Contrasting Juniper Management Projects of the Past with an Ecologically based, Landscape-scale Approach

CSR Natural Resources Consulting, Inc.

Hugh Barrett, P.I.

January 21, 2009

Acknowledgements

I owe a debt of gratitude to two people for their help in drafting this report. First to Mr. Tim Rose, a retired timber faller, who commented on an early draft and pressed me for clearer explanations on several points and topics – telling me that if he could understand what I was trying to say, he and many others might support the outcomes I hope for. Thank you, Tim. I hope you are not disappointed.

Secondly, to Dr. John Buckhouse who "eared me down" on the science side and filled me in on much of the history in the evolution of the art and science of rangeland watershed management. Blame John for the citations of my work in this report. Without his insistence, that horn would have gone un-tooted.

"…the landscape is an arena for the interaction of natural and social forces, a kind of display, and one that like all displays is not fully under control of its authors.

Native Americans ran the continent as they saw fit. Modern nations must do the same. If they want to return as much of the landscape as possible to its state in 1491, they will have to create the world's largest gardens.

Gardens are fashioned for many purposes with many different tools, but all are collaborations with natural forces. Rarely do their makers claim to be restoring or rebuilding anything from the past; and they are never in full control of the results. Instead, using the best tools they have and all the knowledge that they can gather, they work to create future environments.

If there is a lesson it is that to think like the original inhabitants of these lands we should not set our sights on rebuilding an environment from the past but concentrate on shaping a world to live in for the future."

Charles C. Mann, Author

1491 – New Revelations of the Americas before Columbus 2006

"..and then at this darkest hour...a group of visionary folks from all walks of life began wondering if there wasn't another way forward, something more like a win-win outcome. From this desperate inspiration was born the awareness and appreciation of watershed enhancement as a way to re-shape the runoff hydrograph back into a more gentle curve, as a way to more effectively capture, store and safely release precious water...for all the beneficial uses (within some reasonable sideboards), while at the same time improving a long list of other attributes relating to healthy and functioning ecosystems with sufficient habitat for all kinds of critters, including us rascally and sometimes rapacious humans."

Abstract

This report, prepared by CSR Natural Resources Consulting, Inc., contrasts the management of western juniper (Juniperus occidentalis) of the past with an emerging ecologically based, landscape-scale approach that addresses the site-specific treatment needs of watershed in which juniper has encroached or is in the process of in-fill.

The report details the geologic history, climate, soils and potential and current vegetation of the Crooked River Watershed of Central Oregon. Included is a review of juniper control efforts conducted over the past 60 years. A discussion of the emerging science, ecological principles and landscape-scale approach to watershed prioritization is intended for use in developing a strategy for the enhancement of the semi-arid watersheds of Oregon.

The report concludes with a set of recommendations for the Oregon Watershed Enhancement Board and others in the hope of stimulating an acceleration of cooperative landscape-scale projects in the region and the State.

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Introduction

Purpose

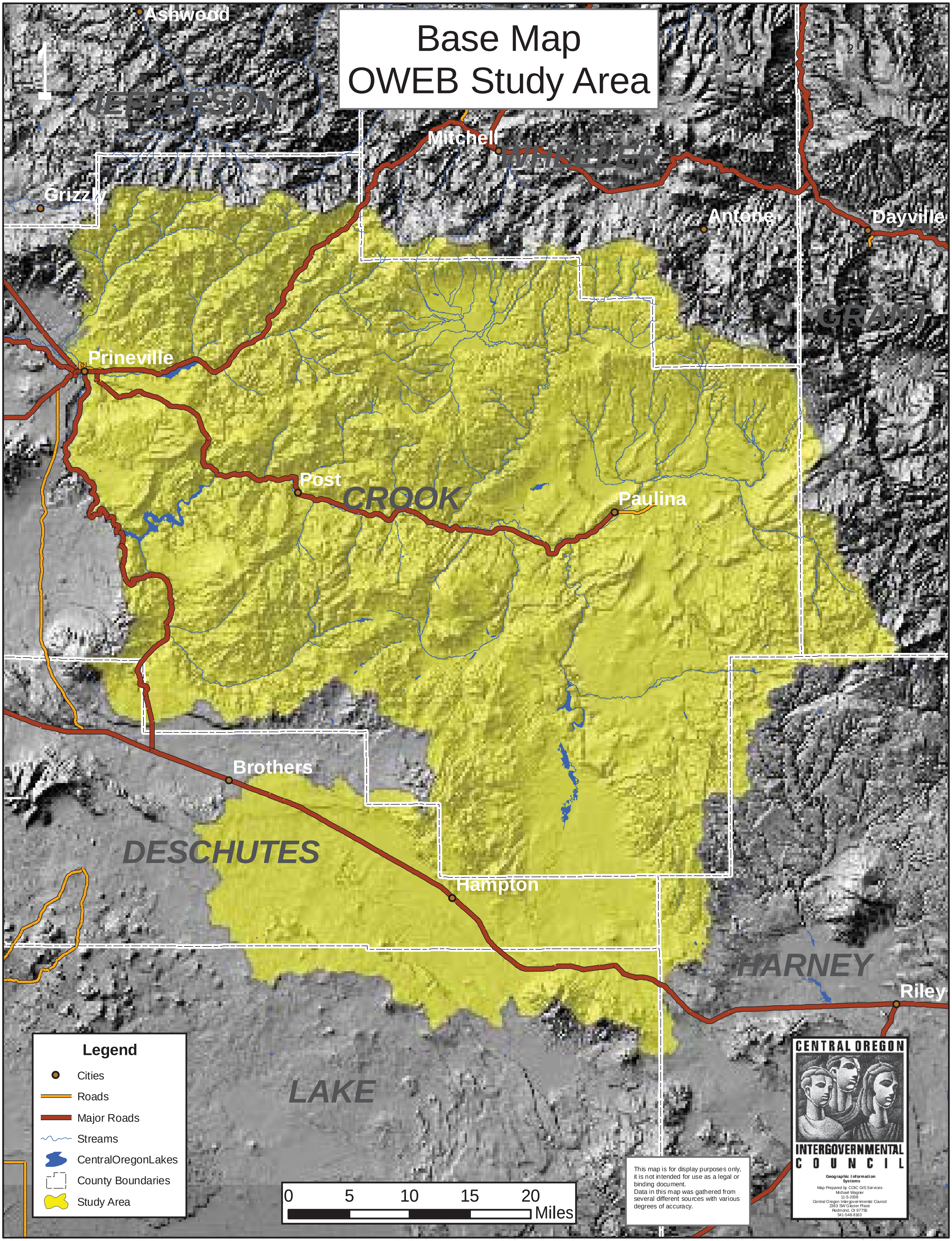
This report offers guidance to the Oregon Watershed Enhancement Board (OWEB) in developing a strategy for the enhancement of the semi-arid rangeland watersheds of central and eastern Oregon. It focuses specifically on the lands where the sagebrush biome is being lost to western juniper encroachment. The report assumes that healthy, well functioning, productive, diverse and sustainable watersheds are a goal the State of Oregon and its citizens. Under this assumption, this report argues for an ecologically based approach to land treatment and watershed repair, rather than an approach based on budgetary expedience and single-purpose objectives.

The report arose from OWEB's juniper control effectiveness monitoring project conducted in 2005 and 2007 by CSR Natural resources Consulting, Inc. (CSR). The results of two year years of project monitoring showed that some juniper control projects were simply "juniper kills" lacking due consideration of basic ecological needs of the treated lands. There were, however, many well-designed, well-implemented projects also reviewed in this process. In contrasