF} is the width of debris flow, w_C is channel width and l is debris-flow track length

Each tree is presumed to break into pieces, with a piece-size distribution a function of tree size. The largest piece from each tree then contributes to the volume of wood carried to the Type-F stream.

The summed volume is then multiplied by the deposition efficiency (E) and the probability of a debris flow occurring (estimated as one over the recurrence interval; $1/T$), to get average annual volume carried to Type-F channels.

To estimate the volume from standing trees carried by debris flows over some interval of time t (e.g., 70-yr rotation), we multiply the volume over the debris-flow track by the deposition efficiency E and by the probability P of a debris-flow occurring over that interval, given by:

$$P(t) = 1 - \left[1 - \left(\frac{1}{T}\right)\right]^t \quad \text{Eq. 10}$$

where $P(t)$ is probability of debris-flow occurrence during time t , t is the time interval (e.g., 70-yr rotation), T is debris-flow recurrence interval (years)

The volume of wood from standing trees carried to Type-F channels by landslides is estimated in a manner analogous to that used for debris flows. The number of trees by size class and species is determined from stem density, piece volumes estimated for each tree, volume of the largest pieces summed, the total volume multiplied by the estimated probability of landsliding (one over the landslide recurrence interval), and integrated over all area potentially traversed by landslides that deliver to a Type F-channel.

To estimate the volume delivered by landslides over some period of time, we multiply the estimated annual volume by the time period. Ideally, we should use the probability of a landslide occurring during that time, as defined with the equation for $P(t)$ (Eq. 5), but that required storing the recurrence interval for landsliding for each DEM cell. Simply multiplying by the time period slightly over-estimates the accumulated volume, but allows for much quicker run times of the program.

Some portion of the wood that accumulates in non-fish channels originates from landslides that deposit material in these channels. We estimate the volume of wood from standing trees delivered to non-fish channels by landsliding in the same manner as used for fish streams.

Wood deposited by landslides into a Type-N channel then decays over time until picked up by a debris flow. The volume ultimately carried to a Type F channel is estimated as:

$$V_{LS_annual} = \frac{EV_{LS}}{kT} (1 - e^{-kT}) \quad \text{Eq. 11}$$

where V_{LS_annual} is the average annual volume of wood from landsliding into Type N carried by debris flow to fish streams, V_{LS} is the average annual volume of wood deposited by landslides in non-fish channels, E is the deposition efficiency and T = debris-flow recurrence interval (years).

The volume from landsliding to Type N carried to Type F over a period of t years is estimated as:

$$V_{LS_accumulated} = \frac{EV_{LS}}{k} P(t) (1 - e^{-kt}) \quad \text{Eq. 12}$$

where $P(t)$ is the probability of debris flow occurring during t years.

Debris flows also scour wood that was deposited in the past. To estimate the volume of legacy wood available to be scoured from non-fish channels we looked at the volume that would be accumulated from the current stand over a period of time long enough that annual inputs equal annual loss to decay ($1 - e^{-kt} = 1$). This is written as:

$$V_{Legacy} = \frac{Er}{kT} \quad \text{Eq. 13}$$

where V_{Legacy} is the verage annual volume of legacy wood scoured from Type N channels and deposited into fish streams, E is depositional efficiency, k is decay rate and T is debris-flow recurrence interval.

The volume of legacy wood deposited into Type F channels over a period t is estimated as:

$$V_{Legacy} = \frac{Er}{k} P(t); \quad \text{Eq. 13}$$

$$P(t) = 1 - \left[1 - \left(\frac{1}{T} \right) \right]^t \quad \text{Eq. 14}$$

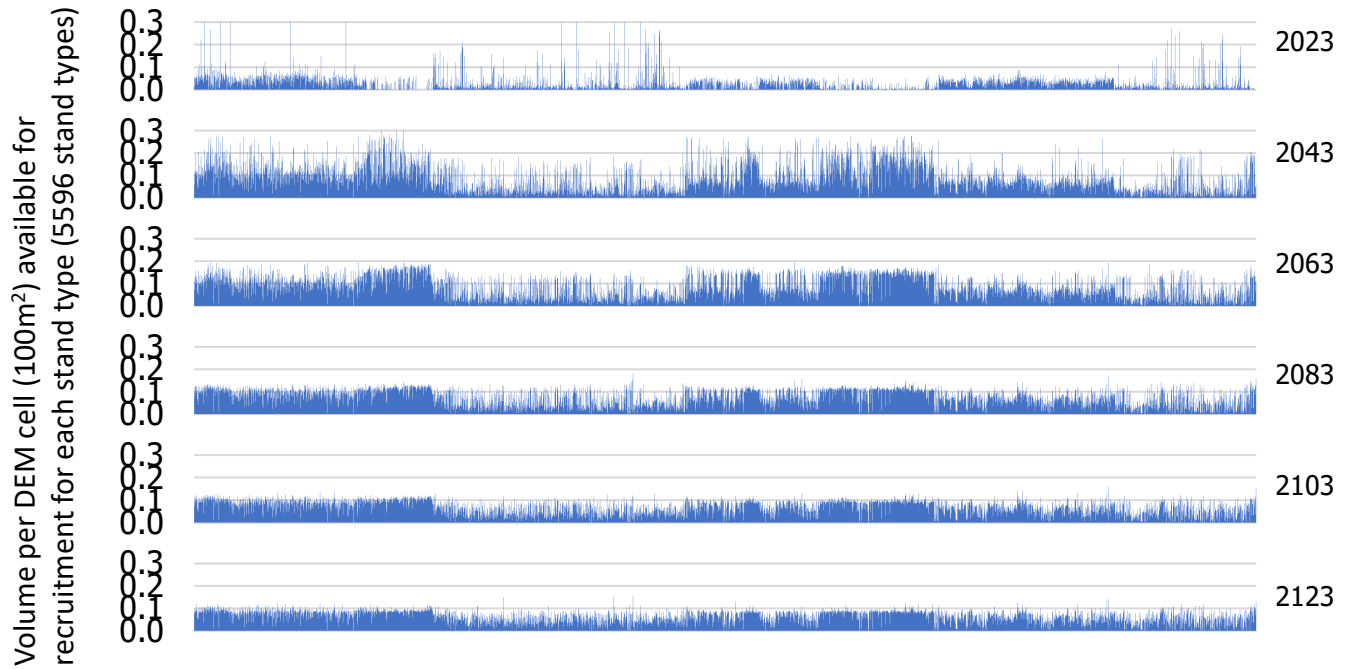


Figure 15. FVS indicates large mortality for some stands through the start of the simulation. Mortality, and hence the number of trees expected to fall, becomes more uniform across stands over time. Trees also become taller, increasing the area from which falling trees can reach channel edges.

4.0 Results

Modeling results include predictions of annual average recruitment to fish-bearing and non-fish streams across the study watersheds. Recruitment is separated into treefall and debris flow deposition of wood.

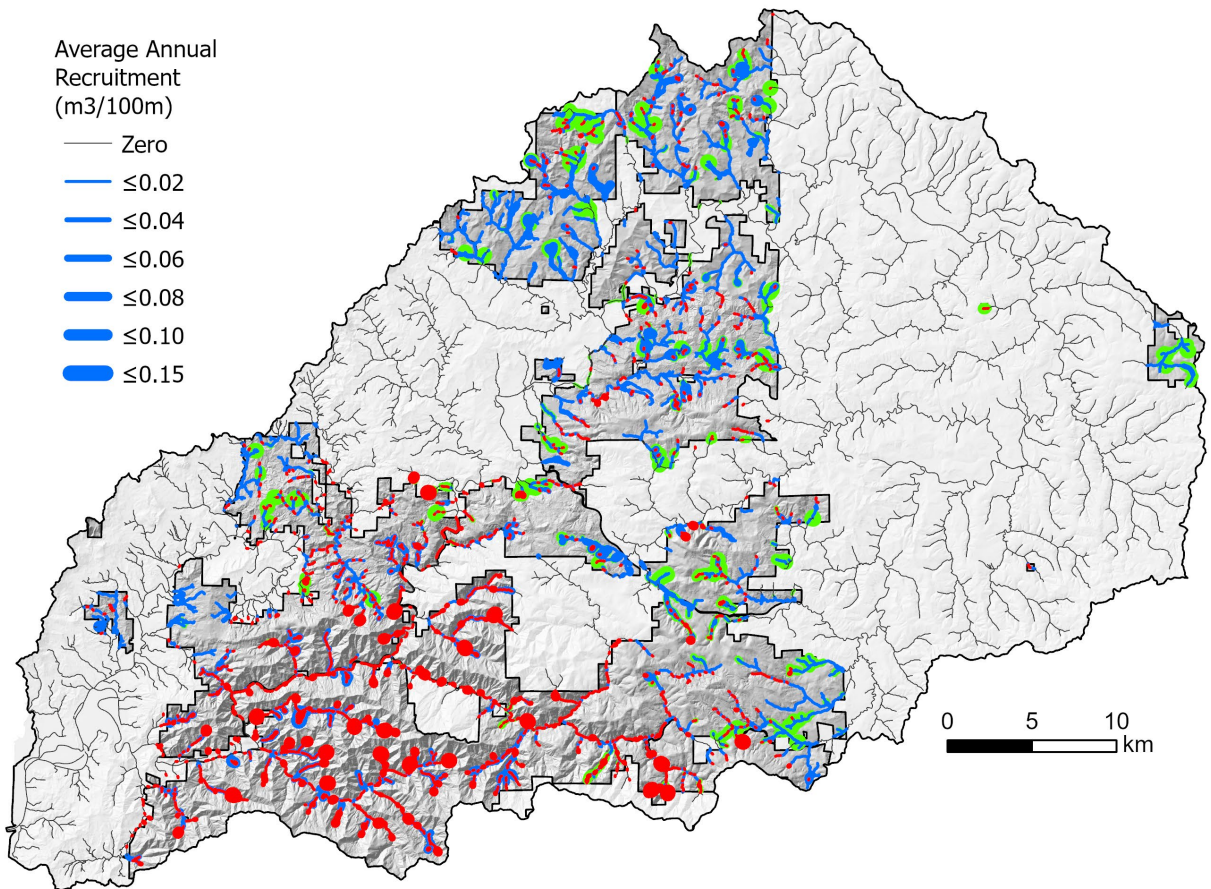


Figure 16. Modeled average annual recruitment of wood in fish-bearing streams across the study areas. Blue is riparian tree fall in year 2028; Green is riparian tree fall in year 2123; Red is debris flow contributed in year 2123.

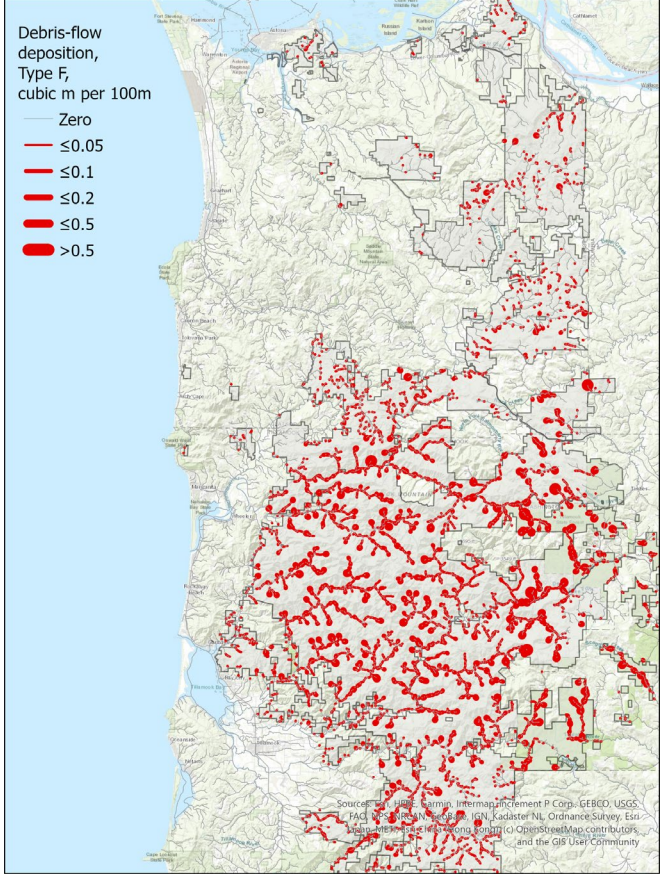
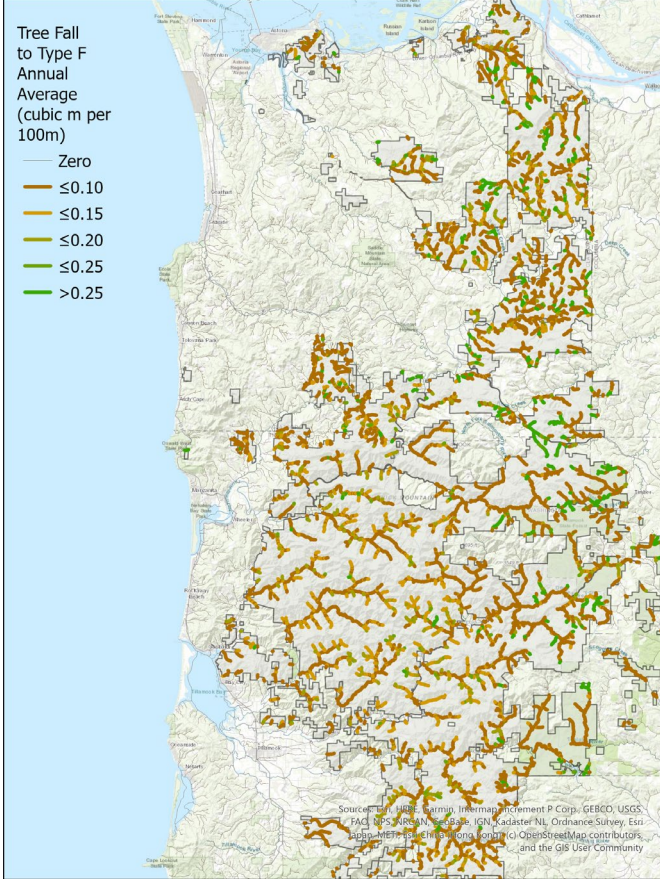
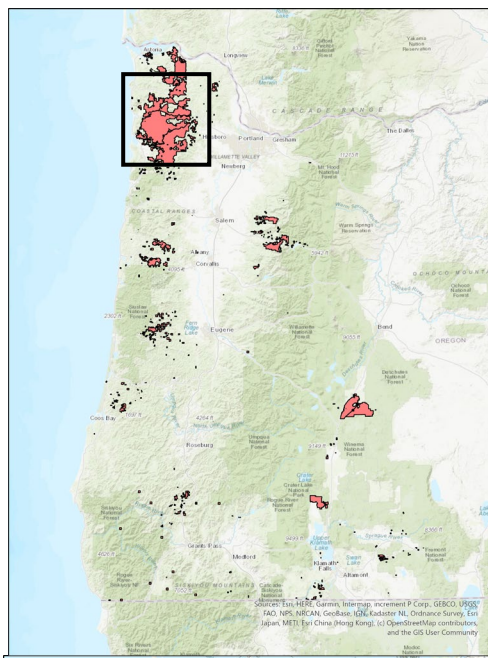


Figure 17. Model predictions include treefall by mortality recruitment and debris flow deposition of wood into fish-bearing streams. The area shown is within and near the Nehalem River watershed in northwestern Oregon.

Model predictions for the entire Nehalem study area for FVS model years 2028 and 2123 shows that the estimated average annual recruited volume increases over time.

As average tree height increases, the effect of buffer width increases, as seen by the decrease in the proportion of maximum recruitment obtained with the two buffer scenarios. However, both scenarios conserve over a high proportion of estimated recruitment.

Across the modeled portion of the basin, debris flows provide 11% to 12% of the total wood supply, although as seen from the previous map, this proportion varies greatly across the basin.

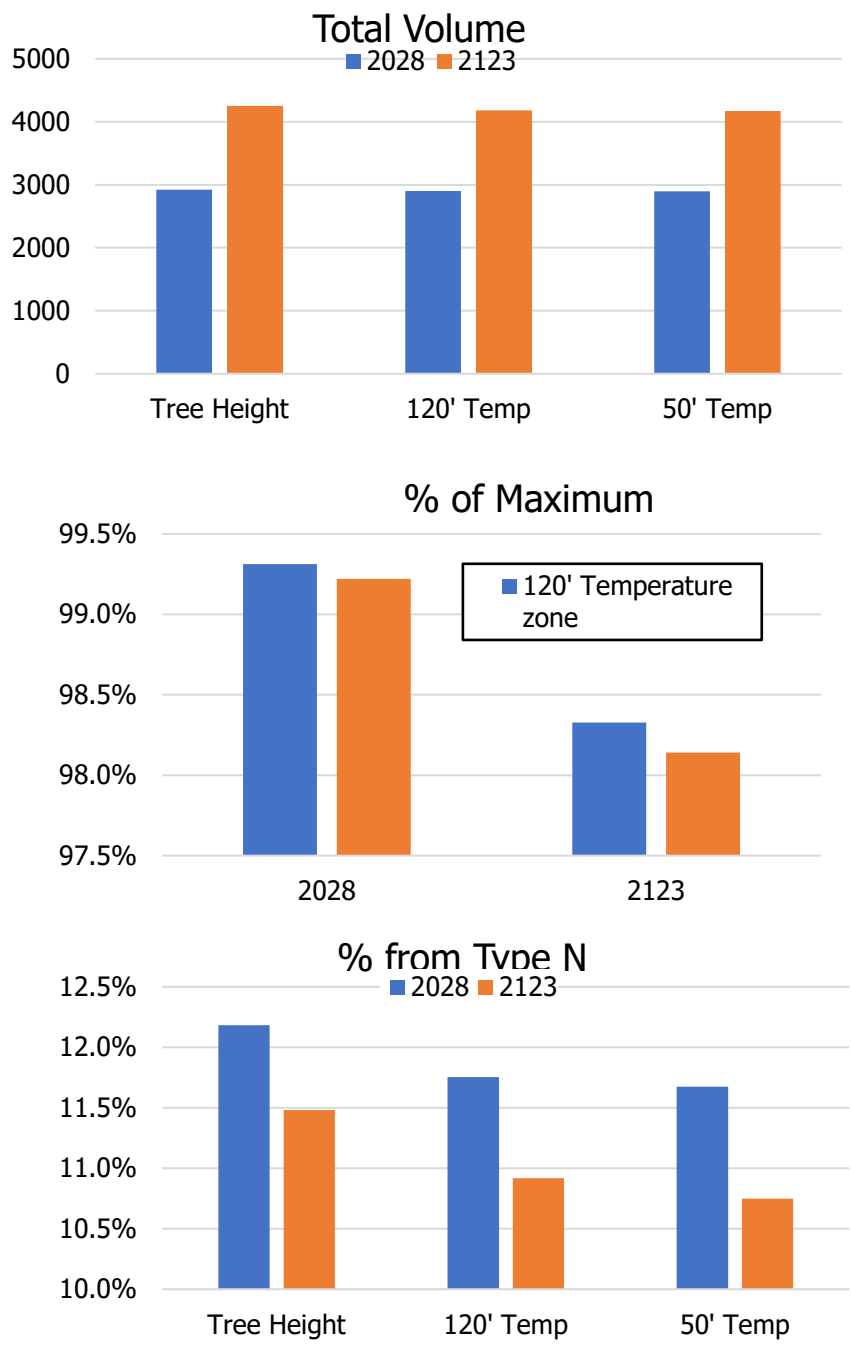


Figure 18. Model predictions reveal how increasing time affects tree heights and the wood volume associated with the 120 foot and 50 foot temperature zones, and the proportion of wood that originates from non-fish streams.

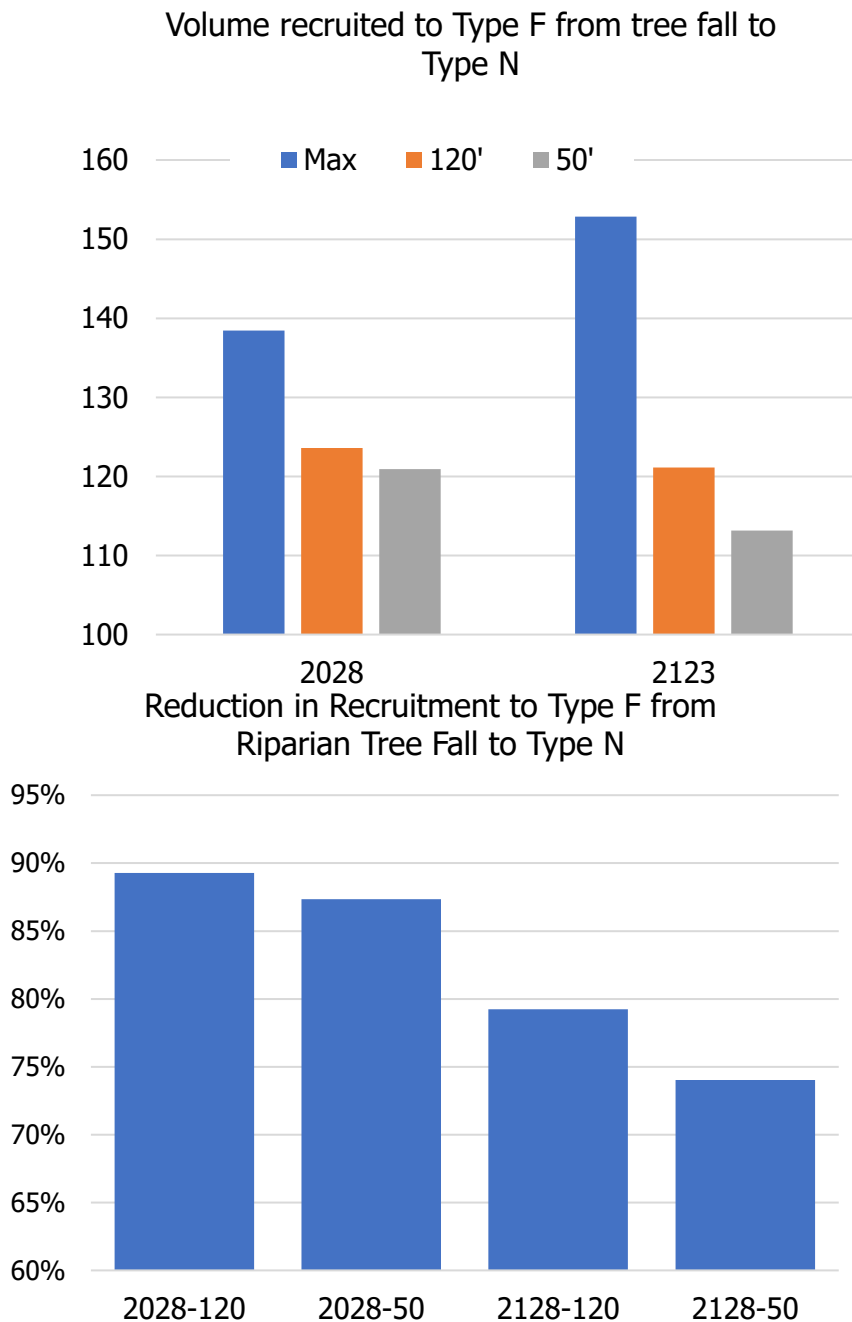


Figure 19. (upper) Predictions for modeled wood in fish-bearing streams that originated from treefall into non-fish streams, shows that changes in buffer width have a substantial effect. (lower) The model predicts a reduction in wood recruitment to fish-bearing streams from riparian treefall into non-fish streams over time (via debris flow).

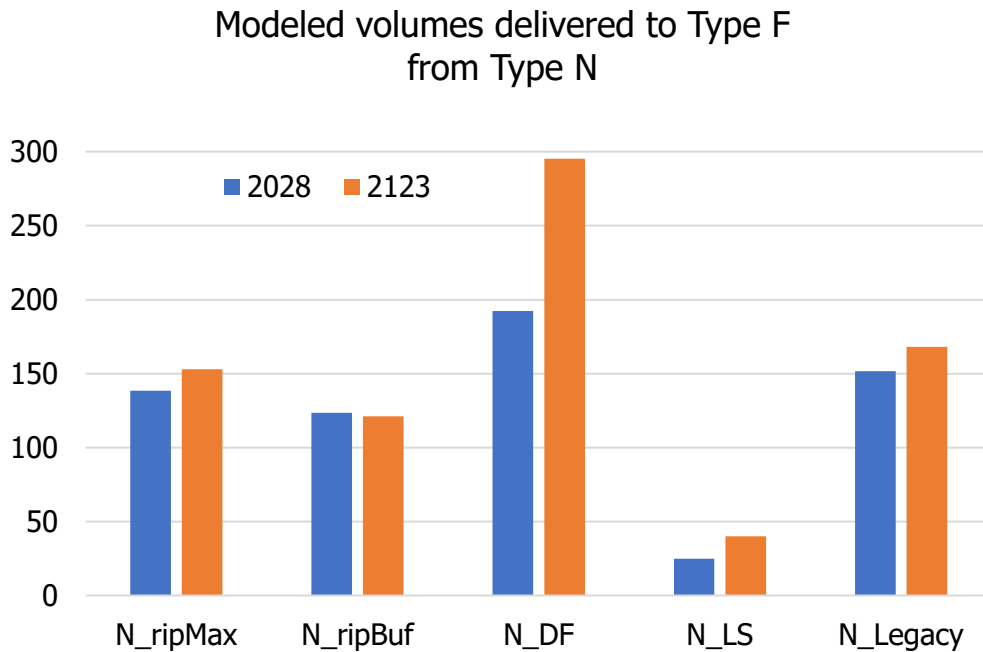


Figure 20. Modeled volumes delivered to fish-bearing channels. N_ripMax is the maximum volume of down wood from tree fall into non-fish; N_ripBuf is the volume with specified buffer; N_DF is the volume of wood from standing trees picked up by debris flow; N_LS is the wood deposited by landslides into non-fish and subsequently carried by debris flow to fish streams; N_Legacy is the wood accumulated since last debris flow.

5.0 Discussion

There are three sources of wood to fish-bearing streams. (1) Riparian tree fall. Trees that fall directly into fish-bearing streams. Wood from these trees accumulates over time with loss to decay. (2) Debris-flow delivery (traversal of non-fish streams by debris flows that travel to fish streams). Trees that fall directly into non-fish-bearing channels. Wood from these trees accumulates over time, with loss to decay, until picked up by a debris flow and carried downslope. (3) Trees deposited into non-fish channels by landslides from adjacent slopes. Wood from these trees also accumulates over time, with loss to decay, until picked up by a debris flow. Includes standing trees knocked over and carried downslope by a debris flow. A portion of debris-flow-carried wood is deposited onto fans and terraces and never accessed by the fish-bearing stream. We estimate that only 40% of all debris-flow-carried wood impacts fish-bearing streams. (3) Direct landslide delivery. Standing trees knocked over and carried downslope by a landslide.

Model estimates suggest that, over any extended time, 99% of observed debris-flows that deposit in fish-bearing streams will occur within 45% of the Type-N channels having a greater-than-zero probability of being traversed by a debris flow that continues to a fish-bearing stream. Type-N channels with modeled debris-flow recurrence intervals (for delivery to Type F streams) less than 5,000 years account for 99%. Likewise, the proportion-of-wood-available versus recurrence-interval curve flattens out around 5,000 years. So 5,000 years seems like a good choice, although we can set it anywhere.

The modeling of wood recruitment indicates that the protection levels of wood inputs (by volume) to fish-bearing streams is very sensitive to proposed stream buffers. The modeled source-distance curves start out very steep, indicating that most wood volume is derived from near the channel edge. This is because the largest-volume pieces are derived from the lowest portion of the tree bole. These pieces have the largest diameters and longest lengths, hence largest volumes, and only trees close to the channel edge that fall directly into the channel contribute these large-volume pieces. This result tends to mask the loss of smaller pieces that originate from trees further from the channel. If we were to examine recruitment in terms of number of pieces by size class, we may find that buffers have a larger impact on the number of smaller pieces recruited to channels.

The model predicts that debris flows constitute about 12% of the wood recruitment to fish streams. This is consistent with other simulation models (Benda and Sias 2003). Wood recruitment by debris flow is strongly dependent on the estimated recurrence interval of landslides in bedrock hollows and debris flows in headwater streams. The estimated recurrence intervals were assigned based on available field-based estimates of debris flow recurrence intervals (May and Gresswell 2004; Lancaster et al. 2010).

References

1. Benda, L.E. and T. Dunne, *Stochastic forcing of sediment supply to channel networks from landsliding and debris flow*. Water Resources Research, 1997. **33**(12): p. 2849-2863.
2. Benda, L.E. and T. Dunne, *Stochastic forcing of sediment routing and storage in channel networks*. Water Resources Research, 1997. **33**(12): p. 2865-2880.
3. Benda, L.E. and J.C. Sias, *A quantitative framework for evaluating the mass balance of in-stream organic debris*. Forest Ecology and Management, 2003. **172**: p. 1-16.
4. Benda, L., et al., *Wood recruitment processes and wood budgeting, in the Ecology and Management of Wood in World Rivers*, S.V. Gregory, K.L. Boyer, and A.M. Gurnell, Editors. 2003, American Fisheries Society: Bethesda, Maryland. p. 49-73.
5. Benda, L., et al., *NetMap: A new tool in support of watershed science and resource management*. Forest Science, 2007. **53**(2): p. 206-219.
6. Benda, L.E., D.J. Miller, and J. Barquin, *Creating a catchment scale perspective for river restoration*. Hydrology and Earth System Science, 2011. **15**: p. 2995-3015.
7. Benda, L. and P. Bigelow, *On the patterns and processes of wood in northern California streams*. Geomorphology, 2014. **209**: p. 79-97.
8. Benda, L.E., et al., *Thinning and in-stream wood recruitment in riparian second growth forests in coastal Oregon and the use of buffers and tree tipping as mitigation*. Journal of Forestry Research, 2015. **27**(4): p. 821-836.
9. Burnett, K.M. and D.J. Miller, *Streamside policies for headwater channels: an example considering debris flows in the Oregon Coastal Province*. Forest Science, 2007. **53**(2): p. 239-253.
10. Miller, D.J. and K.M. Burnett, *Effects of forest cover, topography, and sampling extent on the measured density of shallow, translational landslides*. Water Resources Research, 2007. **43**(W03433).
11. Miller, D.J. and K.M. Burnett, *A probabilistic model of debris-flow delivery to stream channels, demonstrated for the Coast Range of Oregon, USA*. Geomorphology, 2008. **94**: p. 184-205.
12. May, C.L., *Debris flows through different forest age classes in the central Oregon Coast Range*. Journal of the American Water Resources Association, 2002. **38**(4): p. 1-17.
13. May, C.L. and R.E. Gresswell, *Spatial and temporal patterns of debris-flow deposition in the Oregon Coast Range, USA*. Geomorphology, 2004. **57**: p. 135-149.
14. Clarke, S.E., K.M. Burnett, and D.J. Miller, *Modeling streams and hydrogeomorphic attributes in Oregon from digital and field data*. Journal of the American Water Resources Association, 2008. **44**(2): p. 459-477.
15. Lancaster, S.T., E.F. Underwood, and W.T. Frueh, *Sediment reservoirs at mountain stream confluences: Dynamics and effects of tributaries dominated by debris-flow and fluvial processes*. Geological Society of America Bulletin, 2010. **122**(11-12): p. 1775-1786.

Rates of Shallow Landslides, Effects of Forest Management and Implications for the Supply of Sediment and Wood to Fish Streams

Dr. Lee Benda, TerrainWorks, August 18, 2021

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1.0 Introduction

There are three Habitat Conservation Plan (HCP) efforts concurrently underway in Oregon in mid-2021, including the Elliott State Forest, the Western Oregon State Forests and the Oregon Statewide Private Forest Accord. Effects of forest management on the relationship between landslides and fish habitats is an important issue in all three. Terrainworks has been involved with these planning efforts, applying numerical models to predict areas prone to shallow landslides and debris flows and the delivery of wood to stream channels. Model results are being used by planning teams to design stream buffer strategies.

Timber harvest and forest roads can increase the frequency of landslides and debris flows. This is of concern regarding impacts to fish and other aquatic species and as it relates to the design and implementation of streamside riparian buffers and the management of steep slopes. The Elliott State Forest and the Western Oregon State Forest HCPs are concentrated in the Oregon Coast Range, while the Oregon Statewide Private Forest HCP extends across the state, including in the Cascade Range. Geomorphological conditions as they pertain to shallow landslides and debris flows are similar across mountain ranges in Oregon (**Figure 1**). The analysis described below focuses on the Coast Range, but the results can be applied more generally to other areas.

This report presents an overview of the factors governing rates of landslides and debris flows, the effects of forest practices on those rates, and the implications for the supply of sediment and wood to fish streams. It has been funded by the State of Oregon, via the Western Oregon State Forest HCP and Terrainworks. One objective of this analysis is to help inform perceptions of risk to the environment and hence for the need, design and implementation of forest management prescriptions. This is a work in progress and other contributions that would enhance our understanding of the relationships between mass wasting and fish habitats are welcomed.

2.0 Mass Wasting, A Geomorphological and Ecological Process

Stand-replacing wildfires occurred naturally in the Oregon Coast and Cascade Ranges (Teensma et al., 1991; Agee 1993). Landslides and debris flows often followed fires because of altered surface and subsurface runoff, loss of root strength and changes in pore water response during storms (Benda and Dunne, 1997b; Cannon, 2001; Rice, 1973; Keim and Skaugset 2003). Landslides and gully erosion also commonly occur during large rainstorms. Fire suppression that started in earnest after mid-20th century reduced the occurrence of fires, and thus fire-related landslides. Timber harvest since the early 1900s have replaced fire as the largest vegetation disturbance agent in Pacific Northwest forests (Means et al. 1996). Clearcut timber harvest can have similar soil destabilizing effects as fire in terms of loss of rooting strength and pore water response (Benda and Dunne 1997a). Current drought conditions in Oregon, and across the western US more generally is leading to larger fires with implications for erosion processes.

Landslides and debris flows are typically viewed as hazards, including in the context of forestry activities (Benda and Cundy, 1990; Montgomery et al., 2000; Sidle et al., 1985). Mitigation is a high priority at locations where lives and property are at risk, as reflected in Oregon forest practice rules (OAR 629-623-0000 through 0800, Forest Practices Technical Note Number 2 and Number 6). The science of landslides and debris flows as an erosion process that influences sediment supply to channels and shapes landforms in the Coast Range dates back to the late 1970s and early 1980s (Dietrich and Dunne, 1978; Humphrey, 1983; Pierson, 1977). Landslides and debris flows occur in clearcuts and in forests of all ages, including in old growth (Benda et al., 1998; Robison et al., 1999). Studies that quantified the relative importance of different erosion processes in watersheds, using a method called sediment budgeting,

revealed that landslides and debris flows dominate the supply of sediment to stream channels naturally in the absence of land use in the Coast and Cascade Ranges (Swanson et al., 1982; Benda and Dunne 1987). Mass wasting also contributes substantial amounts of large wood to streams across the Pacific Northwest (**Figure 2**) (Benda and Bigelow, 2014; Benda et al., 2003a; Bigelow et al., 2007; Reeves et al., 2003). Sediment budgets in other mountain terrains of the Pacific Northwest (Washington and California) also documented that mass wasting dominates the supply of sediment to river channels naturally (Lehre, 1982; Miller et al., 2002) and is responsible for much of fluvial and valley morphology (Benda et al., 2003b; Grant and Swanson, 1995). There is considerable literature on the productive ecological effects of mass wasting in terrestrial environments, including increased biodiversity (Geertsema and Pojar, 2006; Gonzalez-Ollauri and Mickovski, 2017). But the focus in the Pacific Northwest, particularly in Oregon, has been on aquatic systems.

Viewing landslides and debris flows as an ecological process in the Coast Range began in the early 1980s (Everest and Meehan, 1981). Mass wasting controls on fish habitat in coastal Oregon include deposition of boulders and large wood, besides gravel (Benda, 1990; May and Gresswell 2004), a process that was also documented in the Olympic Mountains of Washington, Cascades of Oregon and in Idaho (Benda et al., 2003a; Benda et al., 2003a; Miller and Benda, 2000). Pool habitats increase near deposits of logs and boulders and gravel provides spawning areas. Habitat cover and complexity can increase. Fish and riparian habitats in certain landscapes depends on the punctuated supply of sediment and wood from mass wasting, post fire or during large rainstorms (Flitcroft et al., 2016; Miller et al., 2008; Naiman et al., 1992; Reeves et al., 1995). In the Oregon Coast Range, mass wasting is responsible for much of the gravel bed morphology of fish streams (Benda 1990; Benda and Dunne 1997b; Reeves et al. 1995). Large, deep-seated landslides and earthflows also widen valleys and lower channel gradients, thereby creating high quality habitat for certain species, such as coho salmon (Benda and Miller 2008; May et al. 2013; Beeson et al. 2018).

Mass wasting, either naturally or related to human activities, also has immediate negative impacts on fish habitats. Landslides and debris flows likely cause immediate mortality of juveniles and adults in the area of deposition (Everest and Meehan, 1981). Debris-laden floods can impact habitats downstream from where landslides and debris flows deposit (Benda, 1985; Robison et al. 1999). Abrupt deposition of large quantities of coarse and fine sediment, along with trees, can bury pre-existing land- and stream forms, under the new habitat-forming materials. The timing and spatial distribution of landslides affect morphological outcomes. Widespread mass wasting following a hot fire can deposit very large quantities of coarse sediment in channels, leading to dewatering as flows go subsurface. In Harvey Creek, a tributary of the lower Umpqua River, the mid and lower parts of the channel network are buried under several meters of gravel, even covering the ubiquitous debris flow boulders at mouths of headwater tributaries (Reeves et al. 1995; Bigelow et al., 2007). Summer low flow is even lower. The abundant burned wood within the deposits and the uniform 150-year-old age of the forest, reveal that a wildfire burned through the watershed around the mid-1800s, followed by widespread mass wasting. Aerial photographs following the late-1930s Tillamook fires in coastal Oregon revealed widespread landslides, debris flows and gullying (Benda and Dunne 1997a, Figure 3) that led to deep sediment deposits in channels that was observed 60 years later.

Models for predicting locations of shallow landslides and debris flow runout began in the early 1990s (Benda and Cundy, 1990). By the mid-1990s, digital elevation models were being employed for predicting susceptibility to shallow failures (Montgomery and Dietrich, 1994). Comprehensive landslide

inventories (including landslides under forest canopy) following the large, 1996 storms in the Coast Range (Bush et al., 1997; Robison et al., 1999), led to development of empirically-calibrated landslide susceptibility and debris flow runout models (Miller and Burnett, 2007, 2008). The advent of these tools, combined with the newly available higher-resolution digital elevation data (LiDAR), led to calls to identify and protect upland mass wasting sources of large wood to fish streams (Burnett and Miller, 2007; Reeves et al., 2003; Reeves et al., 2016). The Oregon Dept. of Forestry adopted the concept of protecting debris flow sources of large wood in their Northwest and Southwest Oregon State Forests Management Plans (2001, rev. 2010). The HCPs underway in Oregon are engaging this concept in different ways.

There is a historical context when considering the effects of landslides on channel environments and specifically on fish habitats. Oregon Coast Range streams and rivers have had a long history of splash dams and log drives (Miller, 2010; Phelps, 2011; Sedell and Luchessa, 1981). A period of aggressive stream cleaning followed that removed wood. Some of the cleaning following timber harvest where the lack of riparian buffers led to debris entering streams until around the late 1970s. Between 1956 and 1976, the Oregon Game Commission removed large wood debris for the mistaken purpose of enhancing fish habitats and passage (Forestry, 2003). These activities contributed to low volumes of large wood in Coast Range streams. Many channels were scoured to bedrock and the lack of large wood further contributes to lower volumes of gravel storage (Montgomery et al. 2003). Consequently, in-channel restoration efforts often place log structures in streams (Banks et al., 2001; Forestry, 2003) to catch sediment, mobile wood and to create pools. Boulders have been placed in channels to mimic debris flow deposits and to enhance habitat complexity (Mueller, 2009). The artificial deposits of wood and boulders have been shown to create larger pool areas and attract higher densities of juvenile coho and trout (Roni et al., 2006). In these altered environments, mass wasting that supplies boulders, large wood and gravel can be particularly effective in enhancing aquatic habitats.

The processes involved with landslides and debris flows and their relationships to riparian and aquatic habitats are complex. There are aspects that are reasonably well known and are portrayed in numerical models, including the potential for shallow landslides in hollows and debris flow runout in headwater channels (see citations above). There is also considerable information on how mass wasting can alter and create habitats. But, predicting habitat losses and gains over time in a watershed, including related to formation of fans, terraces and boulder accumulations, downstream bedload transport and wood-related habitats, has not lent itself to quantitative predictive models. However, analysis of the relative magnitude of rates of landslides and debris flows across a watershed and over time, as described below, can inform our understanding of the ecological effects of mass wasting and the influence of forest management activities.

3.0 Stochastic versus Central Tendency Analysis

The occurrence of landslides and debris flows is fundamentally a dynamic process that varies over space and time. Rates of landslides are strongly dependent on the number and geometry of available landslide sites that vary spatially across watersheds and landscapes (Miller et al. 2003). The frequency, magnitude and location of natural landslides (or ones influenced by forestry activities) are governed by the number of potential landslide sites, the failure frequency of each (governed primarily by topography and soil production rates), and the frequency of storms, fires, tree blowdown and timber harvest. The number of

landslides that can occur in any year is a probabilistic outcome of the interaction between topography and climate, and the history of landslide-triggering storms and fires (Benda and Dunne 1997a).

Landslides are best characterized by a distribution of rates (number of slides per specified time period per area) associated with a particular likelihood or probability of occurrence (Miller et al. 2003) (**Figure 3**). Background landslide rates can be estimated using stochastic simulation modeling (Benda and Dunne 1997a; Miller et al. 2003), where predicted annual rates can vary by a few orders of magnitude, including many zeros. In this dynamic context, effects of timber harvest on landslide rates would be manifest as shifts in the probability distribution of those rates over time. This would be the most effective means of understanding the effects of forestry on landslides and aquatic habitats.

Stochastic simulation requires considerable information on climatic, vegetative and topographic controls on shallow failures, including soil production rates, geometries of population of landslide sites, vegetative root strength, soil cohesion, frequency and magnitude of wildfires and frequency and magnitude of storms. This type of analysis has been done (Benda and Dunne, 1997a, b; Dunne, 1991; Gabet and Dunne, 2003; Miller et al., 2002) but is rare in the Pacific Northwest. Into this mix in a forest management setting is the frequency and spatial distribution of timber harvest. Stochastic simulation modeling is beyond the scope of the present analysis involving HCPs. An alternate approach is to use central tendencies, or average values, to estimate the effect of timber harvest on landslide rates and its implications for the in-stream supply of sediment and wood. Characterizing the behavior of complex systems, like erosion regimes in mountain watersheds, often relies on estimating averages of process rates, including those of landslides and other types of erosion (Dietrich et al., 1982; Lehre, 1982; Reid, 1998; Swanson et al., 1982). A central tendency analysis of landslide rates that focuses on the Oregon Coast Range is presented below, but should be applicable to other landscapes.

4.0 Effects of Timber Harvest on Landslide Rates

Forestry activities can affect mass-wasting processes: timber harvest can increase susceptibility to landslide initiation and alter rates of landslides; increase the supply of sediment to streams; increase the supply of wood and boulders; and reduce the quantity and size of wood available to streams if certain upland areas lack buffers. All of these are concerns in the context of forest management generally, and specifically for HCPs and the management prescriptions associated with them.

There have been several field studies that have estimated the rate of landslides in the Oregon Coast Range and the effects of timber harvest. An often-cited statistic is the factor of increase of shallow landslides in clearcuts compared to older forests based on history of mass wasting. Field studies using a combination of photogrammetry and field work have reported a range of factors of increase, including 1.9 (Swanson et al., 1977); 3.6 (Ketcheson and Froehlich, 1978); approximately 2.0 (Robison et al., 1999); and 3.4 (Miller and Burnett, 2007) based on data collection by Bush et al. (1997) and Robison et al. (1999). The average across these four studies is 2.8, or an increase of 180%. The factors of increase were calculated over periods of one to a dozen years. These are similar to a clearcut factor of increase of 2-3 associated with a single, large storm in southwest Washington using a combination of photogrammetry and ground surveys (Turner et al. 2010). Montgomery et al. (2000), using a photogrammetry-based count of landslides in a regional setting available from numerous watershed analyses (WA, OR), estimated a factor of increase of 3 to 9 (average 5). But that estimate, unlike the others, used a C_{14} -based evaluation of a background landslide rate for comparison. C_{14} -analysis of landslide rates, inclusive of that study, is discussed below in 6.0. A re-evaluation of the Montgomery et al. (2000) analysis using

higher resolution topography (using an increase in bedrock hollow density [see 5.0]) reveals a factor of increase that averages closer to 3. Landslide inventories using aerial photography can undercount failures under canopy and thus over-represent landslides in clearcuts (Brardinoni et al., 2003). Only the Robison (1999), Miller and Burnett (2007) and Turner et al. (2010) studies accounted for that potential bias. The effect of fire on background landslide rates is not considered in the present analysis, but could be added.

The increase rate of landslides observed in clearcuts is considered primarily to be the result of decay of tree roots, loss of vegetative root strength and changes to pore water response during storms (Keim and Skaugset 2003; Schmidt, 1999; Sidle et al., 1985; Ziemer, 1981; Ziemer and Swanston, 1977). The immediate decay of tree roots following timber harvest results in a downward trajectory of root strength. Subsequent regrowth of the forest creates a corresponding increase in root strength. But the resulting temporary net deficit creates a period of heightened susceptibility to landslides called the “window of vulnerability” (**Figure 4**), a period estimated to extend for 10 to 15 years following harvest (Phillips et al., 2012; Ziemer, 1981). In the analysis below, the factor of increase of landslides because of timber harvest is applied to the first 15 years following harvest, during the window of vulnerability.

5.0 Spatial Density of Landslide Sites

Steep and convergent topography, commonly referred to as bedrock hollows and headwalls, is the primary landform associated with shallow landslides in soil-mantled hillslopes underlain by bedrock, including in the Oregon Coast and Cascade Ranges (Oregon Forest Practice Rules Tech. Notes #2 and #6; Pierson 1977; Humphrey 1983; Benda and Dunne, 1987; Dietrich and Dunne, 1978) (**Figure 1**). Mass wasting in bedrock hollows triggers scouring debris flows in steep, headwater basins that transport the accumulated sediment and organic materials downstream to larger channels (Benda and Dunne, 1987; Dietrich and Dunne, 1978).

Individual bedrock hollows can be identified using topographic maps (Pierson, 1977) and DEM-based landslide susceptibility models (Miller and Burnett, 2007; Montgomery and Dietrich, 1994). Using 1:24,000 aerial photography of clearcut areas in the Coast Range, Benda and Dunne (1997b) estimated an average bedrock hollow density of 100 per km². Montgomery et al. (2000) estimated a range of hollow density of between 80 to 100 per km² using similar techniques. Greater topographic detail is available using 1m LiDAR, and the application of the Miller and Burnett (2007) landslide model reveals a hollow density that averages closer to 160/km² (range 120 – 200) in highly dissected terrain, like in the central Oregon Coast Range (**Figure 5**). Lower-gradient hillsides and terrain modified by large landslides and earthflows have lower hollow densities. The average of 160 hollows per km² is likely approaching the upper limits of hollow density in Oregon mountain landscapes.

6.0 Landslide Recurrence Intervals and Rates of Landslides

The average recurrence interval (RI) of landslides at any site (average time between landslides at a particular location) is controlled by rates of bedrock weathering and soil accumulation (Dietrich et al. 1982; Benda and Dunne 1997). Dietrich et al. (1982) estimated an average landslide RI in individual bedrock hollows of 3,000 years based on filling an evacuated hollow with an estimated soil creep rate to a depth (2 m) considered susceptible to failure. Using an estimated average colluvium transport rate of 32 cm³/cm/year obtained from radiocarbon dating of bedrock hollows in the Coast Range by Reneau and Dietrich (1991), Benda and Dunne (1997a) estimated an average landslide RI in Coast Range hollows of 2,500 years (range 750 to 3,750). This was similar to four radiocarbon dates collected at the base of

surviving colluvium in landslide scars in hollows in the Coast Range (1,600, 4,000, 6,300 and 9,400 years) that averaged 5,300 years (Benda and Dunne 1987). Montgomery et al. (2000) compiled 13 radiocarbon dates from remnant colluvium in failed bedrock hollows (including from Benda and Dunne 1987 and Reneau and Dietrich 1991) and calculated an average landslide RI of 5,600 years (+/- a standard deviation of 2,800 years). It is likely that landslide RIs vary across a population of bedrock hollows, with lower RIs associated with steeper and more convergent landforms and higher RIs associated with less steep and convergent areas. There aren't enough data to determine this type of variability and so a single, average value is used in the analysis below.

Thirteen dates out of thousands of bedrock hollows represent a small sample and it could be argued that they aren't representative of the larger population. But there is other, more commonly observed evidence that accords with the reasoning that colluvium accumulates along hollow axes over thousands of years attaining depths of a few meters prior to failure. Observations made by the author (Benda and Dunne 1987; Benda and Cundy 1990; Benda and Dunne 1997a) and by others (Reneau and Dietrich 1991; Humphrey 1983; Pierson 1977; Dunne 1991; Wilson and Dietrich 1987) indicate that depths of colluvium in unfailed hollows are commonly on the order of a few meters. Based on principles of bedrock weathering (Dietrich et al. 1982; Reneau and Dietrich 1991), development of colluvium of a meter or more along axes of hollows would require several thousand years, in accordance with C_{14} dates. Moreover, principles of slope stability pertinent to shallow failures indicate thicknesses of a few meters of colluvium are necessary to promote landslides (Dietrich et al. 1982; Benda and Dunne 1997a).

6.1 C_{14} -Based Long-Term Background Landslide Rate

Rates of landslides are generally described in terms of number of slides per unit area per unit time. Using the C_{14} -based average landslide RI, a theoretical background landslide (ls) rate is estimated by multiplying the RI with the average landslide site density, or $1/5,600 \text{ years} * 160 \text{ sites/km}^2 = 0.029/\text{km}^2/\text{year}$. Varying the RI from 2,800 to 8,400 years (+/- one standard deviation) yields $0.057 - 0.019/\text{km}^2 \text{ year}$. This is similar to the C_{14} -based landslide rate of 0.017 (range 0.01 to 0.03) by Montgomery et al. (2000) that used the same C_{14} -based average landslide RI (5,600 years) but with a hollow site density of 80 to 100 per km^2 . Using a higher bedrock hollow density detectable from LiDAR ($160/\text{km}^2$), Montgomery et al. (2000) estimated average landslide rate would be the same as reported here.

6.2 Average Landslide Rate Affected by Timber Harvest

The calculated average rate of landslides can be increased by a factor because of lower root strength during the window of vulnerability. Using the landslide inventories reported in 4.0, the average rate of increase is about three. This yields an estimate of the adjusted average post-harvest (clearcut) landslide rate of $3 \times 0.029/\text{km}^2/\text{year} = 0.086/\text{km}^2 \text{ year}$. Varying the RI from 2,800 to 8,400 years yields a range of $0.171 - 0.057/\text{km}^2 \text{ year}$.

The landslide rate can be integrated over a timber harvest rotation; in Oregon, the average rotation age of industrial private forest lands is approximately 40-years. The increase in landslide rates, post-timber harvest, is assumed to apply to the first 15 years, reflecting the window of vulnerability. It is assumed that there is no increase from year 16 through 40. The timber harvest rotation integrated landslide rate is: $[0.086/\text{km}^2/\text{year} * (15/40)] + [0.029/\text{km}^2/\text{year} * (25/40)] = 0.05/\text{km}^2/\text{year}$.

6.3 Measured Short-Term Landslide Rates

Field studies that counted landslides in clearcuts compared to older forests, using photogrammetry, can be used to calculate landslide rates over short time periods covering small areas.

Table 1. Empirical landslide inventory studies in the Oregon Coast Range that predicted landslide rates in clearcuts (not including roads).

- 1) Swanson et al. (1977): 317 landslides in 57 km² in 10 years, or 0.6/km²/year.
- 2) Ketcheson and Froelich (1978): 104 slides in 4.4 km² over 6 years, or 2.2/km² year.
- 3) Robison et al. 1999 (1996 single storm): 5 core study areas (Elk, Scottsburg, Mapleton, Tillamook and Vida) 151, 77, 92,49 and 52 slides in 16.8, 18.6, 21.5,11.7 and 7.4 km² yielding rates of: 9, 4.1, 4.3, 4.3 and 7.1/km²/year.
- 4) Montgomery et al. (2000): 25 landslides in 0.43 km² in 10 years includes 1996 storm: 5.8/km²/yr.

Montgomery et al. (2000) also calculated a regional timber harvest-effected landslide rate across 2,993 km² covering 50-years of inventory records compiled during watershed analyses in Oregon and Washington. Based on their landslide susceptibility modeling, 13% of that study area was considered highly prone to landslides (389 km²). The average landslide rate for non-road failures over the 13% of the study area was 0.09 ls/km²/year. A review of a subsample of five watershed analyses (West Fork Tilton [1998], Hoko [1993], Cabin Creek [1997], Warnick [1994] and Canyon Lake Creek [1993]) indicated that inventoried landslides in clearcuts comprised an average of 90% of the sample (range 82% - 100). Thus, Montgomery's calculated average rate of 0.09/km²/year likely applies to recent clearcuts. Using Montgomery et al. (2000) C₁₄-based RI of landslides of 0.017/km²/yr (based on an average hollow density of ~100 per km²), yielded a clearcut factor of increase of 3 to 9 (based on C₁₄ RI standard deviation, average 5). Using a higher hollow density detectable using LiDAR (160/km², described in 5.0, Figure 5) would adjust the C₁₄-based RI equivalent to 0.029 (6.2), yielding a factor of increase closer to 3.

Landslide inventories designed to document effects of timber harvest (or even fire, see Klock and Helvey 1976) seek out areas with countable events (Robison et al. 1999). Landslide inventories over relatively small areas and short time intervals will result in higher rates compared to the long-term C₁₄-based rate. Conversely, landslide inventories in older forests over short time and small spatial extents should document small landslide rates, including zeros. This is expected, as rates estimated over small areas and short time intervals should have large departures around mean values (Figure 2) (Miller et al. 2003). A plot of empirical and C₁₄-based landslide rates reveals a negative correlation between area and time product and landslide rates (**Figure 6**). The area-time product of empirical landslide studies corresponds to the size of the study area and the time period covered by the data collection, and in the case of C₁₄ rates, the RI of landslides per site and the hollow density per km².

The calculated average landslide rate applies to large watershed areas over multiple decades and longer. Landslide rates that occur over shorter time intervals can be much larger. Rates measured in clearcut areas of 0.5 to 50 km² over one to ten years ranged from about 1 to 6/km²/yr (Table 1); some were associated with large storms, like in 1996. Landslide rates will vary year to year, some higher, some lower, with several-year watershed averages above and below the longer-term average. But, over multiple decades, the year-to-year rates, when averaged, should match the longer-term regional rate. This is evidenced by the parity of Montgomery et al. (2000) regional landslide rate in clearcuts compared to the average C₁₄ rate estimated for clearcuts (0.09/km²/yr vs. 0.086/km²/yr).

In the context of the average landslide rate for clearcuts with trees less than 15 years old (window of vulnerability), what proportion of time would have those rates (assuming the higher rates applied to all clearcut areas at any particular time)? Or, in other words, how common would the higher rates be within a probability distribution of rates? The average clearcut landslide rate is 0.086/km²/yr (3 x background C₁₄ landslide rate). The larger, shorter-term rates would need to be offset by smaller rates over time, that may include zeros. For the purpose of an illustrative calculation and lacking other data,

it's assumed that the lower rates are equivalent to the background rate of $0.029/\text{km}^2/\text{yr}$. Across an arbitrary area of post-timber harvest with vegetation less than 15-years old, 1.6% of time would have the larger empirical rate of $3.5/\text{km}^2/\text{yr}$ (average of rates in Table 1) or $[(3.5/\text{km}^2/\text{yr} * 0.016) + [0.029/\text{km}^2/\text{yr} * 0.984] = 0.086/\text{km}^2/\text{yr}$. Using the highest rates in Table 1 that included the large 1996 storms (5.8 and $6.0/\text{km}^2/\text{yr}$), yields an estimate of about half that, or $< 1\%$ of the time. This is equivalent to an approximate one in 100-year probability. The 1996 storms have been estimated to have a recurrence interval of 50- to 100-years (Robison et al. 1999).

7.0 Calculating Landslide Rates and Number of Landslides Related to Timber Harvest

Using the estimates of C_{14} -based landslide rates and the increase because of timber harvest, we can calculate the average number of landslides that could be expected to occur over specified areas and times. To estimate the average number of landslides over a given area over a given time, the landslide rate is multiplied by land area and the time period of interest. Landslide rates, including the effects of timber harvest, can be calculated for private forest lands only. But, in Oregon, and in particular in the Coast Range, private forest land is intermixed with federal forest lands (national forest, BLM), often in a "checkerboard" pattern. Private – federal forest land boundaries are numerous and cut across streams and hillsides. In the context of an HCP concerned with populations of fish (like coho salmon) within large watersheds over decades (timespan of an HCP) with mixed ownership and diverse forest management, landslide rates can be calculated at the watershed scale, encompassing all lands. Across all of the basins supporting independent populations of coho salmon within the Oregon Coast Evolutionarily Significant Unit (ESU, NMFS 2016), private forest lands comprise an average of 55% (+/- 1 Std of 24%) of the area (Terrainworks, unpublished data).

Landslide rates are calculated for a generic square kilometer of watershed. It's assumed that the area is equally prone to shallow landslides, with an average bedrock hollow density of 160 per km^2 . The increase in landslide rates (3x, or 200%), post-timber harvest, is applied to the first 15 years, reflecting the window of vulnerability. There is no increase from year 16 through 40. Federal land that is managed under the Northwest Forest Plan restricts harvest on landslide-prone slopes; no increase in landslide rates on federal land is applied.

7.1 Private Land, Background Forest vs Timber Harvest, 40 years:

In this estimate, the average C_{14} -based background rates of landslides ($0.029/\text{km}^2/\text{yr}$) and the timber harvest-integrated rate ($0.05/\text{km}^2/\text{yr}$) (6.1 and 6.2) are applied.

Background: $0.029/\text{km}^2/\text{year} * 40 \text{ years} = 1.16 \text{ landslide per km}^2 \text{ per 40 years}$ (1)

Managed: $0.05/\text{km}^2/\text{year} * 40 \text{ years} = 2 \text{ landslides per km}^2 \text{ per 40 years}$ (2)

The increase in the predicted average number of slides during a timber harvest rotation is $2 - 1.16 = 0.84$ landslides per km^2 over 40 years. The factor of increase is $2/1.16 = 1.72$ (72%). This is equivalent to an average increase in the number of landslides over a 40-yr harvest rotation of about one landslide per square kilometer (or 2 landslides per square mile per 40-year rotation).

Based on the landslide and debris flow model of Miller and Burnett (2007, 2008), as applied to study watersheds in the Oregon Coast Range (PFA HCP pilots, Terrainworks unpublished data), 65% to 75% of predicted landslide source areas deliver to fish streams, via direct landslide delivery to channels, or because landslides trigger debris flows in steep, headwater channels that deposit in fish streams. Thus, the expected increase in the average number of landslides-debris flows that deliver to fish over a 40-

year timber harvest rotation period (using 70% average delivery) is about 0.6 landslide per square kilometer (0.7×0.84) or 1.6 landslide per square mile.

As outlined above, landslide rates, whether background or in timber harvest areas, can be much higher (and lower) than the mean rate. That would shift the estimates above to higher values over shorter time frames, that would need to be offset by smaller values over other time frames, to match the longer-term mean. To estimate those effects would require a stochastic simulation analysis, presently not available.

7.2 All Lands Analysis (Private + Federal)

In this estimate, the average proportion of federal lands in coho independent population basins (45%) is applied, with the remainder assigned to private forest lands (55%); state and other lands are ignored.

Background: $0.029/\text{km}^2/\text{year} \times 40 \text{ years} = 1.16 \text{ landslide per km}^2 \text{ per 40 years}$ (3)

Managed: $[0.55 \times 0.05/\text{km}^2/\text{year} \times 40 \text{ years}] + [0.45 \times 0.029/\text{km}^2/\text{year} \times 40 \text{ years}] =$
 $1.1 + 0.52 = 1.62 \text{ landslide per km}^2 \text{ per 40 years.}$ (4)

The increase in the predicted average number of slides during a timber harvest rotation is $1.6 - 1.16 = 0.46 \text{ landslides/km}^2/\text{yr}$. The factor of increase is $1.62/1.16 = 1.4$ (40%). This is equivalent to an average increase in number of landslides of about 0.5 landslide per square kilometer over the 40-year rotation (or 1.3 landslide per square mile per 40-year rotation).

Using an average landslide/debris flow delivery rate of 0.7, the delivered landslide rates for background and managed are respectively 0.8 and 1.1 landslide per km^2 per 40 years. The expected increase in the average number of landslides-debris flows over a 40-year timber harvest rotation period is thus 0.33 landslide per square kilometer or 0.85 landslide per square mile.

The estimated number of landslides and percent increases are based on average long-term rates (6.0). Variation around the mean (+/- one standard deviation) would result in small increases and decreases in the predicted average number of landslides. The calculated average landslide rates and their increases over the 40-year rotation are not time sensitive. In any year, 1/40th of private forest land is within each forest age annual year class; so, the landslide window of vulnerability accounts for 15/40ths (38%) of the area; to calculate the absolute number of average landslides expected to occur across space and time (40-year rotation), watershed area does matter.

8.0 Interpretation

Landslides and debris flows are a natural process that supply large amounts of wood and gravel to streams that create fish habitats. Yet, mass wasting can impact existing habitats and kill fish at the site of deposition. Interpreting the ecological effects of any increase (or decrease) in rates of landslides and debris flows is made complicated by this dichotomy. There are several lines of evidence and reasoning that can be used to help understand the geomorphological and ecological implications of changing rates of landslides and debris flows in managed forests to gauge measures of risk and the need and design of management prescriptions.

Landslides in hollows often trigger debris flows in headwater channels that deposit sediment and woody material into larger, fish-bearing streams. There's a relationship between recurrence intervals of landslides in hollows and recurrence intervals of debris flows in first- and second-order channels. In their analysis, Benda and Dunne (1997a, b) estimated an average RI of landslides of 0.0004 (1/2,500 years)

compared to the average RI of debris flows in first- and second-order channels of 0.0017 (1/600 years) and 0.0033 (1/300 years). In a typical watershed square kilometer, there are approximately two first-order and three-second-order channels, and 20 hollows, that intersect alluvial, fish-bearing third- and higher order channels (Benda and Dunne 1997). Based on this average network geometry and RIs, the aggregate rate of landslides and debris flows intersecting the higher-order channel is approximately 0.021/km²/yr. This is similar to the background landslide rate (0.029/km²/yr) computed above. Debris flows in headwater streams may be more frequent (Lancaster and Casebeer 2007; Lancaster 2008) which would increase the aggregate rate. In the analysis below on implications for sediment budgets and channel impacts, the term landslides, in regards to rates, is also used to refer to the aggregate occurrence of landslides and debris flows intersecting alluvial channels.

8.1 Spatial and Temporal Context of Landslide Rates and Landslide Numbers

The analysis indicates that the landslide rates calculated over small areas and short time intervals (whether from large storms, timber harvest or fires) are not representative of landslide rates that occur across watersheds and longer, multi-decadal time periods (Figure 6). It also reveals that the long-term C₁₄-based average landslide rates are representative of landslide rates that apply to larger watersheds over longer time frames (like timber harvest rotations or the average interval between stand-replacing fires); at subbasin scales, there may be decades with zero failures as forests regrow. The longer-term landslide rates representative of forested, clearcut and timber harvest (40-year rotations) conditions should be representative across Coast Range Coho ESU independent population basins that average 1,100 km², over multi-decades.

Failures at individual bedrock hollow landslide sites are rare occurrences, happening on average once every 5,600 years (background) or 3,200 years in timber harvest areas (40-year rotation). Hence, in clearcuts (vegetation < 15 years old), on average, 0.03% of potential landslide sites will fail in any year (99.95% not failing) and 0.5% in the 15-year window of vulnerability during one harvest rotation. But, as shown in empirical landslide inventories over shorter time intervals, landslide rates in clearcuts can be much higher than the mean rate (3.5 ls/km²/yr [average of Table 1 rates] / 0.086 ls/km²/yr [clearcut rate, Section 6.2] = 40). The highest rates will be offset by lower rates, so that their average, over time, should match the long-term estimated clearcut rate of 0.086 ls/km²/yr. It was estimated (Section 6.3) that the highest empirical rates (like those associated with the 1996 storms) would occur rarely, every 50 to 100 years.

These predicted proportional increases in landslide rates because of timber harvest can translate to actual landslide numbers. The central tendency analysis of landslide rates indicated that the expected average increase in landslides that deliver to fish streams on private forest lands over a timber harvest rotation (40-years) is a relatively modest, < 1 landslide/debris flow per km² per 40-year timber harvest rotation. When federal lands are included, the average landslide (and debris flow) rate drops to ~1/3 ls/km²/year. As shown in Figure 6, landslide numbers over smaller areas and shorter time intervals can be higher and lower compared to mean values, but to analyze that effect would require stochastic simulation, an analysis presently not available. The estimated landslide occurrences are representative of large areas over several decades, as evidenced by their parity with Montgomery et al. (2000) regional landslide rate (Figure 6). At the scale of an average-sized ESU-relevant watershed (~1,000 km²), there would be, on average, 330 additional landslides per 40-years, or about 8 landslides or debris flows that deliver to fish streams per year.

8.2 Changes to the Sediment and Wood Budget

How does one interpret the 3x (200%) increase in landslide rates because of timber harvest during the window of vulnerability (Section 6.2), or its reduction to 1.7x (70%) when integrating over a 40-year timber harvest rotation (Section 7.1)? Or, a reduction to 1.4x increase (40%) when all checkerboard lands, including federal, are included in a watershed context (Section 7.2)?

Research in the Coast Range indicates that landslides in hollows and debris flows in non-fish headwater channels are responsible for approximately 70% of the long-term sediment supply to the alluvial, fish-bearing portion of the network (Benda and Dunne 1987; Benda and Dunne 1997). The remaining 30% of sediment supply to the alluvial network originates from soil creep along all channels and fluvial transport of sediment along all non-fish tributaries, including those prone to debris flows. Thus, the average increase in sediment supply to the alluvial channel network from landslides in clearcuts can be estimated as: $(0.7 \times 1.4 \text{ [factor of increase in landslide rate, all lands]}) + (0.3 \times 1.0) = 0.98 + 0.3 = 1.28$; $1.28/1.0 = 28\%$. *The average increase of 40% in the landslide rate (all lands) is equivalent to a 28% increase in sediment to the alluvial network (landslides and debris flows).* Based on granulometry studies, only 20% of sediment originating from landslides in bedrock hollows and debris flows in headwater channels is sand and finer ($< 1\text{mm}$). Approximately 60% of sediment is larger than pebble/small gravel (Benda and Dunne 1987). The remainder is comprised of cobbles and boulders. But statistical proportions tell only part of the story. Absolute amounts of sediment associated with different processes are more meaningful to channel environments (see below).

Similar to sediment, the supply of wood to fish streams would also increase if landslide and debris flow rates increase because of timber harvest. Based on theoretical modeling of a wood budget, Benda and Sias (2003b) predicted that debris flows in the Oregon Coast Range contribute, on average, 12% of the long-term supply of wood to the alluvial channel network. Modeling of wood recruitment in two watersheds in the Coast Range indicated an upslope landslide-related contribution of wood to fish streams of between 10 and 20% (Terrainworks, unpublished data). The estimated factor of increase in landslide rates of 1.4 (Section 7.2) would result in an increase in wood supply by a proportional amount, and an overall increase in total wood to fish streams on the order of 10% $([1.4 \times 0.2] + [1.0 \times 0.8])$. This assumes that wood recruitment to debris flow-prone channels is the same as fully forested, unmanaged conditions. Partial buffering of debris flow-prone channels would reduce this amount of increase.

Terrainworks has been applying riparian and upslope (mass wasting) wood recruitment models in all three HCPs in Oregon. Predictions of wood recruitment by mortality treefall, bank erosion, landslides and debris flows are based on specific riparian management prescriptions applied to fish and non-fish streams. Protection levels are estimated by comparing proposed prescriptions to background, fully-forested conditions, using a range of tree heights. Refer to specific HCPs for additional details.

8.3 Temporal and Spatial Distribution of Channel Changes/Impacts

It is feasible to estimate the proportion of fish-bearing channels that will be impacted by landslide/debris flow deposition using the central tendency of an existing stochastic simulation analysis. Based on an average channel network geometry, Benda and Dunne (1997a) simulated sediment transfer probabilities that linked landslides from hollows and debris flows in first- and second-order channels to higher-order alluvial streams. Volumes of landslides in hollows and debris flows in first- and second-order channels averaged respectively $1,200 \text{ m}^3$, $2,200 \text{ m}^3$ and $6,000 \text{ m}^3$. These were assigned probabilities of sediment delivery to higher-order, fish-bearing streams of 0.12, 0.08 and 0.24 (Benda

and Dunne 1997a, Table 1). Using the computed increase in the landslide rate between background and all-lands managed (7.2) of $0.008/\text{km}^2/\text{yr}$ (7.2, #3 and #4, with delivery considered), and a sediment delivery ratio (sediment delivered to channels/total sediment) of 0.4 (e.g., 60% stored in fans) (Benda and Dunne 1997a), yields an average mass wasting delivered sediment volume of $5.5 \text{ m}^3/\text{km}^2/\text{yr}$. If a mass wasting (colluvial) deposition condition of one-half meter depth in an average 10-m wide fish-bearing channel (5 m^2) is posited (0.5 m depth assumed for habitat burial), the affected average stream length is $1.1 \text{ m}/\text{km}^2/\text{yr}$. The density of fish-bearing channels (all species) estimated in one independent coho population (i.e., ESU-relevant) watershed in the Oregon Coast Range (PFA HCP pilot) is $\sim 1 \text{ km}/\text{km}^2$ (Terrainworks, unpublished analysis). Thus, the affected channel length represents 0.1% of the fish-bearing channel per year, or 4 to 5% per 40-year rotation. Across an ESU-relevant $1,000 \text{ km}^2$ watershed containing 10^6 m of fish-bearing channel, the predicted increase in mass wasting deposition would affect 1 km of channel per year or 40 km of channel per 40-year harvest rotation. Floods typically occur concurrently with mass wasting so that they will incorporate some of the wood and sediment, thereby extending certain types of channel impacts/changes downstream. The extent of this process is highly variable depending on local conditions and isn't predictable.

The central tendency estimates are different compared to what is observed at individual landslide/debris flow deposit sites in one year. Debris volumes at points of deposition can be several thousand cubic meters (Benda and Cundy 1990; Benda 1990). This amount of sediment can bury a channel reach 100 m by 10 m wide by 2 m deep ($2,000 \text{ m}^3$ or 3,200 tons). But that event may occur once every few thousand years to a few centuries at any site with very little sediment supply in between events. Such punctuated processes at point locations can't be directly compared to average rates that integrate space and time.

Another approach can be used to estimate the effects of increased rates of landslides on alluvial channels. The average sediment yield rate from undisturbed and partially disturbed watersheds in the Coast Range has been measured at approximately $100 \text{ t}/\text{km}^2/\text{yr}$, with uncertainty associated with levels of disturbance and proportion of bedload ((Brown and Krygier 1971; Beschta 1978; Larson and Sidle 1980) as reported in Reneau and Dietrich (1991)), Benda and Dunne (1987) and Benda (1994). An average 28% increase in sediment yield associated with a timber harvest increase in landslide rates equals an additional $28 \text{ tons}/\text{km}^2/\text{yr}$ (0.28×100). This is equivalent to an average increase in sediment to the alluvial (fish-bearing) network in one square kilometer of 18 m^3 (using a sediment bulk density of $1,600 \text{ kg}/\text{m}^3$). Only a portion of this increased sediment would directly enter channels via mass wasting and the delivery ratio of 0.4 is applied, yielding $7.2 \text{ m}^3/\text{km}^2/\text{yr}$. Positing a condition of direct colluvial deposition of 0.5 m in depth over a 10-m wide channel (as above) leads to an average channel affected length of 1.4 m, or $0.14\%/\text{km}^2/\text{yr}$ or 5 to 6% per a 40-year rotation. Variability around the estimated average sediment yield ($80 - 140 \text{ t}/\text{km}^2/\text{yr}$) would decrease and increase the estimated affected channel proportion above. This analysis and the one above suggests that the increased rates of landslides and debris flows on private forest lands, but considered in the context of all lands, could lead to, on average, an increase of 4% to 6% (+/- a couple percent) of direct channel impacts (both negative and positive) over a 40-year timber harvest rotation.

Higher, short-term landslide rates (Table 1) may result in higher proportions of alluvial channels being impacted by direct colluvial sediment deposition and related debris contained within floods. Maximum landslide rates that ranged from 4 to $9 \text{ km}^2/\text{yr}$ (Table 1) were associated with the large 1996 storms over areas of 0.4 to 23 km^2 . At the scale of a typical ESU watershed in the Coast Range ($10,000 \text{ km}^2$),

heightened landslide activity because of timber harvest would be confined to private forest lands that comprise about 55% of the area, of which about 18% of that area would have forests less than 15 years (15-year window of vulnerability within a typical 40-year harvest rotation). Consequently, about 20% of the watershed area would be exposed to increased channel impacts. At that scale, the maximum landslide rate might be less than $1/\text{km}^2/\text{yr}$ (Figure 6). Applying a similar analysis described above based on network geometry and probabilities of sediment transfer by landslides and debris flows, the proportion of impacted alluvial channel length could approach 15% during a single big storm with a recurrence interval of many decades to a century. Higher rates ($4 - 9 \text{ km}^2/\text{yr}$, Table 1) that have been reported over small areas (0.5 to 20 km^2) during a single large storm could result in larger proportions of affected channels. Robison et al. (1999) reported observable channel impacts from the 1996 storms of 22% to 66% (average 35%) in the focus study areas ($12 - 22 \text{ km}^2$) having the highest landslide rates; some of the impacts may have been associated with dam-break floods and debris-laden flows. Higher rates over smaller areas may occur over less than a few percent of the typical ESU watershed. It is difficult to forecast landslide rates associated with large storms, given the nonlinear relationship between rainfall intensity and duration and landslide activity (Turner et al. 2010).

In addition to negatively impacting existing aquatic habitats, including killing organisms in the area of direct colluvial deposition, large influxes of sediment and wood by mass wasting also create fish habitats (Reeves et al. 1995; Benda et al. 1998; Bigelow et al. 1977; Burnett et al. 2007). It is not possible to predict the net negative or net positive effects of spates of mass wasting, whether using average conditions or rare events. Nevertheless, estimating the relative magnitudes of channel altering events, using averages or rare occurrences, can inform perceptions of risk and the need and types of protection strategies.

8.4 Changes in Gravel Supply, Storage and Channel Morphology

What is the implication of the higher frequency of landslides and debris flows on alluvial (fish) stream gravel supply and storage? Computer modeling predicts a dominance of older debris flow fan ages at mouths of first- and second-order channels, including at the scale of a large (200 km^2) watershed, driven by rare wildfires (frequency $1/300$ -years) and periodic rainstorms, in the absence of land use (Benda and Dunne 1997b) (**Figure 7**). This resulted in a predicted occurrence of bedrock-dominated channels in many alluvial reaches, or channels with thin ($< 0.3 \text{ m}$ depth) alluvial cover (**Figure 8**), a consequence of a boom-and-bust-cycle of gravel supply driven by punctuated sediment delivery by mass wasting. This accords with field observations and measurements of bedrock to gravel-filled channels in the Coast Range (Reeves et al. 1995), although current conditions likely reflect the history of land uses, including splash dams, log drives and riparian logging (lack of wood and associated gravel storage).

Based on the simulation model (Figures 7 and 8), more frequent landslides that lead to more frequent debris flows because of timber harvest (40%, Section 7.0 and a 28% in alluvial sediment supply, Section 8.2) should result in a shift in the distribution of debris flow fan ages to younger categories. This should result in less punctuated delivery of coarse sediment to fish-bearing streams, creating a steadier supply of gravel, thereby yielding a higher proportion of gravel-bed streams over space and time, compared to a sediment supply regime driven by large infrequent fires (e.g., the Harvey Creek example, Figure 8). Examining the shift in the distribution of sediment deposit ages would provide a more direct measure of changing channel morphology and fish habitats, compared to examining changes in landslide (and debris flow) rates. There are, however, no census of debris flow fan ages to investigate these issues at the present time.

8.5 Effect of Landslide Recurrence Intervals

The estimated C_{14} -based average landslide RI is an important aspect of the analysis above. A limited set of C_{14} dates ($n=13$) was used to estimate the average and standard deviation (5,600 years $\pm$ 2,800 years). Sampling of charcoal fragments from surviving colluvium in landslide scars in hollows in southwest Washington yielded similar, several thousand-year estimates for landslide RI (Murray Pacific 1999), suggesting the universality of landslide thousand-year recurrence intervals in bedrock hollow landforms. Using a different approach, Dietrich et al. (1982) and Benda and Dunne (1997a) estimated an average landslide RI in individual bedrock hollows of 3,000 and 2,500 years based on filling an evacuated hollow with an estimated soil creep rate to a depth considered susceptible to failure. These estimates are similar to the lower end of the C_{14} -measured values (2,800 years, Montgomery et al. 2000).

Varying the average landslide RI would not change the proportional differences between background and timber harvest landslide rates. However, it would change the absolute estimates of number of landslides and predicted sediment volumes and length of channel effects. Decreasing the average landslide RI in the calculations above, would increase some of the estimates of absolute values associated with predicted sediment yields, sediment volumes and lengths of affected channels. Increasing the average landslide RI would have the opposite effect.

Variation in landslide site density would also affect the analyses above. Proportional effects would not be affected but absolute values could go higher or lower, depending on variation in site density. A stochastic simulation analysis employing LiDAR would be required to explore this source of spatially explicit topographic variation.

8.6 Forest Roads

Montgomery et al. (2000) found that road-related landslides comprised about 50% of all inventoried events, although the landslide inventories extended into the 1960s through the 1980s when road construction were poorer than more modern (late 20th and early 21st century) practices. Robison et al. (1999) found that road-related landslides comprised a smaller proportion of the total number of landslides in the analysis of the 1996 storms, less than in previous studies; the proportion of road-related slides to total inventoried landslides averaged 12% (range 5 to 20% across 5 core study areas). But road-related landslides were several times larger on average compared to slides not associated with roads.

Road-related landslides are not included in the analysis since estimating a rate of increase in landslides isn't feasible given uncertainties about existing and future road placement, design, construction and condition, including how these factors are reflected in older landslide inventories. Increases in landslide rates because of forest roads should be considered, if only qualitatively; increases in rates by forest roads would change some of the estimates above. Technologies exist for reducing the destabilizing effects of forest roads (Gucinski et al. 2001; Benda et al. 2015) and the HCPs in Oregon are addressing the issue of forest roads using various approaches.

9.0 Conclusions

9.1 Summary

- Estimated average recurrence interval of shallow landslides in bedrock hollows: 5,600 years.
- Increase in landslide rates ($\#/area/time$) associated with timber harvest in the first 15-years, post-harvest (window of vulnerability): 3x (200%).

- Background landslide rate: 0.029/km²/yr
Clearcut landslide rate: 0.086/km²/yr
Timber harvest rotation (40-year) rate: 0.05/km²/yr.
- Measured clearcut landslide rates over 1 – 10 years and small areas, inclusive of the 1996 storm: 1 – 6/km²/yr. Empirical long-term clearcut landslide rate (2,993 km², 50-years): 0.09/km²/yr.
- Estimated average number of landslides:
Private land only (over one 40-year harvest rotation)
-Background: 1.16 ls/km² per 40-years.
-Managed: 2 ls/km² per 40-years.
1.7 x (70%) increase.

All lands (private, federal)

-Background: 1.16 ls/km² per 40-years.

-Managed: 1.62 ls/km² per 40-years.

1.4 x (40%) increase.

Landslides delivered to fish streams: 65 – 75%.

- 1.4 factor of landslide rate increase (all lands) yields a 1.28 (28%) increase in sediment yield to alluvial channels (sediment budget).
- The average increase in landslide rates in clearcuts could lead to direct channel impacts (some mix of negative and positive) affecting, on average, 0.1 to 0.2% of stream length per year, or 4 to 6% per 40-year rotation.
- Higher, short-term landslide rates could occur, similar to the 1996 storm events. The proportion of impacted channels could approach 15% across affected lands, with a recurrence interval of many decades to a century or more. Over smaller areas, very high rates may result in tens of percent affected channels, but that would likely be restricted in spatial extent.

9.2 Disturbance Ecology: A Context to Consider Mass Wasting as an Ecological Process

“Disturbance ecology” has been a key part of the discipline of ecology since the 1980s, displacing the long-held belief in nature’s balance and order. The classic definition of disturbance is “any relatively discreet event that disrupts the structure of an ecosystem, community or population, and changes resource availability or the physical environment” (Pickett and White 1985). Within the concept of ecosystems (Tansley 1935), a state of “dynamic non-equilibrium” exists, that has been characterized as the “flux of nature”, highlighting the “variation, fluidity and change in natural systems, rather than stasis implied by the word balance” (Pickett and White 1985). Within this ecological framework, “disturbances such as wildfires, fluctuations in climate, wind and soil erosion do not disrupt the delicate equilibrium of nature, but characterize or punctuate its flux”. Disturbance ecology is primarily concerned with disturbance regimes, in terms of event frequencies, magnitudes, spatial distributions and compositions, and how human activities can alter them (Swanson et al. 1988; Benda et al. 1998; Reice 1995).

In the Oregon Coast Range and in other montane landscapes, landslides and debris flows can provide the majority of sediment to streams and rivers and also contribute substantial amounts of wood to aquatic systems, thereby creating the foundation for aquatic habitats. Even under unmanaged conditions, mass wasting destroys a portion of existing aquatic and riparian habitats during the natural process of creating and rejuvenating those habitats. Timber harvest activities can alter the regime of mass wasting, with implications for both existing habitats and the formation of new ones. The issue of forestry and landslides lends itself to the concept of disturbance ecology. The foregoing analysis evaluated how timber harvest can shift the mass wasting regime, using central tendencies and some

estimates of rare events. The estimated changes to the mass wasting regime can be used to examine the geomorphological and ecological implications in the formation and maintenance of fish habitats in the Coast Range and in other landscapes.

Based on the density of fish streams in the average ESU-relevant watershed (~1,000 km²), there are approximately 10,000, 100-m reaches. A fish species, like coho salmon, have individual fish, or groups of fish, distributed across those reaches, with their attendant physical habitats. Individual animals, like fish, don't experience the average environmental condition, like average landslide rates, sediment flux, wood supply or flows. The average is a statistical condition representing multiple events across space (watershed) and time. But, the status of a fish population, made up of thousands to millions of individuals distributed across thousands of individual reaches, should track the large range in channel conditions that reflect rates of landslides, sediment supply, wood supply and flows, across a watershed. The population should reflect the aggregate condition of all reaches over some relevant time period, a few years to a few decades, in addition to marine conditions.

The objective of this review and analysis is to provide additional information about the relationship between landslides and fish habitats in support of the HCP process in Oregon. Ideally, this work in progress will promote further discussion and other assessments that will contribute to forest management planning.

Acknowledgments

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Figures and citations follow



Figure 1. (A) Landslide in a forested bedrock hollow. (B) Debris flow in a forested headwater channel (circle shows two people for scale). (C, D) Debris flow scoured channel. (E, F) Debris flow deposits.



Figure 2. (Upper left) Recent debris flow deposit with boulders, with a beaver pond upstream. (Upper right) A decade old debris flow deposit with boulders. (Lower left) An old boulder deposit in an old growth stream capturing wood. (Lower right) Debris flow related terraces that are ubiquitous in Coast Range valleys.

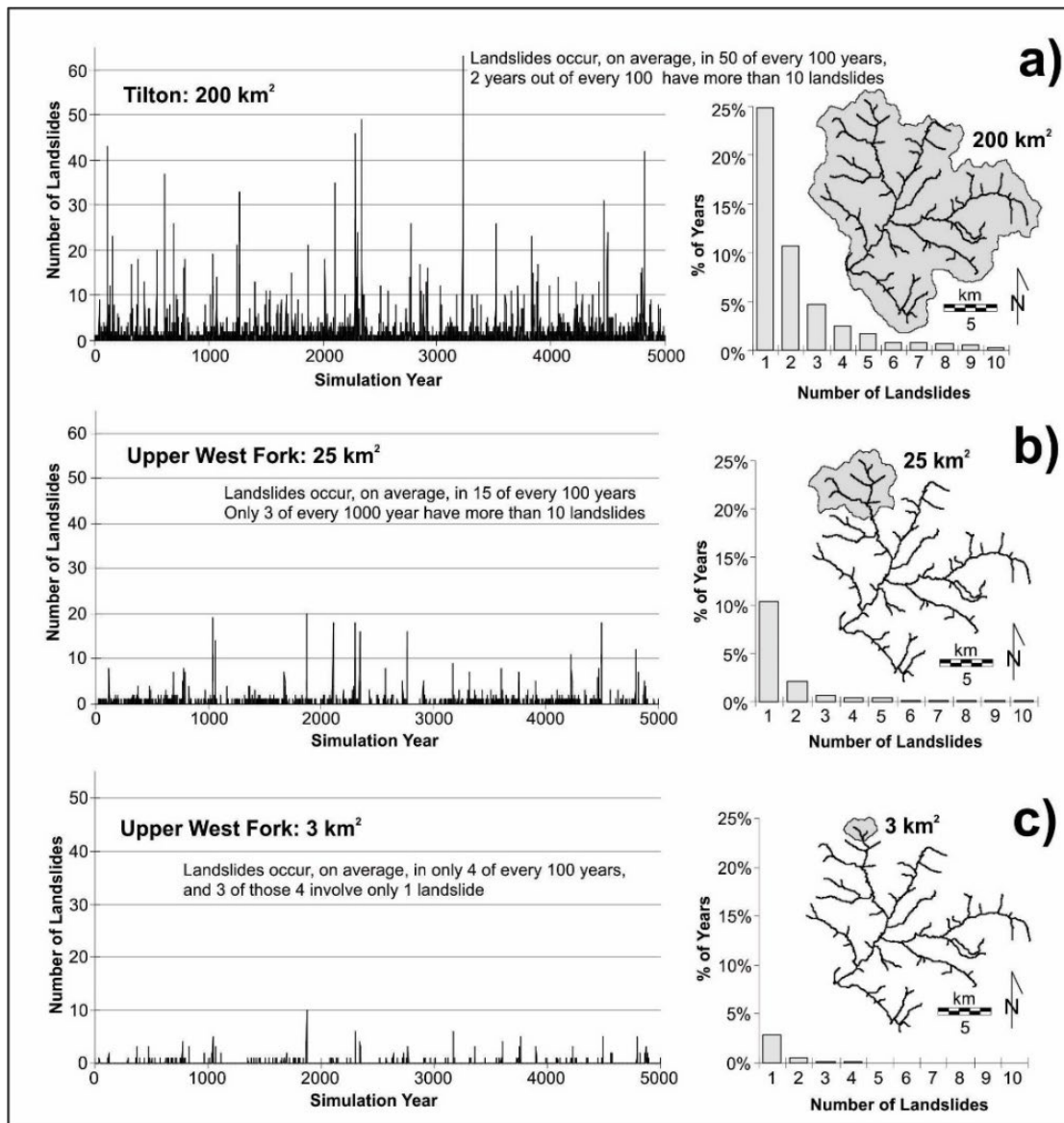


Figure 3. Stochastic simulation modeling reveals that background landslide rates are variable over time and are best represented as a distribution of values (Miller et al. 2003; Benda and Dunne, 1997).

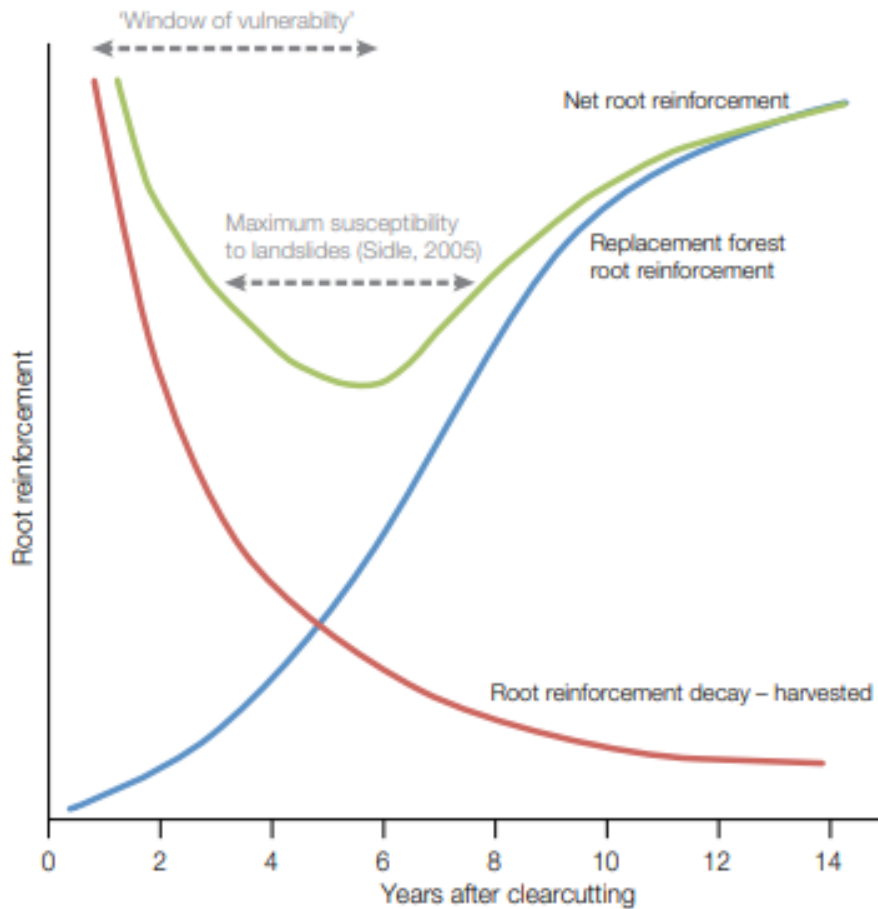


Figure 4. The relationship between the decay of root reinforcement following timber harvest and the replacement of root strength by new vegetation creates a “window of vulnerability”, when increased landslide occurrence is most likely (adapted from Phillips et al. 2012). See also Ziemer (1981).

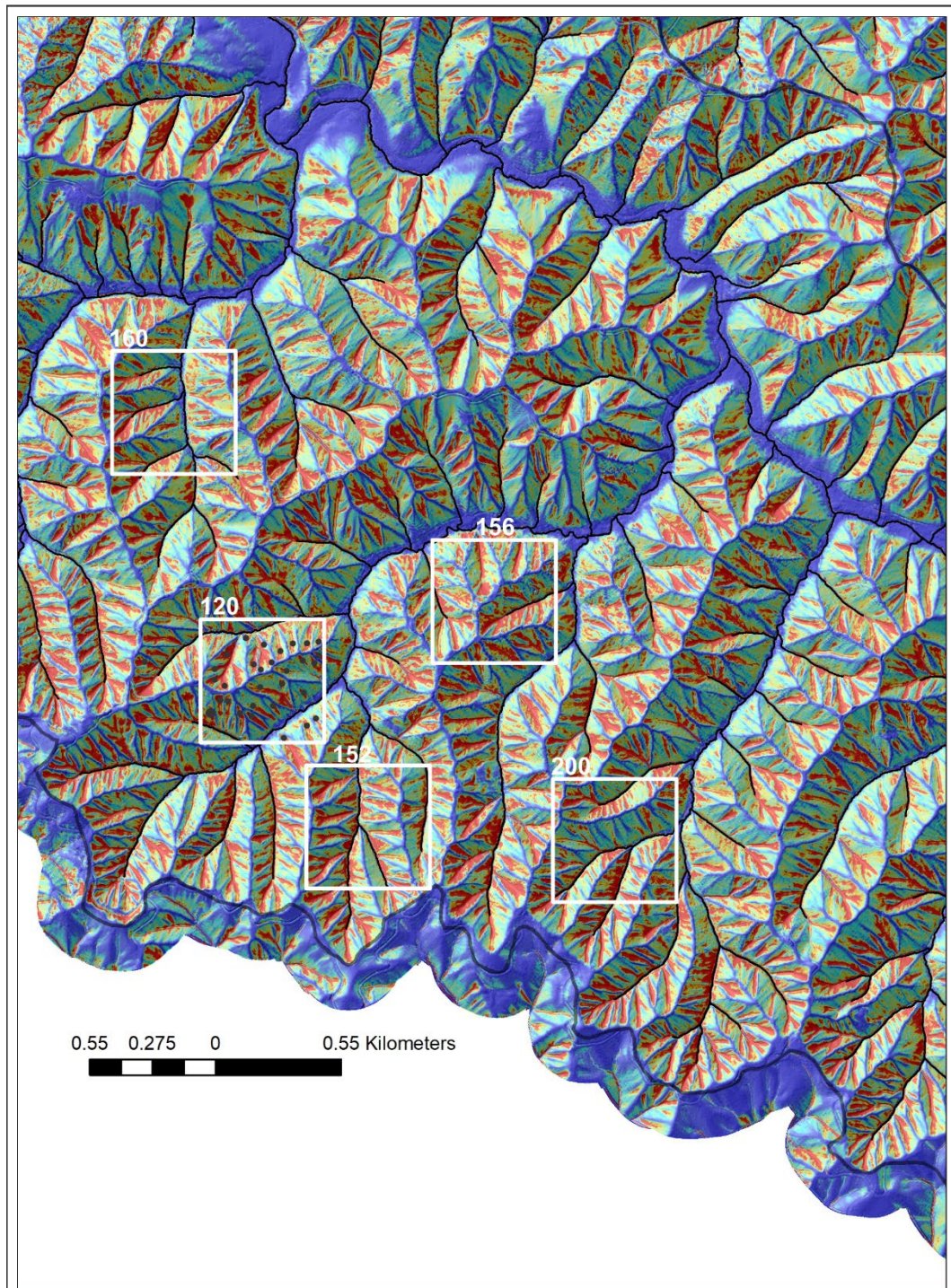


Figure 5. The Miller and Burnett (2007) landslide susceptibility model applied using 2m LiDAR DEMs in the central Oregon Coast Range reveals hollow densities between 100 and 200 per km².

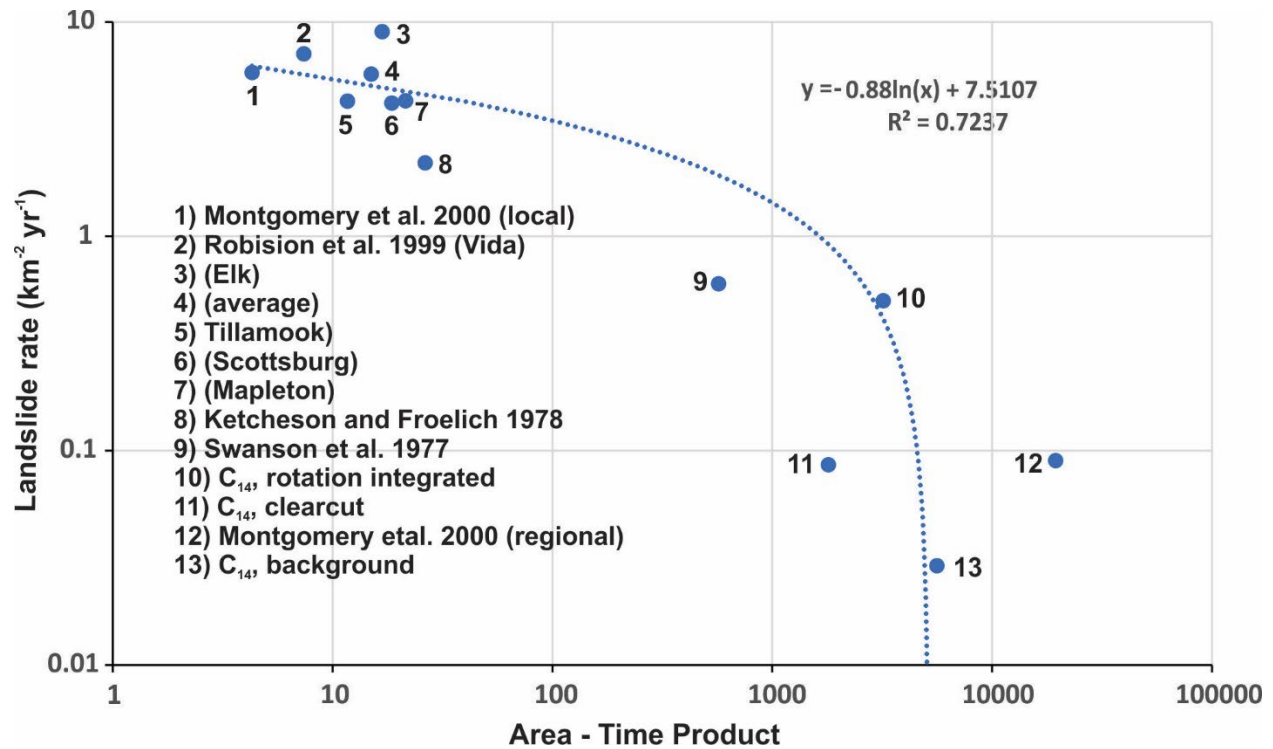


Figure 6. The relationship between empirical and C_{14} -based landslide rates and the area – time product over which they were calculated. The area-time product of empirical landslide studies corresponds to the size of the study area and the time period covered by the data collection. The empirical studies of Swanson et al. (1977), Ketchison and Froelich (1978) and Montgomery et al. (2000, Mettman Ridge) focused on post-timber harvest and storms where landslides were relatively abundant. Robison et al. 1999 focused on the two 1996 storms in five core study areas. Empirical studies targeting regenerating or older forests over small areas and short time periods would likely report low values, including zeros over similar space and time scales. The area-time product for the C_{14} -based rates corresponds to the estimated recurrence interval of landslides in hollows (5,600 years) that translates to a landslide rate per km^2 based on density of bedrock hollows. The C_{14} clearcut and rotation-integrated rates are described in the text.

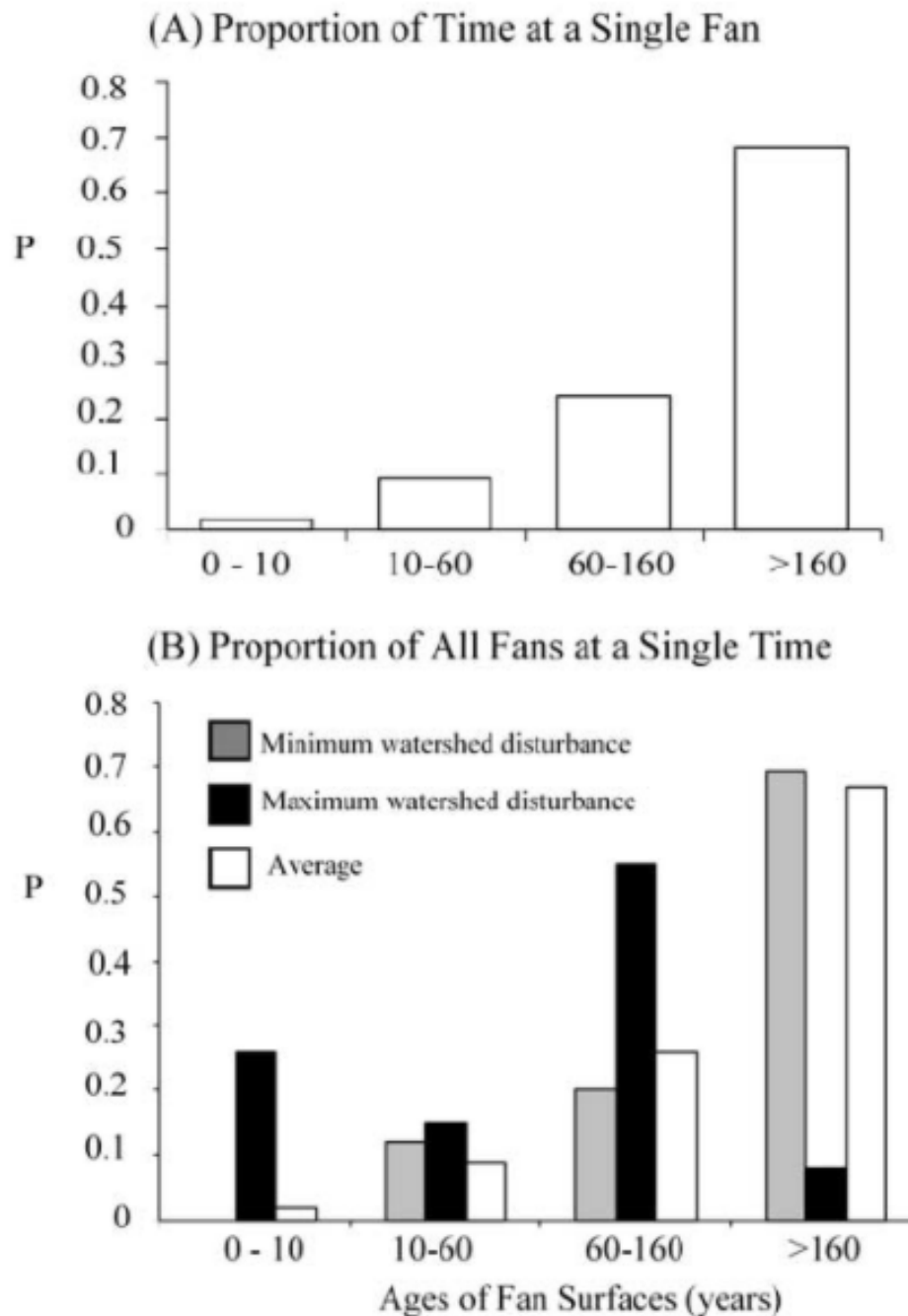


Figure 7. Predicted distributions of debris flow fan ages (i.e., age equivalent to time since last depositional event) for a 200-km² basin in the central Oregon Coast Range using a stochastic simulation model (Benda and Dunne, 1997a,1997b; Benda et al. 2004). (a) Predicted fan ages over time at a single low-order confluence (i.e., first- and second-order channel confluences). (b) Predicted fan ages for the entire population of low-order confluences (~1,000) at a single time for periods of low to high watershed disturbance (i.e., high watershed disturbance refers to numerous fires and storms and no land use). Increased frequency of landslides and debris flows (1.4x, Section 7.0) would shift the average age distribution to the left, into younger age categories, similar to a more frequency fire regime.

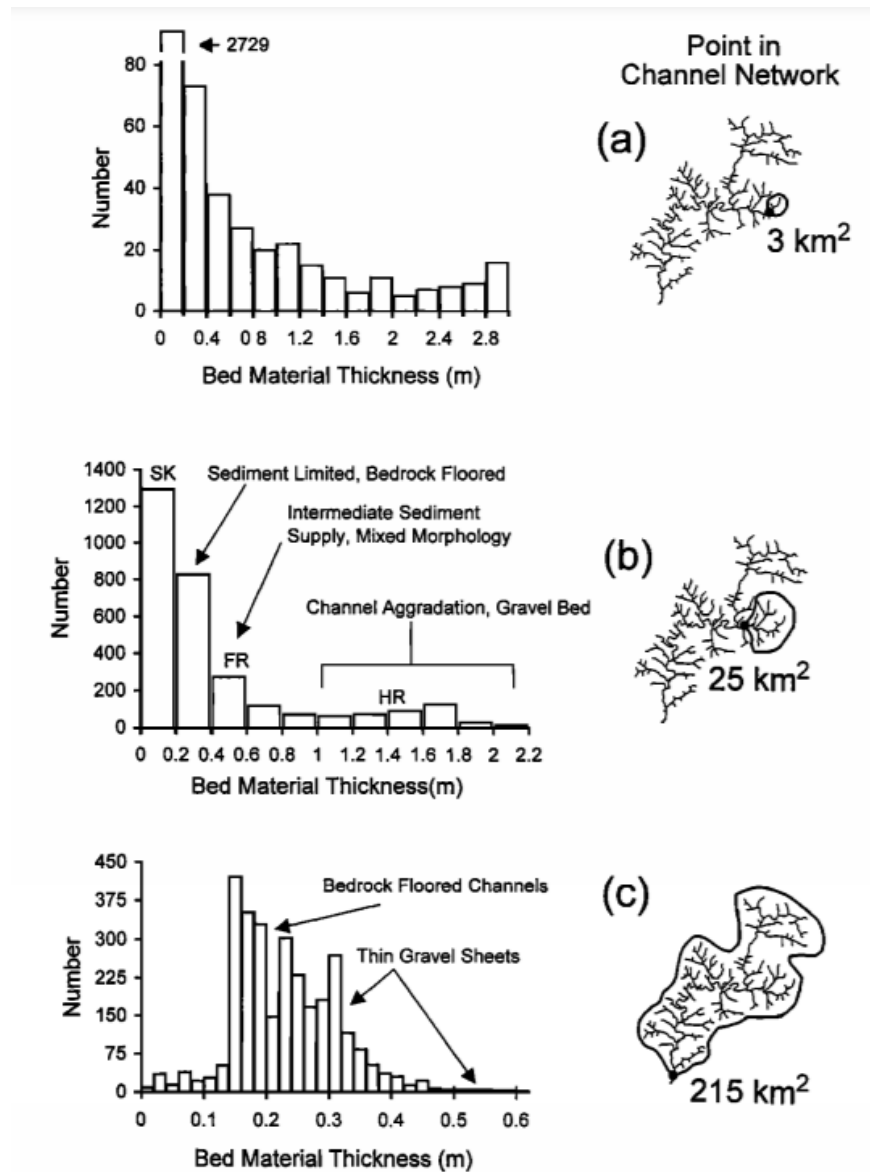


Figure 8. The predicted frequency distribution of sediment thicknesses at three drainage areas (all fish bearing) derived from stochastic simulation modeling in the Oregon Coast Range (Benda and Dunne 1997a, b). Gravel limited, bedrock-dominated channels are predicted to occur commonly, as verified in the field. Field measurements of channel morphology are shown for comparison. Skate Creek (SK) is dominated by old growth (little natural disturbance); Harvey Cr. (HR) was burned by wildfire in the mid-1800s and has evidence of massive mass wasting; Franklin Creek (FR) was considered in an intermediate disturbance state (none of the watersheds have land use impacts) (Benda 1994; Reeves et al. 1995).

References

- Banks, J., Kolkemo, E., Colby, J., and Souder, J. A., 2001, "Effectiveness Monitoring of Large Wood, Boulder Weirs and Culvert Replacement Projects in Selected in Selected streams of the Coos Watershed, Coos Watershed Association.
- Beeson, H.W., et al., *Deep-Seated Landslides Drive Variability in Valley Width and Increase Connectivity of Salmon Habitat in the Oregon Coast Range*. JAWRA Journal of the American Water Resources Association, 2018. **54**(6): p. 1325-1340.
- Benda, L., 1985, Behavior and effect of debris flows on streams in the Oregon Coast Range, in Bowles, D. S., ed., *Delineation of landslide, flash flood, and debris flow hazards in Utah*, Volume General Series UWRL/G-85/03: Utah State University, Logan, Utah, Utah Water Research Laboratory, p. 153-162.
- Benda, L., 1988, Debris flows in the Tye Sandstone Formation of the Oregon Coast Range [Master's: University of Washington, 125 p.
- Benda, L., and Bigelow, P., 2014, On the patterns and processes of wood in northern California streams: *Geomorphology*, v. 209, p. 79-97.
- Benda, L. E., 1990, The influence of debris flows on channels and valley floors in the Oregon Coast Range, U.S.A.: *Earth Surface Processes and Landforms*, v. 15, p. 457-466.
- Benda, L. E., and Cundy, T. W., 1990, Predicting deposition of debris flows in mountain channels: *Canadian Geotechnical Journal*, v. 27, p. 409-417.
- Benda, L. E., and Dunne, T., 1987, Sediment routing by debris flow, *Erosion and Sedimentation in the Pacific Rim*, Volume 165: Corvallis, OR, IAHS.
- Benda, L. 1994. Stochastic geomorphology in a humid mountain landscape. Dissertation. Dept. of Geological Sciences, University of Washington.
- , 1997a, Stochastic forcing of sediment routing and storage in channel networks: *Water Resources Research*, v. 33, no. 12, p. 2865-2880.
- , 1997b, Stochastic forcing of sediment supply to channel networks from landsliding and debris flow: *Water Resources Research*, v. 33, no. 12, p. 2849-2863.
- Benda, L. E., Miller, D. J., Bigelow, P., and Andras, K., 2003a, Effects of post-wildfire erosion on channel environments, Boise River, Idaho: *Forest Ecology and Management*, v. 178, p. 105-119.
- Benda, L. E., Miller, D. J., Dunne, T., Reeves, G. H., and Agee, J. K., 1998, Dynamic landscape systems, in Naiman, R. J., and Bilby, R. E., eds., *River Ecology and Management*: New York, Springer-Verlag, p. 261-288.
- Benda, L.E. and Sias, J.C. (2003b) A Quantitative Framework for Evaluating the Mass Balance of In-Stream Organic Debris. *Forest Ecology and Management*, 172, 1-16.
- Benda, L. E., Veldhuisen, C., and Black, J., 2003a, Debris flows as agents of morphological heterogeneity at low-order confluences, Olympic Mountains, Washington: *Geological Society of America Bulletin*, v. 115, no. 9, p. 1110-1121.
- Benda et al., 2004, Tributary effects in river networks: Role of basin scale, basin shape, network geometry, and disturbance regimes. *Water Resources Research*. 40, 1-15.
- Benda, L. and D. Miller, *Wilson River Watershed Analysis, 7.3 Deep-Seated Landslides*. 2008, Oregon Department of Forestry: Salem, Oregon.
- Benda, L., C. James, D. Miller and K. Andras. 2015. Road Erosion and Delivery Index (READI): A Model for evaluating unpaved road erosion and stream sediment delivery. *JAWRA Journal of the American Water Resources Association* 55(4).
- Bigelow, P. E., Benda, L. E., Miller, D. J., and Burnett, K. M., 2007, On debris flows, river networks, and the spatial structure of channel morphology: *Forest Science*, v. 53, no. 2, p. 220-238.

- Bisson, P.A., J.B. Dunham, and G.H. Reeves, *Freshwater ecosystems and resilience of Pacific Salmon: habitat management based on natural variability*. Ecology and Society, 2009. **14**(1): p. 45.
- Brardinoni, F., Slaymaker, O., and Hassan, M. A., 2003, Landslide inventory in a rugged forested watershed: a comparison between air-photo and field survey data: Geomorphology, v. 54, p. 179-196.
- Burnett, K. M., and Miller, D. J., 2007, Streamside policies for headwater channels: an example considering debris flows in the Oregon Coastal Province: Forest Science, v. 53, no. 2, p. 239-253.
- Bush, G., McConnel, C., Cloyd, C., Musser, K., Metzger, B., and Plumley, H., 1997, Assessment of the effects of the 1996 flood on the Siuslaw National Forest: USDA Forest Service, Siuslaw National Forest.
- Cannon, S. H., 2001, Debris-flow generation from recently burned watersheds: Environmental & Engineering Geoscience, v. 7, no. 4, p. 321-341.
- Clements, F., *Plant succession: an analysis of the development of vegetation*. 1916, Carnegie Institution of Washington: Washington, D.C.
- Dietrich, W. E., Dunne, D., Humphrey, N. F., and Reid, L. M., 1982, Construction of sediment budgets for drainage basins.
- Dietrich, W. E., and Dunne, T., 1978, Sediment budget for a small catchment in mountainous terrain: Zietschrift für Geomorphologie, v. Suppl. Bd. 29, p. 191-206.
- Dunne, T., 1991, Stochastic aspects of the relations between climate, hydrology and landform evolution: Transactions of the Japanese Geomorphological Union, v. 12, p. 1-24.
- Everest, F. H., and Meehan, W. R., 1981, Forest management and anadromous fish habitat productivity: Transactions of the North American Wildlife and Natural Resources Conference, v. 46, p. 521-530.
- Flitcroft, R. L., Falke, J. A., Reeves, G. H., Hessburg, P. F., McNyset, K. M., and Benda, L. E., 2016, Wildfire may increase habitat quality for spring Chinook salmon in the Wenatchee River subbasin, WA, USA: Forest Ecology and Management, v. 359, p. 126-140.
- Forestry, O. D. o., 2003, Elliott State Forest Watershed Analysis.
- Foster, D.R., D.H. Knight, and J.F. Franklin, *Landscape patterns and legacies resulting from large, infrequent forest disturbances*. Ecosystems, 1998. **1**: p. 497-510.
- Gabet, E. J., and Dunne, T., 2003, A stochastic sediment delivery model for a steep Mediterranean landscape: Water Resources Research, v. 39, no. 9.
- Geertsema, M., and Pojar, J. J., 2006, Influence of landslide on biophysical diversity - A perspective from British Columbia: Geomorphology.
- Gleason, H., *The individualistic concept of the plant association*. The Bulletin of the Torrey Botanical Club, 1926. **53**: p. 7-26.
- Gonzalez-Ollauri, A., and Mickovski, S. B., 2017, Shallow landslides as drivers for slope ecosystem evolution and biophysical diversity: Landslides, no. 14, p. 1699-1714.
- Grant, G. G., and Swanson, F. J., 1995, Morphology and processes of valley floors in mountain streams, Western Cascades, Oregon, in Costa, J. E., Miller, A. J., Potter, K. W., and Wilcock, P. R., eds., Natural and Anthropogenic Influences in Fluvial Geomorphology, Geophysical Monograph 89: Washington, D.C., American Geophysical Union, p. 83-101.
- Gucinski, H., M.J. Furniss, R.R. Zeimer, and M.H. Brookes (editors). 2007. Forest roads: a synthesis of scientific information. U.S. Dep. Agric. For. Serv., Pacific NW Res. Sta., Portland, Oreg., Gen. Tech. Rep. No. PNWGTR-509.
- Humphrey, N. F., 1983, Pore pressures in debris failure initiation [M.S.: University of Washington.
- Ketcheson, G., and Froehlich, H. A., 1978, Hydrologic factors and environmental impacts of mass soil movements in the Oregon Coast Range: Water Resources Research Institute, 56.
- Keim, R. and A. Skaugset. 2003. Modelling Effects of Forest Canopies on Slope Stability. Hydrological

- Processes 17(7):1457 - 1467.
- Klock, G. O., and Helvey, J. D., 1976, Debris flows following wildfire in north central Washington., Proceedings Third Federal Interagency Sediment Conference: Denver, CO, p. 1-91 - 91-98.
- Lancaster, S.T. and Casebeer, N.E., 2007. Sediment storage and evacuation in headwater valleys at the transition between debris-flow and fluvial processes. *Geology*, 35(11), 1027-1030.
- Lancaster, S.T., 2008. Evolution of sediment accommodation space in steady-state bedrock-incising valleys subject to episodic aggradation. *Journal of Geophysical Research*, 113,
- Lehre, A. K., 1982, Sediment budget of a small Coast Range drainage basin in North-Central California, Sediment Budgets and Routing in Forested Drainage Basins, U.S.D.A. Forest Service General Technical Report PNW-141, p. 67-77.
- May, C. and R. Gresswell. 2004. Spatial and temporal patterns of debris flow deposition in the Oregon Coast Range. *Geomorphology*. 54, 3-4, p135-149.
- May, C., et al., *Controls on valley width in mountainous landscapes: The role of landsliding and implications for salmonid habitat*. *Geology*, 2013. **41**(4): p. 503-506.
- Means, J., Spies, T., Shu-huei, C., Kertis, J., and Teensma, P. D. A., 1996, Forests of the Oregon Coast Range: Considerations for Ecological Restoration, in Hardy, C. C., and Arno, S. F., eds., The use of fire in forest restoration, Volume Gen. Tech. Report INT-GTR-341: Odgen, Utah, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, p. 68-71.
- Miller, D., Benda, L., Furniss, M., and Penney, M., 2002, Landscape Dynamics and Forest Management, General Technical Report RMRS-GTR-101-CD, US Forest Service.
- Miller, D. J., and Benda, L. E., 2000, Effects of punctuated sediment supply on valley-floor landforms and sediment transport: *Geological Society of America Bulletin*, v. 112, no. 12, p. 1814-1824.
- Miller, D. J., and Burnett, K. M., 2007, Effects of forest cover, topography, and sampling extent on the measured density of shallow, translational landslides: *Water Resources Research*, v. 43, no. W03433.
- , 2008, A probabilistic model of debris-flow delivery to stream channels, demonstrated for the Coast Range of Oregon, USA: *Geomorphology*, v. 94, p. 184-205.
- Miller, D. J., Burnett, K. M., and Benda, L. E., 2008, Factors controlling availability of spawning habitat for salmonids at the basin scale, in Sear, D., and DeVries, P., eds., *Salmon Spawning Habitat in Rivers: Physical Controls, Biological Responses and Approaches to Remediation*, Volume Symposium 65: Bethesda, MD, American Fisheries Society, p. 103-120.
- Miller, R. R., 2010, Is the Past Present? Historical Splashdam Mapping and Stream Disturbance Detection in the Oregon Coastal Province [MS: Oregon State University.
- Montgomery, D. R., and Dietrich, W. E., 1994, A physically based model for the topographic control on shallow landsliding: *Water Resources Research*, v. 30, no. 4, p. 1153-1171.
- Montgomery, D. R., Schmidt, K. M., Greenberg, H. M., and Dietrich, W. E., 2000, Forest clearing and regional landsliding: *Geology*, v. 28, no. 4, p. 311-314.
- Montgomery, D. R., B. D. Collins, J. M. Buffington, and T. B. Abbe 2003. Geomorphic effects of wood in rivers, in *The Ecology and Management of Wood in World Rivers, American Fisheries Society Symposium*, vol. 37, edited by S. V. Gregory, K. L. Boyer, and A. M. Gurnell, pp. 21– 48, American Fisheries Society, Bethesda, Maryland.
- Mueller, K., 2009, Salmon restoration expert Charley Dewberry's presentation blows my mind, The Caddis Fly: Oregon Fly Fishing Blog.
- Naiman, R. J., Beechie, T. J., Benda, L. E., Berg, D. R., Bisson, P. A., and McDonald, L. H., 1992, Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion, in Naiman, R. J., ed., *Watershed Management: Balancing Sustainability and Environmental Change*: New York, Springer-Verlag, p. 127-188.

- Phelps, J. D., 2011, THE GEOMORPHIC LEGACY OF SPLASH DAMS IN THE SOUTHERN OREGON COAST RANGE [MSc: Oregon State University, 38 p.
- Phillips, C. J., Marden, M., and al., e., 2012, Plantation Forest Harvesting and Landscape Response – What We Know and What We Need to Know.: New Zealand Journal of Forestry, v. 56, no. 4, p. 4-12.
- Pickett, S.T.A. and P.S. White, *The Ecology of Natural Disturbance and Patch Dynamics*. 1985: Academic Press.
- Pierson, T. C., 1977, Factors controlling debris-flow initiation on forested hillslopes in the Oregon Coast Range. [Ph.D.: University of Washington, 167 p.
- Reeves, G. H., Benda, L. E., Burnett, K. M., Bisson, P. A., and Sedell, J. R., 1995, A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest, *in* Nielson, J. L., and Powers, D. A., eds., *Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation*, American Fisheries Society Symposium 17: Bethesda, Maryland, USA, American Fisheries Society, p. 334-349.
- Reeves, G. H., Burnett, K. M., and McGarry, E. V., 2003, Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon: Canadian Journal of Forest Research, v. 33, p. 1363-1370.
- Reeves, G. H., Pickard, B. R., and Johnson, K. N., 2016, An initial evaluation of potential options for managing riparian reserves of the aquatic conservation strategy of the Northeast Forest Plan: USDA Forest Service.
- Reice, S.R. 1994. Nonequilibrium determinants of biological community structure. *American Scientist*. 82: 424-435.
- Reid, L. M., 1998, Calculation of average landslide frequency using climatic records: *Water Resources Research*, v. 34, no. 4, p. 869-877.
- Reneau, S. L., and Dietrich, W. E., 1991, Erosion rates in the southern Oregon Coast Range: Evidence for an equilibrium between hillslope erosion and sediment yield: *Earth Surface Processes and Landforms*, v. 16, no. 4, p. 307-322.
- Rice, R. M., 1973, The hydrology of chaparral watersheds, *Proceedings Symposium Living with Chaparral: Riverside, California*, Sierra Club, p. 27-33.
- Robison, G. E., Mills, K. A., Paul, J., Dent, L., and Skaugset, A., 1999, Storm impacts and landslides of 1996: final report: Oregon Department of Forestry, 4.
- Roni, P., Bennett, T., Morley, S., Pess, G. R., and Hanson, K., 2006, Rehabilitation of bedrock stream channels: the effects of boulder weir placement on aquatic habitat and biota: Northwest Fisheries Science Center National Marine Fisheries Service; Bureau of Land Management Coos Bay District.
- Schmidt, K. M., 1999, Root Strength, Colluvial Soil Depth, and Colluvial Transport on Landslide-Prone Hillslopes [Ph.D. Dissertation]: University of Washington, 255 p.
- Sedell, J. R., and Luchessa, K. J., Use of the historical record as an aid to salmonid habitat enhancement, *in* *Proceedings Symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information* 1981.
- Sidle, R. C., Pearce, A. J., and O'Loughlin, C. L., 1985, Hillslope Stability and Land Use, Washington D. C., American Geophysical Union, *Water Resources Monograph*, 140 p.
- Tansley, A., *The use and abuse of vegetational concepts and terms*. *Ecology*, 1935: p. 284-307.
- Turner, M.G., *Disturbance and landscape dynamics in a changing world*. *Ecology*, 2010. **91**(10): p. 2833-2849.
- Turner, T. R., Duke, S. D., Fransen, B. R., Reiter, M. L., Kroll, A. J., Ward, J. W., Bach, J. L., Justice, T. E., and Bilby, R. E., 2010, Landslide densities associated with rainfall, stand age, and References |

- 113 topography on forested landscapes, southwestern Washington, USA: Forest Ecology and Management, v. 259, p. 2233-2247.
- Swanson, F. J., Fredriksen, R. L., and McCorison, F. M., 1982, Material transfer in a western Oregon forested watershed, *in* Edmonds, R. L., ed., analysis of Coniferous Forest Ecosystems in the Western United States: Stroudsburg, Penn., Hutchinson Ross Publishing Co., p. 233-266.
- Swanson, F. J., Swanson, M. M., and Woods, C., 1977, Inventory of mass erosion in the Mapleton Ranger District, Siuslaw National Forest, Final Report.: U.S. Forest Service.
- Swanson F.J., T. K. Kratz, N. Caine, and R.G. Woodmansee. 1988. Landform effects on ecosystem patterns and processes. *BioScience* 38(2):92-98.
- Wilson, C. J., and W. E. Dietrich, The contribution of bedrock groundwater flow to storm runoff and high pore pressure development in hollows, in *Proceedings, Symposium on Erosion and Sedimentation in the Pacific Rim*, IAHS Publ. 165, 49–60, 1987.
- Wimberly, M.C., et al., *Simulating historical variability in the amount of old forests in the Oregon Coast Range*. *Conservation Biology*, 2000. **14**: p. 167-180.
- Ziemer, R. R., 1981, Roots and the Stability of Forested Slopes, *in* Davies, T. R. H., and Pearce, A. J., eds., *Erosion and Sediment Transport in Pacific Rim Steeplands*, Volume 132, International Association of Hydrological Sciences, p. 343-361.
- Ziemer, R. R., and Swanston, D. N., 1977, Root strength changes after logging in southeast Alaska: USDA Forest Service.

BGO and Objectives Crosswalk

Terrestrial

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	1	Establish Riparian Conservation Areas	Exclude salvage from RCAs (except hazards) to retain critical habitat and reduce disturbance.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	1	Establish Riparian Conservation Areas	Maintain riparian habitat in RCAs within the range of the species.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	2	Riparian Equipment Restriction Zones	Minimize impacts associated with harvesting from ERZs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance approximately 27,000 acres of existing denning, resting, foraging, and dispersal habitat in the range of the species.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	—	6	Establish Habitat Conservation Areas	Include all occupied stands in HCAs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks with interior forest for covered species.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Increase the quality of denning, resting, foraging, and dispersal habitat within the 27,000 existing acres over the permit term.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
	the Quantity of High-Quality Habitat Over Time					
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase the quality of denning, resting, foraging, and dispersal habitat within the 27,000 existing acres over the permit term.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of denning, resting, foraging, and dispersal habitat through regeneration and partial cut harvests, in addition to stand management activities.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Fire Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Recreation Infrastructure, Maintenance, and Operations	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Conservation Strategy Implementation Activities	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Seasonally restrict mountain beaver control activities within 2.5 miles of a known den site.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	7	Manage Habitat Conservation Areas	Increase the quality of denning, resting, foraging, and dispersal habitat within the 27,000 existing acres over the permit term.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase the quality of denning, resting, foraging, and dispersal habitat within the 27,000 existing acres over the permit term.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of denning, resting, foraging, and dispersal habitat through regeneration and partial cut harvests, in addition to stand management activities.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
	the Quantity of High-Quality Habitat Over Time					
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain old growth trees and trees surrounding a known den (100 foot radius) within regeneration harvest units.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two leave trees per acre within regeneration harvest units.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain decadent snags within regeneration harvest units.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two hard snags per acre within regeneration harvest units.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain decadent large diameter down wood within regeneration harvest units.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain at least 600 cubic feet of hard conifer logs on average, per acre within regeneration harvest units.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Fire Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Recreation Infrastructure, Maintenance, and Operations	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Conservation Strategy Implementation Activities	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Protect denning females and young through seasonal restrictions of any covered activities within 0.25 mile of a known occupied den site located either inside or outside an HCA.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Seasonally restrict mountain beaver control activities within 2.5 miles of a known den site.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Road System Management	5	Standards for Road Improvement and Vacating	Vacate and stabilize roads to improve habitat quality and reduce disturbance.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance approximately 78,600 acres of all existing suitable habitat and 2,300 acres of existing highly suitable habitat in HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	—	6	Establish Habitat Conservation Areas	Include nearly all occupied stands in HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks with interior forest for covered species.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 68,000 acres, and suitable habitat between 44,000 to 55,000 acres over the permit term.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 68,000 acres, and suitable habitat between 44,000 to 55,000 acres over the permit term.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of highly suitable and suitable habitat through regeneration and partial cut harvests, in addition to stand management activities.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Track patch size and interior inside HCAs for reducing edge effects, predation, and microclimate degradation.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Conduct passive acoustic monitoring and follow field surveys using accepted protocols to detect occupancy trends and validate habitat development strategy.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain old growth trees and known nest trees within regeneration harvest units.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two leave trees per acre within regeneration harvest units.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Monitor effectiveness of upland leave strategy to confirm adequacy of habitat features.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Conservation Strategy Implementation Activities	9	Strategic Terrestrial Species Conservation Actions	Coordinate barred owl removals where they overlap murrelet habitat to reduce disturbance.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Covered Species	Implement trash management and removal barred owl removal management program for all planned management activities in designated occupied habitat and associated buffers to reduce corvid attractions.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Recreation Infrastructure, Maintenance, and Operations	10	Operational Restrictions to Minimize Effects on Covered Species	Implement trash management and removal barred owl removal management program for all planned management activities in designated occupied habitat and associated buffers to reduce corvid attractions.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Fire Management	10	Operational Restrictions to Minimize Effects on Covered Species	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat (highly suitable with unknown occupancy or occupied sites identified through monitoring) inside HCAs.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat (highly suitable with unknown occupancy or occupied sites identified through monitoring) inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat (highly suitable with unknown occupancy or occupied sites identified through monitoring) inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat (highly suitable with unknown occupancy or occupied sites identified through monitoring) inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near known nest trees (includes incidentally observed) outside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near known nest trees (includes incidentally observed) outside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near known nest trees (includes incidentally observed) outside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near known nest trees (includes incidentally observed) outside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Minimize impacts from tailhold and guyline anchor installations inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Conservation Strategy Implementation Activities	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Exclude known nest trees, trees with existing nest platforms, and surrounding trees that provide cover to nest platforms from use in aquatic restoration projects.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	Timber Harvest	13	Stay Ahead Provision	Minimize or eliminate the risk of any temporal net losses of habitat associated with the impacts from covered activities.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	Road System Management	5	Standards for Road Improvement and Vacating	Vacate and stabilize roads to improve habitat quality and reduce disturbance.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance approximately 78,600 acres of all existing suitable habitat and 2,300 acres of existing highly suitable habitat in HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	—	6	Establish Habitat Conservation Areas	Include nearly all occupied stands in HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks with interior forest for covered species.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 68,000 acres, and suitable habitat between 44,000 to 55,000 acres over the permit term.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 68,000 acres, and suitable habitat between 44,000 to 55,000 acres over the permit term.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of highly suitable and suitable habitat through regeneration and partial cut harvests, in addition to stand management activities.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Conduct passive acoustic monitoring and follow field surveys using accepted protocols to detect occupancy trends and validate habitat development strategy.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	7	Manage Habitat Conservation Areas	Track patch size and interior inside HCAs for reducing edge effects, predation, and microclimate degradation.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	10	Operational Restrictions to Minimize Effects on Covered Species	Implement trash management and removal barred owl removal management program for all planned management activities in designated occupied habitat and associated buffers to reduce corvid attractions.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Recreation Infrastructure, Maintenance, and Operations	10	Operational Restrictions to Minimize Effects on Covered Species	Implement trash management and removal barred owl removal management program for all planned management activities in designated occupied habitat and associated buffers to reduce corvid attractions.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Fire Management	10	Operational Restrictions to Minimize Effects on Covered Species	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat during the nesting season. Includes highly suitable habitat with unknown occupancy and occupied sites identified through effectiveness monitoring.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat during the nesting season. Includes highly suitable habitat with unknown occupancy and occupied sites identified through effectiveness monitoring.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat during the nesting season. Includes highly suitable habitat with unknown occupancy and occupied sites identified through effectiveness monitoring.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur in or near designated occupied habitat during the nesting season. Includes highly suitable habitat with unknown occupancy and occupied sites identified through effectiveness monitoring.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Minimize impacts from tailhold and guyline anchor installations inside HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Conservation Strategy Implementation Activities	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Exclude known nest trees, trees with existing nest platforms, and surrounding trees that provide cover to nest platforms from use in aquatic restoration projects.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.
MAMU	Goal 6: Support the Persistence of Marbled Murrelet	Objective 6.2: Increase the Amount of High-Quality Habitat for Marbled Murrelet	Timber Harvest	13	Stay Ahead Provision	Minimize or eliminate the risk of any temporal net losses of habitat associated with the impacts from covered activities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Road System Management	5	Standards for Road Improvement and Vacating	Vacate and stabilize roads to improve habitat quality and reduce disturbance.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Include currently active sites on ODF lands in HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Include historic activity sites in HCAs that had a previous history of consistent occupancy or reproduction.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Include habitat in HCAs in support of activity centers on adjacent (nonpermit) lands where ODF manages a significant amount of habitat within the provincial home range radius.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance ≥30,000 acres existing nesting/roosting habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance ≥90,000 acres existing foraging habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks for owls.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	7	Manage Habitat Conservation Areas	Increase nesting and roosting habitat between 110,000 to 138,000 acres, and foraging habitat by 30,000 acres over the permit term.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Increase nesting and roosting habitat between 110,000 to 138,000 acres, and foraging habitat by 30,000 acres over the permit term.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Accelerate development of nesting, roosting, and foraging habitat through regeneration and partial cut harvests, in addition to stand management activities.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of nesting, roosting, and foraging habitat through regeneration and partial cut harvests, in addition to stand management activities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Maintain ≥ 500 acres nesting, roosting, or foraging habitat within 0.7 mile of an activity centers to support nesting owls.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Conservation Strategy Implementation Activities	9	Strategic Terrestrial Species Conservation Actions	Monitor active and historical sites using passive acoustic monitoring and call back surveys while targeting barred owl management areas to detect recolonization, survival, and reproduction.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Conservation Strategy Implementation Activities	9	Strategic Terrestrial Species Conservation Actions	Implement a barred owl removal management program to reduce competition and stressor on productivity and survival.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	—	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Monitor active and historical sites using passive acoustic monitoring and call back surveys while targeting barred owl management areas to detect recolonization, survival, and reproduction.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Fire Management	10	Operational Restrictions to Minimize Effects on Covered Species	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.

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NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites outside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites outside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites outside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites outside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	Timber Harvest	13	Stay Ahead Provision	Minimize or eliminate the risk of any temporal net losses of habitat associated with the impacts from covered activities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	1	Establish Riparian Conservation Areas	Maintain riparian corridors to aid landscape connectivity that facilitates owl dispersal.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	1	Establish Riparian Conservation Areas	Conserve approximately 41,200 acres nesting, roosting, and foraging habitat in RCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	1	Establish Riparian Conservation Areas	Exclude salvage from RCAs (except hazards) to retain critical habitat and reduce disturbance.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Include currently active sites on ODF lands in HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Include historic activity sites in HCAs that had a previous history of consistent occupancy or reproduction.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Include habitat in HCAs in support of activity centers on adjacent (nonpermit) lands where ODF manages a significant amount of habitat within the provincial home range radius.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance ≥30,000 acres existing nesting/roosting habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance ≥90,000 acres existing foraging habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks for owls.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Monitor effectiveness of upland leave strategy to confirm adequacy of habitat features.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Maintain a minimum of 40% of the permit area outside HCAs that meet the definition of dispersal or foraging habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain old growth trees and known nest trees within regeneration harvest units.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two leave trees per acre within regeneration harvest units.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain decadent snags within regeneration harvest units.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two hard snags per acre within regeneration harvest units.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain decadent large diameter down wood within regeneration harvest units.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain at least 600 cubic feet of hard conifer logs on average, per acre within regeneration harvest units.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Conservation Strategy Implementation Activities	9	Strategic Terrestrial Species Conservation Actions	Implement a barred owl removal management program to reduce competition and stressor on productivity and survival.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply seasonal restrictions for activities that may occur near known active nest sites inside HCAs during critical breeding period.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Fire Management	10	Operational Restrictions to Minimize Effects on Covered Species	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Road System Management	5	Standards for Road Improvement and Vacating	Vacate and stabilize roads to improve habitat quality and reduce disturbance.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Include currently active sites on ODF lands in HCAs.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Include historic activity sites in HCAs that had a previous history of consistent occupancy or reproduction.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Include habitat in HCAs in support of activity centers on adjacent (nonpermit) lands where ODF manages a significant amount of habitat within the provincial home range radius.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance ≥30,000 acres existing nesting/roosting habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance ≥90,000 acres of existing foraging habitat.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks for owls.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.

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NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Timber Harvest	7	Manage Habitat Conservation Areas	Increase nesting and roosting habitat between 110,000 to 138,000 acres, and foraging habitat by 30,000 acres over the permit term.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase nesting and roosting habitat between 110,000 to 138,000 acres, and foraging habitat by 30,000 acres over the permit term.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of nesting, roosting, and foraging habitat through regeneration and partial cut harvests, in addition to stand management activities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Timber Harvest	7	Manage Habitat Conservation Areas	Maintain ≥ 500 acres nesting, roosting, or foraging habitat within 0.7 mile of an activity centers to support nesting owls.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Conservation Strategy Implementation Activities	9	Strategic Terrestrial Species Conservation Actions	Monitor active and historical sites using passive acoustic monitoring and call back surveys while targeting barred owl management areas to detect recolonization, survival, and reproduction.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Conservation Strategy Implementation Activities	9	Strategic Terrestrial Species Conservation Actions	Implement a barred owl removal management program to reduce competition and stressor on productivity and survival.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	Timber Harvest	13	Stay Ahead Provision	Minimize or eliminate the risk of any temporal net losses of habitat associated with the impacts from covered activities.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	1	Establish Riparian Conservation Areas	Maintain an additional 4,200 acres of existing suitable habitat in RCAs within the range of the species.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	1	Establish Riparian Conservation Areas	Exclude salvage from RCAs (except hazards) to retain critical habitat and reduce disturbance.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	2	Riparian Equipment Restriction Zones	Minimize impacts associated with harvesting from ERZs.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	—	6	Establish Habitat Conservation Areas	Conserve, maintain, and enhance 19,200 acres of existing suitable habitat in HCAs within the range of the species.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks for covered species.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Enhance 3,600 acres of low quality of habitat through thinning to promote late-seral forest development.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Retain ≥80 square feet basal area per acre of trees >11 inches diameter at breast height through thinning harvest to preserve canopy cover.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting to promote sustainable reforestation.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting, constructing, and the use of new recreational facilities.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	1	Establish Riparian Conservation Areas	Exclude salvage from RCAs (except hazards) to retain critical habitat and reduce disturbance.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	2	Riparian Equipment Restriction Zones	Minimize impacts associated with harvesting from ERZs.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain old growth trees and known nest trees within regeneration harvest units.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two leave trees per acre within regeneration harvest units.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain decadent snags within regeneration harvest units.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two hard snags per acre within regeneration harvest units.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain decadent large diameter down wood within regeneration harvest units.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain at least 600 cubic feet of hard conifer logs on average, per acre within regeneration harvest units.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and increase the quantity of high-quality habitat in the Santiam State Forest over time.	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	Timber Harvest	9	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Monitor effectiveness of upland leave strategy to confirm adequacy of habitat features.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Road System Management	5	Standards for Road Improvement and Vacating	Vacate and stabilize roads and trails to improve habitat quality and reduce disturbance.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Road System Management	5	Standards for Road Improvement and Vacating	Vacate and stabilize roads and trails to improve habitat quality and reduce disturbance.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance approximately 61,200 acres of all existing suitable habitat and 10,600 acres of existing highly suitable habitat in HCAs.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
	the Quantity of High-Quality Habitat Over Time					
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	—	6	Establish Habitat Conservation Areas	Include nearly all occupied stands in HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks with interior forest for covered species.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Timber Harvest	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 67,000 acres, and suitable habitat between 30,000 to 37,000 acres over the permit term.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 67,000 acres, and suitable habitat between 30,000 to 37,000 acres over the permit term.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of highly suitable and suitable habitat through regeneration and partial cut harvests, in addition to stand management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting, that are suitable forage for red tree vole.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Fire Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	—	6	Establish Habitat Conservation Areas	Conserve, maintain, enhance approximately 61,200 acres of all existing suitable habitat and 10,600 acres of existing highly suitable habitat in HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	—	6	Establish Habitat Conservation Areas	Include nearly all occupied stands in HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	—	6	Establish Habitat Conservation Areas	Concentrate large habitat blocks with interior forest for covered species.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	—	6	Establish Habitat Conservation Areas	Disperse conservation areas across permit area to improve species resilience and redundancy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Manage habitat with climate adaptation focus to improve resilience to fire, drought, and disease.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	7	Manage Habitat Conservation Areas	Exclude salvage from HCAs (except hazards) to retain critical habitat and reduce disturbance.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	7	Manage Habitat Conservation Areas	Conduct low-impact hazard tree removal to minimize habitat damage from safety removals.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	7	Manage Habitat Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 67,000 acres, and suitable habitat between 30,000 to 37,000 acres over the permit term.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Increase highly suitable habitat between 54,000 to 67,000 acres, and suitable habitat between 30,000 to 37,000 acres over the permit term.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Conservation Strategy Implementation Activities	7	Manage Habitat Conservation Areas	Accelerate development of highly suitable and suitable habitat through regeneration and partial cut harvests, in addition to stand management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Fire Management	7	Manage Habitat Conservation Areas	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
RTV	the Quantity of High-Quality Habitat Over Time Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Reforestation and Young Stand Management	7	Manage Habitat Conservation Areas	Plant diverse, resilient species and interplanting, that are suitable forage for red tree vole.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain old growth trees and known nest trees within regeneration harvest units.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Retain two leave trees per acre within regeneration harvest units.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Monitor effectiveness of upland leave strategy to confirm adequacy of habitat features.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	8	Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Limit unit size for regeneration harvest unit to reduce habitat fragmentation.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Fire Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Implement fuels reductions to mitigate fire risk while maintaining key habitat structures.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Apply 10 acre block of contiguous habitat around known red tree vole nest trees inside HCAs during management activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Reforestation and Young Stand Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Road System Management	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Quarries, Borrow Sites, and Stockpile Sites	10	Operational Restrictions to Minimize Effects on Terrestrial Species	Retain nest trees incidentally identified outside HCAs will be retained as part of the leave tree strategy.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Road System Management	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Conduct an assessment of impacts near sensitive sites inside HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	Minimize impacts associated with siting and constructing new recreational facilities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreational Facilities	New trail development limits throughout permit area, including RCAs, ERZs, and HCAs.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	13	Stay Ahead Provision	Minimize or eliminate the risk of any temporal net losses of habitat associated with the impacts from covered activities.
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	Timber Harvest	13	Stay Ahead Provision	Minimize or eliminate the risk of any temporal net losses of habitat associated with the impacts from covered activities.

Aquatics

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure/Action
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs		1	Establish Riparian Conservation Areas (RCAs)	Maintain and protect important riparian vegetation adjacent to the aquatic zone by the establishment of RCAs based on modeled or field verified stream classifications, sensitive areas (e.g., seeps, springs, disconnected perennial stream reaches), and potential unstable slopes
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs		1	Establish Riparian Conservation Areas (RCAs)	No harvest, as defined in Section 3.2.3 will occur in RCAs including harvesting of standing or downed trees for salvage after disturbance events
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Timber Harvest	1	Establish Riparian Conservation Areas (RCAs)	Felling of hazard live or dead trees in RCAs shall only occur where such trees threaten public safety or infrastructure and will be felled towards the aquatic zone or left as downed wood inside the RCA

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure/Action
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Timber Harvest	1	Establish Riparian Conservation Areas (RCAs)	Implement processed-based restoration targeted to reduce the stem density of subdominant trees to accelerate the development of heterogenous late-seral forest structure
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs		2	Establish Equipment Restriction Zones (ERZs)	When covered activities take place in RCA, a 35-foot ERZ will be maintained, where vegetative, ground-disturbance, and tree-canopy removal will be minimized and BMPs implemented
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Conservation Strategy Implementation	3	Stream Complexity	Restore natural stream processes to create instream channel complexity
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Conservation Strategy Implementation	3	Stream Complexity	Minimize stream entry with machinery and choose locations to minimize the loss or riparian trees or erosion to the stream banks
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs		6	Establish Habitat Conservation Areas	Designated HCAs adjacent to RCAs will provide larger areas of passive management providing additional benefits to the covered fish species
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Road System Management	11	Road and Trail Construction and Management Measures	Limit new road construction in RCAs where upland road placement options do not exist due to operational or economical constraints
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Development of new facilities in RCAs will be limited to boat launches and trail segments
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Infrastructure such as parking lots, campsites, bathrooms, kiosks, etc. will be sited outside of RCAs
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Over the permit term, a net increase of 115.5 trail miles may occur in RCAs and 50.5 miles in ERZs (including Seasonal Other streams). Relocated trails do not count toward the total planned miles of new trails as long as the net total trail miles is not exceeded
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Over the permit term, a net increase of 17.5 motorized trail miles (stream crossings only) and 98 non-motorized trail miles may occur in RCAs
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Over the permit term, a net increase of 22.5 motorized trail miles and 28 non-motorized trail miles (stream crossings only) may occur in RCAs; including Seasonal Other stream
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.1: Conserve, maintain, and enhance riparian conditions that promote long-term large wood recruitment in streams through the establishment of RCAs	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Motorized trail development in RCAs will be limited to stream crossings and will only occur when other alternatives are not operationally feasible
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species		1	Establish Riparian Conservation Areas (RCAs)	Maintain and protect important riparian vegetation adjacent to the aquatic zone by the establishment of RCAs based on modeled or field verified stream classifications, sensitive areas (e.g., seeps, springs, disconnected perennial stream reaches), and potential unstable slopes
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species		1	Establish Riparian Conservation Areas (RCAs)	No harvest, as defined in Section 3.2.1 will occur in RCAs including harvesting of standing or downed trees for salvage after disturbance events

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure/Action
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species	Timber Harvest	1	Establish Riparian Conservation Areas (RCAs)	Felling of hazard live or dead trees in RCAs shall only occur where such trees threaten public safety or infrastructure and will be felled towards the aquatic zone or left as downed wood inside the RCA
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species	Timber Harvest	1	Establish Riparian Conservation Areas (RCAs)	Implement processed-based restoration targeted to reduce the stem density of subdominant trees to accelerate the development of heterogenous late-seral forest structure
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species		2	Establish Equipment Restriction Zones (ERZs)	When covered activities take place in RCA, a 35-foot ERZ will be maintained, where vegetative, ground-disturbance, and tree-canopy removal will be minimized and BMPs implemented
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species	Conservation Strategy Implementation	3	Stream Complexity	During the permit term, complete 440 instream improvement projects located in areas where covered activities are occurring
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species	Conservation Strategy Implementation	3	Stream Complexity	Prioritize stream reaches for large wood placement based on priorities identified in Section 4.7.3.5
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species	Conservation Strategy Implementation	3	Stream Complexity	Minimize stream entry with machinery and choose locations to minimize the loss or riparian trees or erosion to the stream banks
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species		6	Establish Habitat Conservation Areas	Designated HCAs adjacent to RCAs will provide larger areas of passive management providing additional benefits to the covered fish species
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.2: Conserve, maintain, and enhance overall stream channel complexity through targeted stream enhancement projects to address limiting factors for covered fish species	Conservation Strategy Implementation	10	Operational Restrictions to Minimize Effects on Covered Species	Follow ODFW recommended in-water work periods. Obtain approval from ODFW for variances to recommended in-water work periods
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow		1	Establish Riparian Conservation Areas (RCAs)	Maintain and protect important riparian vegetation adjacent to the aquatic zone by the establishment of RCAs based on modeled or field verified stream classifications, sensitive areas (e.g., seeps, springs, disconnected perennial stream reaches), and potential unstable slopes
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow		1	Establish Riparian Conservation Areas (RCAs)	No harvest, as defined in Section 3.2.3 will occur in RCAs including harvesting of standing or downed trees for salvage after disturbance events
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Timber Harvest	1	Establish Riparian Conservation Areas (RCAs)	Felling of hazard live or dead trees in RCAs shall only occur where such trees threaten public safety or infrastructure and will be felled towards the aquatic zone or left as downed wood inside the RCA
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends	Timber Harvest	1	Establish Riparian Conservation Areas (RCAs)	Implement processed-based restoration targeted to reduce the stem density of subdominant trees to accelerate the development of heterogenous late-seral forest structure

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure/Action
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	in temperature, fine sediment, pool temperature and depth, and summer low-flow Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow		2	Establish Equipment Restriction Zones (ERZs)	When covered activities take place in RCA, a 35-foot ERZ will be maintained, where vegetative, ground-disturbance, and tree-canopy removal will be minimized and BMPs implemented
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow		2	Establish Equipment Restriction Zones (ERZs)	Minimize effects in ERZs adjacent to the seasonal streams by restricting ground-based equipment and one-end suspension cable operations when there is no flowing or ponded water
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow		2	Establish Equipment Restriction Zones (ERZs)	Limit skid trails on seasonal streams to locations where the least disturbance is expected to occur and retain existing stumps, downed wood, and limit disturbance to vegetation
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Conservation Strategy Implementation	3	Stream Complexity	Minimize stream entry with machinery and choose locations to minimize the loss or riparian trees or erosion to the stream banks
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	5	Standards for Road Improvement and Vacating	Identify roads through Hydrocon surveys that are high risk for sedimentation and implement priority projects for improvement and/or vacating
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	5	Standards for Road Improvement and Vacating	Identify historic roads that are located in unsuitable areas (e.g., unstable, unsafe) and vacate, close, or stabilize when operationally or economically feasible
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	5	Standards for Road Improvement and Vacating	Identify roads through desktop and field inspections that exhibit a high likelihood of failure for improvement, vacate, or relocation to reduce the potential for contributing fine sediment to streams
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow		6	Establish Habitat Conservation Areas	Designated HCAs adjacent to RCAs will provide larger areas of passive management providing additional benefits to the covered fish species
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Water Drafting and Storage	10	Operational Restrictions to Minimize Effects on Covered Species	Follow water drafting specifications found in Section 4.7.10.6 and implement BMPs to reduce fine sediment delivery to streams
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends	Road System Management	11	Road and Trail Construction and Management Measures	Follow road design specifications (e.g., proper drainage of surface water) and implement BMPs to reduce fine sediment delivery to streams

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure/Action
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	in temperature, fine sediment, pool temperature and depth, and summer low-flow Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Roads, including native surface roads, within or adjacent to RCAs that cannot be hydrologically disconnected (or connection mitigated) or are otherwise unsuitable for wintertime haul will be closed to logging trucks during wintertime wet weather
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	New road construction within 200' of a stream channel will be limited by ESU for each covered fish species over a 10-year period
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Commercial road use will be suspended where turbid runoff is likely to reach streams, defined here as equal to events that lead to at least 2-inches of rain in a 24-hour period
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Commercial road use will be suspended when there is observed turbid runoff into streams independent of the rainfall amount until the concern is addressed
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Storage and staging areas for road/trail construction will be sited outside of RCAs and ERZs and hydrologically disconnected from the aquatic environment. Storage of materials with no potential to deliver contaminants (e.g., culverts, large wood, bales of mulch) may be stored in RCAs and ERZs
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Road improvement and construction activities will be conducted during the dry season (April 1 - October 31). If rainy weather (2-inches of rain has occurred in a 24-hour period), construction will be suspended and erosion and sediment control measures will be implemented and reinforced
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Outside of the dry season (November 1 - March 31), ODF may allow road improvement and construction activities through a written waiver during prolonged periods of dry weather
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Vegetation removal, soil disturbance, and clearing and grubbing will be limited to the minimum needed to construct a road or trail
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Excess road and trail excavation materials will be disposed of at a stable location that will not contribute to sedimentation or otherwise degrade covered fish species habitat

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FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Roads and trails with high erosion potential will be rocked with the most durable rock available
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	All road and trail drainage structures (i.e., ditches, out-sloping, culverts, water bars) will be in place as soon as possible during construction and before the rainy season (November 1 to March 31)
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Roads and trails with bare soil will have effective drainage established or will be mulched and/or seeded with native species before the start of the rainy season (November 1 - March 31)
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	When a road construction project is partially completed prior to the beginning of the rainy season (November 1), drainage structures, silt fences, and/or straw dams will be installed on uncompleted subgrades to minimize erosion during the rainy season (November 1 - March 31)
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	When a road construction project is partially completed prior to the beginning of the rainy season (November 1), mulching and/or seeding (native species) will be dispersed on all cut slopes, unarmored fill slopes, and any other areas of bare soil
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	When a road construction project is partially completed prior to the beginning of the rainy season (November 1), the road will be barricaded and routine inspections will occur, and corrective measures will be implemented when necessary throughout the rainy season (November 1 - March 31)
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Road and trail surfaces will have effective drainage including crowning, insloping or outsloping, grade reversals (rolling dips), and waterbars or a combination of these methods
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management / Recreation Infrastructure, Maintenance, and Operations	11	Road and Trail Construction and Management Measures	Upon completion of a road and trail, native seed and mulch will be applied as early as possible to increase germination and growth to cut-and-fill slopes, ditchlines, and waste disposal sites with potential for erosion and fine sediment delivery to streams. Sites shall be reseeded if necessary to address erosion control.
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	Prior to the wet season, effective road surface drainage maintenance will be performed on roads used for harvest operations during the season and observed to need maintenance. Ditch lines will be cleared where there is low capacity or where obstructed. Accumulated sediment and blockages will be removed at cross-drain inlets and outlets
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends	Road System Management	11	Road and Trail Construction and Management Measures	Prior to the wet season, natural surface and aggregate roads will be graded where the surface is uneven from surface erosion or vehicle rutting where potential for fine sediment delivery to streams. Crowning, outsloping, or insloping will be

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FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	in temperature, fine sediment, pool temperature and depth, and summer low-flow Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Road System Management	11	Road and Trail Construction and Management Measures	restored for effective runoff. Outlets will be removed or provided for berms on the road shoulder Cleaned ditch lines and bare soils that have the potential for fine sediment delivery to streams will be seeded with native herbaceous species and mulched. Undercutting of cut-slopes will be avoided when cleaning ditch lines on roads and trails
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Upon completion of an inventory of recreational trail and facility infrastructure, segments of the existing trail system and infrastructure that have been found to be delivering fine sediment to streams will be prioritized for improvement. Completion of the improvements are intended to be completed by the 20th year of the permit term
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Construction of trails will be suspended when soils become saturated with water that would become muddy when disturbed and have potential for erosion and fine sediment delivery to stream. Erosion and sediment control measures will be implemented and reinforced. Soils will be allowed to drain before construction resumes.
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	When a trail construction project is partially completed prior to the beginning of the rainy season (November 1), the trail will be left in a condition that will minimize erosion and potential for fine sediment delivery to streams
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	When a trail construction project is partially completed prior to the beginning of the rainy season (November 1), drainage structures, silt fences, and/or straw dams will be installed on uncompleted subgrades to minimize erosion during the rainy season (November 1 - March 30)
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	When a trail construction project is partially completed prior to the beginning of the rainy season (November 1), the road will be barricaded and routine inspections will occur, and corrective measures will be implemented when necessary throughout the rainy season (November 1 - March 31)
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Trail improvement and construction activities will be implemented during the dry season (April 1 - October 31). Construction could occur outside of this timeframe during prolonged periods of dry weather.
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.3: Maintain and enhance water quality and quantity conditions most important to covered fish species as determined by current conditions and long-term trends in temperature, fine sediment, pool temperature and depth, and summer low-flow	Recreation Infrastructure, Maintenance, and Operations	12	Restrictions on Recreation Facilities	Prior to the beginning of the wet season (November 1), effective trail surface drainage maintenance will be implemented as needed on designated trails that were used and observed to have the potential for fine sediment delivery to streams and are in need of maintenance
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.4: Maintain or enhance fish passage to suitable spawning and rearing habitat by removing or modifying artificial barriers during the course of construction, routine maintenance, and emergency road repair	Conservation Strategy Implementation	4	Remove or Modify Artificial Fish Passage Barriers	Remove, modify, or replace all barriers identified in Table 4-7
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.4: Maintain or enhance fish passage to suitable spawning and rearing habitat by removing or modifying	Conservation Strategy Implementation	4	Remove or Modify Artificial Fish Passage Barriers	Prioritize the removal, modification, or replacement of artificial barriers based on physical and biological elements found in Section 4.7.4

Species	Biological Goal	Biological Objective	Covered Activity	CA_ID	Conservation Action	Measure/Action
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	artificial barriers during the course of construction, routine maintenance, and emergency road repair Objective 1.4: Maintain or enhance fish passage to suitable spawning and rearing habitat by removing or modifying artificial barriers during the course of construction, routine maintenance, and emergency road repair	Conservation Strategy Implementation	4	Remove or Modify Artificial Fish Passage Barriers	Design new and replacement stream crossings to meet NOAA Fisheries (2022) and ODFW passage criteria to maintain upstream and downstream passage for covered fish species
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.4: Maintain or enhance fish passage to suitable spawning and rearing habitat by removing or modifying artificial barriers during the course of construction, routine maintenance, and emergency road repair	Conservation Strategy Implementation	4	Remove or Modify Artificial Fish Passage Barriers	Follow ODFW recommended in-water work periods. Obtain approval from ODFW for variances to recommended in-water work periods
FISH	Goal 1: Support the Persistence and sustainability of Covered Fish Species	Objective 1.4: Maintain or enhance fish passage to suitable spawning and rearing habitat by removing or modifying artificial barriers during the course of construction, routine maintenance, and emergency road repair	Conservation Strategy Implementation	11	Road and Trail Construction and Management Measures	Design new and replacement stream crossings to meet NOAA Fisheries (2022) and ODFW passage criteria to maintain upstream and downstream passage for covered fish species

Appendix N

Monitoring Tables

Terrestrial Species

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	Yes/No	—	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA7: Manage Habitat Conservation Areas	Compliance	5	Document silvicultural treatments in HCAs that enhance suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity.	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	37	Conduct survey of coastal marten distribution in first 15 years of permit term.	Species presence/absence	Currently accepted protocols	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	38	Conduct targeted follow up monitoring to evaluate species response to management, located den sites, and potentially collar females.	Species presence/absence	Currently accepted protocols	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	15	Monitor a subset of management activities and relative changes in habitat quality compared to anticipated modeled outcomes.	Harvest actions and relative changes in habitat quality to inform future management actions.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	39	Conduct field-based habitat surveys on a rolling basis, in a subset of stands inferred to be suitable, in order to confirm microhabitat features necessary for likely species occupancy.	Presence of microhabitat features useful for denning, resting, and foraging.	Surveys in suitable habitat can begin immediately; over time an association of habitat characteristics and LiDAR-based inventory information can be used to better predict habitat quality within the range of the species.	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	40	Document if retention of old-growth trees, known den structures (i.e., tree, snag, log, other), and trees surrounding the known den site occurred during	Yes/No	Old-growth trees and known den structures will be identified in the field pre-harvest by ODF biologists and foresters. Old growth trees will be	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
						any harvest using regeneration techniques.		identified using standard forest mensuration tools and techniques. Inside HCAs, harvest will be avoided in stands with known dens. Outside HCAs, a 100-foot radius no harvest retention area will be centered on the den. Observed in contract administration process.	
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	24	Document if two leave trees per acre were retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	25	Document if snags representative of decay classes 3 - 5 were retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	26	Document if two snags representative of decay classes 1 and 2 per acre were retained in each harvest unit using regeneration techniques.	Yes/No	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	9	Document if downed wood representative of decay classes 3 - 5 per acre was retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	10	Document if at least 600 cubic feet of hard conifer logs representative of decay classes 1-2, on average, per acre were retained outside of RCAs in each unit harvested with regeneration techniques.	Yes/No; If a sale was unable to meet this requirement, provide an explanation of the rationale and efforts that were taken to mitigate.	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	11	Determine effectiveness of retaining and recruiting structural features outside HCAs in a subset of stands over time.	Legacy feature occurrence or development and distribution outside HCAs.	Trend monitoring through densified FIA plot network.	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA10: Operational Restrictions to Minimize	Compliance	41	Document compliance for any management activities within a 0.25-mile radius of known occupied coastal	Yes/No	Seasonal restrictions apply from March 15 through August 15 or until the den is	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
CM	the Quantity of High-Quality Habitat Over Time		Effects on Terrestrial Species			marten den sites (500 feet for tailholds and guylines)		unoccupied. Observed in contract administration.	
	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	42	Document compliance for any nuisance mountain beaver control trapping activities within 2.5 miles of known marten locations.	Yes/No	Trapping and control activities are prohibited until September 30 or until a tracked individual has left the area.	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.1: Conserve, Maintain, and Enhance Existing Coastal Marten Habitat	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA7: Manage Habitat Conservation Areas	Compliance	5	Document silvicultural treatments in HCAs that enhance suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity.	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA7: Manage Habitat Conservation Areas	Effectiveness	37	Conduct survey of coastal marten distribution in first 15 years of permit term.	Species presence/absence	Currently accepted protocols	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA7: Manage Habitat Conservation Areas	Effectiveness	38	Conduct targeted follow up monitoring to evaluate species response to management, located den sites, and potentially collar females.	Species presence/absence	Currently accepted protocols	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA7: Manage Habitat Conservation Areas	Effectiveness	15	Monitor a subset of management activities and relative changes in habitat quality compared to anticipated modeled outcomes.	Harvest actions and relative changes in habitat quality to inform future management actions.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA7: Manage Habitat Conservation Areas	Effectiveness	39	Conduct field-based habitat surveys on a rolling basis, in a subset of stands inferred to be suitable, in order to confirm microhabitat features	Presence of microhabitat features useful for denning, resting, and foraging.	Surveys in suitable habitat can begin immediately; over time an association of habitat characteristics and LiDAR-based inventory	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
						necessary for likely species occupancy.		information can be used to better predict habitat quality within the range of the species.	
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	41	Document compliance for any management activities within a 0.25-mile radius of known occupied coastal marten den sites (500 feet for tailholds and guylines)	Yes/No	Seasonal restrictions apply from March 15 through August 15 or until the den is unoccupied. Observed in contract administration.	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	42	Document compliance for any nuisance mountain beaver control trapping activities within 2.5 miles of known marten locations.	Yes/No	Trapping and control activities are prohibited until September 30 or until a tracked individual has left the area.	Annual
CM	Goal 8: Support the Persistence of Coastal Marten and Increase the Quantity of High-Quality Habitat Over Time	Objective 8.2: Increase the Amount of High Quality Habitat for Coastal Marten	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	Yes/No	—	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA7: Manage Habitat Conservation Areas	Compliance	28	Document silvicultural treatments in HCAs to develop suitable and highly suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity in HCAs, by habitat suitability categories for the covered species.	Contract administration ^a	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	29	Document acres of suitable or highly suitable habitat in the permit area at 5-year intervals over the permit term and over time link relative changes in habitat quality to silvicultural treatments.	Acres of habitat by suitability category; Difference from baseline acreage and change since last reporting period.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	30	Monitor a subset of suitable and highly suitable habitat for marbled murrelet use during the first 20 years of the permit term.	Species presence/absence	Currently accepted protocols	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	31	After year 20, implement a monitoring effort designed to assess nesting occupancy in the permit area that will prioritize assessing nesting activity inside HCAs that have not been surveyed in the past and where occupancy is more likely as a result of increases in habitat quality and quantity.	Species presence/absence	Currently accepted protocols	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	32	Monitor a subset of management activities and relative changes in habitat quality compared to anticipated modeled outcomes.	Harvest actions and relative changes in habitat quality to inform future management actions. Average and range of habitat patch size and interior to perimeter ratio.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	23	Document if retention of old-growth trees, known nest trees, and groups of trees surrounding known den sites occurred during any harvest using regeneration techniques.	Yes/No	Old-growth trees and known nest trees will be identified in the field pre-harvest by ODF biologists and foresters. Old growth trees will be identified using standard forest mensuration tools and techniques. Observed in contract administration.	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	24	Document if two leave trees per acre were retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	11	Determine effectiveness of retaining and recruiting structural features outside HCAs in a subset of stands over time.	Legacy feature occurrence or development and distribution outside HCAs.	Trend monitoring through densified FIA plot network.	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	20	Document compliance for applying seasonal restrictions for activities in or near designated habitat.	Yes/No; If deviations are identified, the following actions are required: 1. site-	Operational restrictions applied to covered activities following USFWS (2022);	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
							specific review by a biologist, 2. documentation of recommendations, and 3. approval by ODF's HCP administrator.	Described in contract language, enforced during sale contract administration, and documented during sale close out process.	
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	33	Document compliance with trash management and removal for all planned activities within designated occupied habitat and associated buffers within the inland range of the covered species.	Yes/No; Number of trash management activity sites in specified areas.	Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.1: Conserve, Maintain, and Enhance Existing Marbled Murrelet Nesting Habitat	CA13: Stay Ahead Provision	Compliance	21	Document that all modeled or assumed habitat for the covered species lost to harvest are replaced with at least as much habitat of equivalent or better quality (as defined by the same models) grown or maintained over time within HCAs.	Habitat quantity and quality (as defined by the same models) for the covered species.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	Yes/No	—	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA7: Manage Habitat Conservation Areas	Compliance	28	Document silvicultural treatments in HCAs to develop suitable and highly suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity in HCAs, by habitat suitability categories for the covered species.	Contract administration ^a	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA7: Manage Habitat Conservation Areas	Effectiveness	29	Document acres of suitable or highly suitable habitat in the permit area at 5-year intervals over the permit term and over time link relative changes in habitat quality to silvicultural treatments.	Acres of habitat by suitability category; Difference from baseline acreage and change since last reporting period.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA7: Manage Habitat Conservation Areas	Effectiveness	30	Monitor a subset of suitable and highly suitable habitat for marbled murrelet use during the first 20 years of the permit term.	Species presence/absence	Currently accepted protocols	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA7: Manage Habitat Conservation Areas	Effectiveness	31	After year 20, implement a monitoring effort designed to assess nesting occupancy in the permit area that will prioritize assessing nesting activity inside HCAs that have not been surveyed in the past and where occupancy is more likely as a result of increases in habitat quality and quantity.	Species presence/absence	Currently accepted protocols	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA7: Manage Habitat Conservation Areas	Effectiveness	32	Monitor a subset of management activities and relative changes in habitat quality compared to anticipated modeled outcomes.	Harvest actions and relative changes in habitat quality to inform future management actions. Average and range of habitat patch size and interior to perimeter ratio.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	20	Document compliance for applying seasonal restrictions for activities in or near designated habitat.	Yes/No; If deviations are identified, the following actions are required: 1. site-specific review by a biologist, 2. documentation of recommendations, and 3. approval by ODF's HCP administrator.	Operational restrictions applied to covered activities following USFWS (2022); Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	20	Document compliance with trash management and removal for all planned activities within designated occupied habitat and associated	Yes/No; Number of trash management activity sites in specified areas.	Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
MAMU	Goal 6: Support the Persistence of Marbled Murrelet and Increase the Quantity of High-Quality Habitat Over Time	Objective 6.2: Increase the Amount of High Quality Habitat for Marbled Murrelet	CA12: Restrictions on Recreational Facilities	Compliance	8	buffers within the inland range of the covered species. Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	Yes/No	—	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA7: Manage Habitat Conservation Areas	Compliance	12	Document silvicultural treatments in HCAs to develop nesting, roosting, and foraging habitat consistent with standards in CA7.	Acres and type of silvicultural activity in HCAs, by habitat suitability categories for the covered species.	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	14	Document acres of nesting, roosting, and foraging habitat in the permit area at 5-year intervals over the permit term.	Acres of habitat by suitability category; Difference from baseline acreage and change since last reporting period.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	15	Monitor a subset of management activities and relative changes in habitat quality compared to anticipated modeled outcomes.	Harvest actions and relative changes in habitat quality to inform future management actions.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	16	Track status of active sites in addition to previously inactive or unoccupied sites in barred owl management areas.	Site occupancy	Currently accepted protocols	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	17	Monitor a subset of existing habitat and ingrowth of nesting, roosting, and foraging	Site occupancy	Currently accepted protocols	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
NSO	Quantity of High-Quality Habitat Over Time Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA9: Strategic Terrestrial Species Conservation Actions	Compliance	18	habitat inside of HCAs for spotted owl presence. Document barred owl removal efforts within and around active northern spotted owl sites and proximal to HCAs	Spotted owl site status, barred owl presence status, number of barred owls removed, acres treated, locations treated, and conservation fund expenditures.	Methodology and monitoring for the removal of barred owls will follow the USFWS Barred Owl Management Strategy (2024) and currently accepted protocols.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA9: Strategic Terrestrial Species Conservation Actions	Effectiveness	19	Determine effectiveness of barred owl removal on spotted owls in permit area where removals were conducted.	Acres of habitat recolonized by spotted owl, in addition to spotted owl survival and productivity.	Currently accepted protocols	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	20	Document compliance for applying seasonal restrictions for activities in or near designated habitat.	Yes/No; If deviations are identified, the following actions are required: 1. site-specific review by a biologist, 2. documentation of recommendations, and 3. approval by ODF's HCP administrator.	Operational restrictions applied to covered activities following USFWS (2022); Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.1: Conserve, Maintain, and Enhance Existing Northern Spotted Owl Habitat	CA13: Stay Ahead Provision	Compliance	21	Document that all modeled or assumed habitat for the covered species lost to harvest are replaced with at least as much habitat of equivalent or better quality (as defined by the same models) grown or maintained over time within HCAs.	Habitat quantity and quality (as defined by the same models) for the covered species.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA1: Establish Riparian Conservation Areas	Compliance	1	Establish and maintain RCAs.	Yes/No		Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	Yes/No	—	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	22	Maintain a minimum 40 percent of the permit area outside HCAs in conditions that meet the definition of dispersal habitat for northern spotted owl. One half of that target (20%) will be in the form of 60-year-old stands and/or stands representing foraging habitat or better, where RCAs less than 120 feet in width and not part of a stand that meets these standards will not be counted towards this.	Acres and percentage of dispersal habitat outside of HCAs.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	23	Document if retention of old-growth trees, known nest trees, and groups of trees surrounding known den sites occurred during any harvest using regeneration techniques.	Yes/No	Old-growth trees and known nest trees will be identified in the field pre-harvest by ODF biologists and foresters. Old growth trees will be identified using standard forest mensuration tools and techniques. Observed in contract administration.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	24	Document if two leave trees per acre were retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	25	Document if snags representative of decay classes 3 - 5 were retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	26	Document if two snags representative of decay classes 1 and 2 per acre were retained in each harvest unit using regeneration techniques.	Confirm compliance and if additional leave tree retention was used to supplement snag levels.	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and	Compliance	9	Document if downed wood representative of decay classes 3 - 5 per acre was retained in each unit	Yes/No	Contract administration ^a	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
NSO	Quantity of High-Quality Habitat Over Time		Riparian Conservation Areas			harvested with regeneration techniques.			
	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	10	Document if at least 600 cubic feet of hard conifer logs representative of decay classes 1-2, on average, per acre were retained outside of RCAs in each unit harvested with regeneration techniques.	Yes/No; If a sale was unable to meet this requirement, provide an explanation of the rationale and efforts that were taken to mitigate.	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	27	Utilize all spotted owl monitoring information to assess if owls are moving across landscape.	Site occupancy	Currently accepted protocols	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	11	Determine effectiveness of retaining and recruiting structural features outside HCAs in a subset of stands over time.	Legacy feature occurrence or development and distribution outside HCAs.	Trend monitoring through densified FIA plot network.	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA9: Strategic Terrestrial Species Conservation Actions	Compliance	18	Document barred owl removal efforts within and around active northern spotted owl sites and proximal to HCAs	Spotted owl site status, barred owl presence status, number of barred owls removed, acres treated, locations treated, and conservation fund expenditures.	Methodology and monitoring for the removal of barred owls will follow the USFWS Barred Owl Management Strategy (2024) and currently accepted protocols.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA9: Strategic Terrestrial Species Conservation Actions	Effectiveness	19	Determine effectiveness of barred owl removal on spotted owls in permit area where removals were conducted.	Acres of habitat recolonized by spotted owl, in addition to spotted owl survival and productivity.	Currently accepted protocols	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	20	Document compliance for applying seasonal restrictions for activities in or near designated habitat.	Yes/No; If deviations are identified, the following actions are required: 1. site-specific review by a biologist, 2. documentation of recommendations, and 3. approval by ODF's HCP administrator.	Operational restrictions applied to covered activities following USFWS (2022); Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.2: Facilitate Northern Spotted Owl Landscape Connectivity	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing,	Yes/No	Recreational project planning review.	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA6: Establish Habitat Conservation Areas	Compliance	3	and use of new recreational facilities are minimized. Establish and maintain HCAs.	Yes/No	—	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA7: Manage Habitat Conservation Areas	Compliance	12	Document silvicultural treatments in HCAs to develop nesting, roosting, and foraging habitat consistent with standards in CA7.	Acres and type of silvicultural activity in HCAs, by habitat suitability categories for the covered species.	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA7: Manage Habitat Conservation Areas	Effectiveness	14	Document acres of nesting, roosting, and foraging habitat in the permit area at 5-year intervals over the permit term.	Acres of habitat by suitability category; Difference from baseline acreage and change since last reporting period.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA7: Manage Habitat Conservation Areas	Effectiveness	15	Monitor a subset of management activities and relative changes in habitat quality compared to anticipated modeled outcomes.	Harvest actions and relative changes in habitat quality to inform future management actions.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA7: Manage Habitat Conservation Areas	Effectiveness	16	Track status of active sites in addition to previously inactive or unoccupied sites in barred owl management areas.	Site occupancy	Currently accepted protocols	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA7: Manage Habitat Conservation Areas	Effectiveness	17	Monitor a subset of existing habitat and ingrowth of nesting, roosting, and foraging habitat inside of HCAs for spotted owl presence.	Site occupancy	Currently accepted protocols	5 year
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA9: Strategic Terrestrial Species Conservation Actions	Compliance	18	Document barred owl removal efforts within and around active northern spotted owl sites and proximal to HCAs	Spotted owl site status, barred owl presence status, number of barred owls removed, acres treated, locations treated, and	Methodology and monitoring for the removal of barred owls will follow the USFWS Barred Owl Management Strategy	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
NSO	Goal 5: Support the Persistence of Northern Spotted Owl Habitat and Increase the Quantity of High-Quality Habitat Over Time	Objective 5.3: Increase the Amount of High Quality Habitat for Northern Spotted Owl	CA9: Strategic Terrestrial Species Conservation Actions	Effectiveness	19	Determine effectiveness of barred owl removal on spotted owls in permit area where removals were conducted.	conservation fund expenditures. Acres of habitat recolonized by spotted owl, in addition to spotted owl survival and productivity.	(2024) and currently accepted protocols. Currently accepted protocols	5 year
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA1: Establish Riparian Conservation Areas	Compliance	1	Establish and maintain RCAs.	Yes/No	—	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA2: Riparian Equipment Restriction Zones	Compliance	2	Minimize impacts associated with harvesting from ERZs.	Yes/No	Contract administration ^a	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	Yes/No	—	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA7: Manage Habitat Conservation Areas	Compliance	4	Conduct baseline monitoring in a subset of stands to determine covered species occurrence and distribution.	Species presence/absence, abundance	Currently accepted protocols	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA7: Manage Habitat Conservation Areas	Compliance	5	Document silvicultural treatments in HCAs that enhance suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity.	Contract administration ^a	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	6	Conduct pre- and post-harvest surveys to document covered species response to harvest activities.	Species presence/absence and abundance; Volume, diameter, length, and decay class of downed wood; snag abundance, diameter, and decay stage.	Pre- and post-activity species occurrence surveys and assessment of forest legacy features in select stands following management activities. Over time assess linkage between previous harvest actions and relative changes in habitat quality to inform future management actions.	5 year
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	4	Conduct baseline monitoring in a subset of stands to determine covered species occurrence and distribution.	Species presence/absence, abundance	Currently accepted protocols	Annual

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	7	Conduct pre- and post-harvest surveys to document covered species response to harvest activities and downed wood retention standards.	Species presence/absence and abundance; Volume, diameter, length, and decay class of downed wood; snag abundance, diameter, and decay stage; leave tree abundance and diameter (specific to regeneration harvest outside HCAs).	Pre- and post-activity species occurrence surveys and assessment of forest legacy features in select stands following management activities. Over time assess linkage between previous harvest actions and relative changes in habitat quality to inform future management actions.	5 year
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.1: Conserve, Maintain, and Enhance Existing Oregon Slender Salamander Habitat	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	9	Document if downed wood representative of decay classes 3 - 5 per acre was retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	10	Document if at least 600 cubic feet of hard conifer logs representative of decay classes 1-2, on average, per acre were retained outside of RCAs in each unit harvested with regeneration techniques.	Yes/No; If a sale was unable to meet this requirement, provide an explanation of the rationale and efforts that were taken to mitigate.	Contract administration ^a	Annual
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	11	Determine effectiveness of retaining and recruiting structural features outside HCAs in a subset of stands over time.	Legacy feature occurrence or development and distribution outside HCAs.	Trend monitoring through densified FIA plot network.	5 year
OSS	Goal 4: Support the Persistence of Oregon Slender Salamander and Increase the Quantity of High-Quality Habitat Over Time	Objective 4.2: Retain and Recruit Downed Wood to Supoort Oregon Slender Salamander	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	7	Conduct pre- and post-harvest surveys to document covered species response to harvest activities and downed wood retention standards.	Species presence/absence and abundance; Volume, diameter, length, and decay class of downed wood; snag abundance, diameter, and decay stage; leave tree abundance and diameter (specific to	Pre- and post-activity species occurrence surveys and assessment of forest legacy features in select stands following management activities. Over time assess linkage between previous harvest actions and relative changes in habitat quality to inform	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA6: Establish Habitat Conservation Areas	Compliance	3	Establish and maintain HCAs.	regeneration harvest outside HCAs). Yes/No	future management actions. —	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Compliance	28	Document silvicultural treatments in HCAs to develop suitable and highly suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity in HCAs, by habitat suitability categories for the covered species.	Contract administration ^a	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	29	Document acres of suitable or highly suitable habitat in the permit area at 5-year intervals over the permit term and over time link relative changes in habitat quality to silvicultural treatments.	Acres of habitat by suitability category; Difference from baseline acreage and change since last reporting period.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	30	Monitor a subset of suitable and highly suitable habitat for covered species use during the first 20 years of the permit term.	Species presence/absence (arboreal nests)	Currently accepted protocols	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	34	After year 20, implement a monitoring effort designed to assess nesting activity in the permit area focusing on locations with habitat inside of HCAs that have not been surveyed in the past, but where occupancy is expected due to adjacency to other occupied areas, or locations where habitat quality has improved to suitable under the HCP.	Species presence/absence (arboreal nests)	Currently accepted protocols	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	15	Monitor a subset of management activities and relative changes in habitat quality compared to	Harvest actions and relative changes in habitat quality to	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA7: Manage Habitat Conservation Areas	Effectiveness	35	anticipated modeled outcomes. Evaluate red tree vole response to management activities	inform future management actions. Species presence/absence (arboreal nests)	Currently accepted protocols	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	23	Document if retention of old-growth trees, known nest trees, and groups of trees surrounding known den sites occurred during any harvest using regeneration techniques.	Yes/No	Old-growth trees and known nest trees will be identified in the field pre-harvest by ODF biologists and foresters. Old growth trees will be identified using standard forest mensuration tools and techniques. Observed in contract administration.	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Compliance	24	Document if two leave trees per acre were retained in each unit harvested with regeneration techniques.	Yes/No	Contract administration ^a	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA8: Targeted Actions Outside Habitat Conservation Areas and Riparian Conservation Areas	Effectiveness	11	Determine effectiveness of retaining and recruiting structural features outside HCAs in a subset of stands over time.	Legacy feature occurrence or development and distribution outside HCAs.	Trend monitoring through densified FIA plot network.	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	36	Document compliance for any forest management activities within 10 acres of known red tree vole nest trees.	Yes/No	Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.1: Conserve, Maintain, and Enhance Occupied Red Tree Vole Habitat	CA13: Stay Ahead Provision	Compliance	21	Document that all modeled or assumed habitat for the covered species lost to harvest are replaced with at least as much habitat of equivalent or better quality (as defined by the same models) grown or	Habitat quantity and quality (as defined by the same models) for the covered species.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA6: Establish Habitat Conservation Areas	Compliance	3	maintained over time within HCAs. Establish and maintain HCAs.	Yes/No	—	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Compliance	28	Document silvicultural treatments in HCAs to develop suitable and highly suitable habitat consistent with standards in CA 7.	Acres and type of silvicultural activity in HCAs, by habitat suitability categories for the covered species.	Contract administration ^a	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Compliance	13	Document any fuels reduction efforts inside HCAs.	Yes/No; Location and extent of fuel reduction activities; Describe how efforts were intended to minimize effects on habitat suitability.	Contract administration ^a	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Effectiveness	29	Document acres of suitable or highly suitable habitat in the permit area at 5-year intervals over the permit term and over time link relative changes in habitat quality to silvicultural treatments.	Acres of habitat by suitability category; Difference from baseline acreage and change since last reporting period.	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Effectiveness	30	Monitor a subset of suitable and highly suitable habitat for covered species use during the first 20 years of the permit term.	Species presence/absence (arboreal nests)	Currently accepted protocols	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Effectiveness	34	After year 20, implement a monitoring effort designed to assess nesting activity in the permit area focusing on locations with habitat inside of HCAs that have not been surveyed in the past, but where occupancy is expected due to adjacency to other occupied areas, or locations where habitat quality has improved to suitable under the HCP.	Species presence/absence (arboreal nests)	Currently accepted protocols	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Effectiveness	15	Monitor a subset of management activities and relative changes in habitat quality compared to	Harvest actions and relative changes in habitat quality to	Modeled from inventory metrics, using densified FIA plot network, LiDAR, and stand exams.	5 year

Species ^b	Goal	Objective	Conservation Action	Monitoring type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA7: Manage Habitat Conservation Areas	Effectiveness	35	anticipated modeled outcomes. Evaluate red tree vole response to management activities	inform future management actions. Species presence/absence (arboreal nests)	Currently accepted protocols	5 year
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA10: Operational Restrictions to Minimize Effects on Terrestrial Species	Compliance	36	Document compliance for any forest management activities within 10 acres of known red tree vole nest trees.	Yes/No	Described in contract language, enforced during sale contract administration, and documented during sale close out process.	Annual
RTV	Goal 7: Support the Persistence of Red Tree Vole and Increase the Quantity of High-Quality Habitat Over Time	Objective 7.2: Increase the Amount of High-Quality Habitat for Red Tree Vole	CA12: Restrictions on Recreational Facilities	Compliance	8	Document compliance of any new or expanded facility infrastructure and trail development to ensure impacts associated with siting, constructing, and use of new recreational facilities are minimized.	Yes/No	Recreational project planning review.	Annual

^a See Section 8.6, Contract Administration, for additional details on contract administration.
^b CM = coastal marten; MAMU = marbled murrelet; NSO = northern spotted owl; OSS = Oregon slender salamander; RTV = red tree vole

Aquatic Species

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA1: Establish RCAs	Compliance	1	Document adherence to RCA-posted boundaries	Length of stream and acres of RCAs established by stream classification including rational and administrative approvals for exceptions	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA1: Establish RCAs	Compliance	43	Document compliance of potential unstable landforms that are potential sources of debris flows that would deliver large wood to fish-bearing streams	Number and classifications of potential unstable landforms	GIS analysis and field assessments following currently accepted monitoring protocols	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA1: Establish RCAs	Compliance	44	Track Processed Based Restoration (PBR) projects and ensure proper prioritization and prescriptions were implemented	Number and type of PBR projects completed including prioritization and prescription used	Contract administration process and reporting	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA1: Establish RCAs	Compliance	45	Document annual expenditures from the conservation fund	Distribution of conservation funds for PBR projects	Conservation fund report	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA1: Establish RCAs	Effectiveness	46	Track trends in natural large wood recruitment	Number of wood pieces, volume, and distribution	ODFW AQI protocol (2025 or most current version)	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA1: Establish RCAs	Effectiveness	47	Monitor a subset of identified potential unstable landforms to determine if failure and delivery of large wood to fish-bearing streams was achieved	Number of unstable landforms that experienced failure and volume and distribution of large wood	Field assessments following currently accepted monitoring protocols	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA1: Establish RCAs	Effectiveness	48	Document trends in stand and understory conditions of PBR-treated patches	Stand and understory conditions and development	Field assessments following currently accepted monitoring protocols	5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA2: Riparian ERZs	Compliance	2	Document adherence to ERZ conservation actions	Length of stream and acres of ERZs established by stream classification including rational and administrative	Contract administration process and reporting	Annual

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA11: Road and Trail Construction and Management Measures	Compliance	49	Track the number of new roads built within 200' of stream channels	approvals for exceptions Miles of new roads constructed within 200 feet of stream channels by stream classification	GIS analysis and contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.1: Riparian Wood Recruitment	CA12: Restrictions on Recreational Facilities	Compliance	50	Confirm new recreational facility development in RCAs was limited to trails and boat ramps	Location and type of trails and boat ramps within RCAs	New facilities and trail screening in RCAs	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA2: Riparian ERZs	Compliance	51	Document compliance of ODFW recommended in-water work periods including variances approved by ODFW	Yes/No. If in-water work variances were approved by ODFW, the following actions are required: (1) Site-specific review by aquatic biologist; (2) Documentation of recommendations; (3) Consultation with ODFW and NOAA	Stream enhancement reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Compliance	52	Ensure acres harvested by ESU/DPS is part of stream enhancement prioritization	Number and type of stream enhancement projects completed in comparison with acres harvested by ESU/DPS	Stream enhancement reporting	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Compliance	53	Track stream enhancement projects and ensure proper prioritization was utilized	Number and type of stream enhancement projects completed including prioritization used	Stream enhancement reporting	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Compliance	45	Document annual expenditures from the conservation fund	Distribution of conservation funds for stream enhancement projects	Conservation fund report	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Compliance	54	Ensure the presence of Pacific lamprey is part of the stream enhancement project prioritization process	Number and type of stream enhancement projects completed within Pacific lamprey distribution	Stream enhancement reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Effectiveness	55	Document trends in stream channel complexity associated with stream enhancement projects	Stream channel physical habitat features	ODFW AQI Protocol (2025 or most current version)	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Effectiveness	56	Track conservation fund expenditures to ensure projects meet the intent and breakdown between aquatic and terrestrial allocations	Conservation fund expenditures broken down by aquatic and terrestrial allocations	Conservation fund report	Annual 5-Year 10-Year

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.2: Stream Complexity	CA3: Stream Complexity	Effectiveness	57	Track completed stream enhancement projects within Pacific lamprey distribution	Miles of stream enhanced within Pacific lamprey distribution	Stream enhancement reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Compliance	1	Document adherence to RCA-posted boundaries	Length of stream and acres of RCAs established by stream classification including rational and administrative approvals for exceptions	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Effectiveness	58	Monitor current conditions and trends in riparian condition	Stream channel shade	Currently accepted monitoring protocol / ODFW AQI protocol (2025 or most current version)	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Effectiveness	59	Monitor current conditions and trends in riparian function	Channel shade	Currently accepted monitoring protocol / ODFW AQI protocol (2025 or most current version)	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Effectiveness	60	Monitor current conditions and trends in stream temperature	Stream temperature	Currently accepted monitoring protocol, state agency data, stakeholder watershed temperature studies	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Effectiveness	60	Monitor current conditions and trends in stream temperature	Stream temperature	10-year trend analysis showing the trajectory of stream temperature	10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Effectiveness	61	Monitor current conditions and trends in fine sediment	Fine sediment in stream substrate	Currently accepted monitoring protocol / ODFW AQI protocol (2025 or most current version)	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA1: Establish RCAs	Effectiveness	61	Monitor current conditions and trends in fine sediment	Fine sediment in stream substrate	10-year trend analysis showing the trajectory of fine sediment	10-Year

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA2: Riparian ERZs	Compliance	2	Document adherence to ERZ conservation actions	Length of stream and acres of ERZs established by stream classification including rational and administrative approvals for exceptions	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA2: Riparian ERZs	Compliance	62	Document that a Needs Assessment was performed for all roads/motorized trails/temporary crossings, or encroachments and that other options were not economically or operationally feasible	Needs assessment completed	Needs assessment review	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA2: Riparian ERZs	Effectiveness	63	Review a subset of Needs Assessments to determine locations, purpose, frequency and if chosen option created a lesser impact to covered species and were economically or operationally feasible	Were Needs Assessments adequately performed	Needs assessment review	N/A
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA3: Stream Complexity	Effectiveness	64	Monitor a subset of stream enhancement projects to determine trends in the number, temperature, and depth of pools post-project	Localized effects on pool temperature and depth at project site	Currently accepted monitoring protocol / ODFW AQI protocol (2025 or most current version)	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA3: Stream Complexity	Effectiveness	65	Monitor a subset of stream enhancement projects to determine current conditions and trends in fine sediment	Fine sediment in stream substrate	Currently accepted monitoring protocol / ODFW AQI protocol (2025 or most current version)	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA5: Standards for Road Improvement and Vacating	Compliance	66	Identify roads that are at risk of hydrologic connectivity and sediment delivery to streams for improvement or vacating	Miles of roads which have been hydrologically surveyed, miles of road connected and mitigated, and miles of road connected but not mitigated	Hydro-connectivity surveys	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA5: Standards for Road Improvement and Vacating	Compliance	67	Identify roads that are chronic points of sedimentation into streams	Number of connection points that are subject to chronic erosion that	Sediment delivery event report	Annual

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA5: Standards for Road Improvement and Vacating	Compliance	68	Identify roads that are landslide hazards in proposed harvest areas	introduces sediment into streams Miles of roads most susceptible to contribute to degrading aquatic conditions in proposed harvest areas	LiDAR, aerial photos, and/or field surveys by Geotechnical Specialist	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA5: Standards for Road Improvement and Vacating	Effectiveness	69	Monitor trends over time in the ratio of connected, mitigated, and connected but not mitigated road segments	Miles of roads which have been hydrologically surveyed, miles of road connected and mitigated, and miles of road connected but not mitigated	Hydro-connectivity surveys	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA5: Standards for Road Improvement and Vacating	Effectiveness	70	Document roads closed, gated, and/or vacated	Miles of roads closed, gated, and/or vacated	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA10: Road/Trail Construction and Management	Compliance	71	Document compliance for screening water drafting locations and utilization of appropriate screen size	Location, water drafting screen size, and other BMPs	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	72	Document compliance related to road/trail construction standards	Confirm road/trail construction and management measures were properly implemented. When non-compliance occurs, operations will be halted until appropriate corrective measures are implemented to ensure compliance	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	73	Document temporary suspension of operations associated with sediment delivery to streams	Locations of sediment delivery, stream classification, and mitigation actions implemented associated with commercial road use	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	74	Document status of hydrologically disconnecting and mitigating sections of connected road/trail systems from streams	Miles of roads/trails that have been surveyed for hydrologic connection, unconnected, connected and mitigated, and	Hydro-connectivity surveys	Annual

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	75	Document miles of new constructed trails	connected and not mitigated or vacated Net trail miles broken down type, miles within RCAs, ERZs, and HCAs. Compare to allowed established limits	Trail surveys	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	76	Document compliance of ERZ conservation actions	Adherence and exceptions to ERZ conservation actions including rationale and administrative approvals for exceptions	Contract administration process and reporting?	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	77	Document that a Needs Assessment was performed for all roads/motorized trails, the road/trail was necessary, and that other options were not economically or operationally feasible	Needs assessment completed	Needs assessment review	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	78	Document the number of miles of road/trail vacated in RCAs	Miles of roads/trails vacated within RCAs and BMPs followed	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	79	Monitor a subset of road crossings for changes in turbidity following construction of haul roads	Changes in turbidity following construction of haul roads	Currently accepted turbidity monitoring protocols	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Compliance	80	Monitor a subset of new, upgraded, or decommissioned stream crossings for trends associated with changes in turbidity	Changes in turbidity from new, upgraded or decommissioned stream crossings	Currently accepted turbidity monitoring protocols	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Effectiveness	81	Monitor a subset of harvest units for changes in turbidity pre-and-post harvest	Changes in turbidity from road/trail related landslides/debris flows	Currently accepted turbidity monitoring protocols	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA11: Road and Trail Construction and Management Measures	Effectiveness	82	Document changes to hydrologically connected roads/trails	Miles of roads/trails that have been surveyed for hydrologic connection, unconnected, connected and mitigated, and	Hydro-connectivity surveys	Annual 5-Year

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA12: Restrictions on Recreational Facilities	Compliance	8	Document trail and facility infrastructure	connected and not mitigated or vacated Miles of trail by type, list of all designated campground and day use facilities including conditions	Inventory of existing trail networks, campgrounds, and day use facilities including current condition as it relates to potential sediment delivery	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA12: Restrictions on Recreational Facilities	Compliance	83	Identify trails at risk of hydrologic connectivity and sediment delivery to streams for improvement or vacating	Miles of trails that have been surveyed for hydrologic connection, miles of trail connected and mitigated, and miles of trail connected but not mitigated	Hydro-connectivity surveys	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA12: Restrictions on Recreational Facilities	Compliance	84	Document trails that are chronic sources/points of sedimentation to streams	Number of connection points that are subject to chronic erosion that introduces sediment into streams	Trail surveys	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA12: Restrictions on Recreational Facilities	Compliance	85	Document net miles of trails for established limits within HCAs, RCAs and ERZs	Miles of trails broken down by type and miles within HCAs, RCAs, ERZs	Trail surveys	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.3: Water Quality and Quantity	CA12: Restrictions on Recreational Facilities	Compliance	86	Document miles of trails vacated	Miles of designated and user created trails vacated	Trail surveys	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA2: Riparian ERZs	Compliance	51	Document compliance of ODFW recommended in-water work periods including variances approved by ODFW	Yes/No. If in-water work variances were approved by ODFW, the following actions are required: (1) Site-specific review by aquatic biologist; (2) Documentation of recommendations; (3) Consultation with ODFW	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA4: Remove or Modify Artificial Barriers	Compliance	87	Document status of the removal or upgrade of barriers identified in Chapter 4, Section 4.7.4	Status of barriers identified in Chapter 4, Section 4.7.4	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA4: Remove or Modify Artificial Barriers	Compliance	88	Document fish rescue/salvage projects	Location, methods, BMPs implemented, and species and life stages captured	Aquatic organism rescue/salvage report	Annual

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA4: Remove or Modify Artificial Barriers	Compliance	89	Document compliance with ODFW and NOAA fish passage criteria	Location, type, and design criteria of new or upgraded fish passage projects	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA4: Remove or Modify Artificial Barriers	Compliance	51	Document compliance of ODFW recommended in-water work periods including variances approved by ODFW	Yes/No. If in-water work variances were approved by ODFW, the following actions are required: (1) Site-specific review by aquatic biologist; (2) Documentation of recommendations; (3) Consultation with ODFW	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA4: Remove or Modify Artificial Barriers	Compliance	45	Document annual expenditures from the conservation fund	Distribution of conservation funds for fish passage projects that benefited the covered fish species	Conservation fund report	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA4: Remove or Modify Artificial Barriers	Effectiveness	90	Document miles of available suitable habitat upstream resulting from the removal/upgrade of fish passage barriers	Miles of suitable habitat accessible upstream for the covered fish species resulting from the removal/upgrade of fish passage barriers	Fish passage reporting	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA5: Standards for Road Improvement and Vacating	Compliance	89	Document compliance with ODFW and NOAA fish passage criteria	Location, type, and design criteria of new or upgraded fish passage projects	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA5: Standards for Road Improvement and Vacating	Compliance	51	Document compliance of ODFW recommended in-water work periods including variances approved by ODFW	Yes/No. If in-water work variances were approved by ODFW, the following actions are required: (1) Site-specific review by aquatic biologist; (2) Documentation of recommendations; (3) Consultation with ODFW	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA5: Standards for Road Improvement and Vacating	Compliance	45	Document annual expenditures from the conservation fund	Distribution of conservation funds for fish passage projects that benefited the covered fish species	Conservation fund report	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA5: Standards for Road Improvement and Vacating	Effectiveness	87	Document status of the removal or upgrade of barriers identified in Chapter 4, Section 4.7.4	Status of barriers identified in Chapter 4, Section 4.7.4	Fish passage reporting	Annual 10-Year

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA5: Standards for Road Improvement and Vacating	Effectiveness	90	Document miles of available suitable habitat upstream resulting from the removal/upgrade of fish passage barriers	Miles of suitable habitat accessible upstream for the covered fish species resulting from the removal/upgrade of fish passage barriers	Fish passage reporting	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA11: Road and Trail Construction and Management Measures	Compliance	89	Document compliance with ODFW and NOAA fish passage criteria	Location, type, and design criteria of new or upgraded fish passage projects	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA11: Road and Trail Construction and Management Measures	Compliance	91	Document new, upgraded, or decommissioned stream crossings	Location, type, and stream classification of new, upgraded, or decommissioned stream crossings	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA11: Road and Trail Construction and Management Measures	Compliance	88	Document fish rescue/salvage projects	Location, methods, BMPs implemented, and species and life stages captured	Aquatic organism rescue/salvage report	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA11: Road and Trail Construction and Management Measures	Compliance	51	Document compliance of ODFW recommended in-water work periods including variances approved by ODFW	Yes/No. If in-water work variances were approved by ODFW, the following actions are required: (1) Site-specific review by aquatic biologist; (2) Documentation of recommendations; (3) Consultation with ODFW	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA11: Road and Trail Construction and Management Measures	Compliance	45	Document annual expenditures from the conservation fund	Distribution of conservation funds for fish passage projects that benefited the covered fish species	Conservation fund report	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA11: Road and Trail Construction and Management Measures	Effectiveness	90	Document miles of available suitable habitat upstream resulting from the removal/upgrade of fish passage barriers	Miles of suitable habitat accessible upstream for the covered fish species resulting from the removal/upgrade of fish passage barriers	Fish passage reporting	Annual 5-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA12: Restrictions on Recreational Facilities	Compliance	91	Document new, upgraded, or decommissioned stream crossings	Location, type, and stream classification of new, upgraded, or decommissioned stream crossings	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA12: Restrictions on Recreational Facilities	Compliance	88	Document fish rescue/salvage projects	Location, methods, BMPs implemented,	Aquatic organism rescue/salvage report	Annual

Species	Biological Goal	Biological Objective	Conservation Action	Monitoring Type	Monitoring Action ID	Monitoring Action	Metric	Methodology	Reporting
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA12: Restrictions on Recreational Facilities	Compliance	89	Document compliance with ODFW and NOAA fish passage criteria	and species and life stages captured Location, type, and design criteria of new or upgraded fish passage projects	Contract administration process and reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA12: Restrictions on Recreational Facilities	Compliance	51	Document compliance of ODFW recommended in-water work periods including variances approved by ODFW	Yes/No. If in-water work variances were approved by ODFW, the following actions are required: (1) Site-specific review by aquatic biologist; (2) Documentation of recommendations; (3) Consultation with ODFW	Fish passage reporting	Annual
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA12: Restrictions on Recreational Facilities	Compliance	45	Document annual expenditures from the conservation fund	Distribution of conservation funds for fish passage projects that benefited the covered fish species	Conservation fund report	Annual 5-Year 10-Year
FISH	Goal 1: Support the persistence and sustainability of Covered Fish Species	Objective 1.4: Fish Passage	CA12: Restrictions on Recreational Facilities	Effectiveness	90	Document miles of available suitable habitat upstream resulting from the removal/upgrade of fish passage barriers	Miles of suitable habitat accessible upstream for the covered fish species resulting from the removal/upgrade of fish passage barriers	Fish passage reporting	Annual 5-Year

Appendix O

List of Preparers

Oregon Department of Forestry

HCP Team

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Ron Zilli	Past Deputy Division Chief
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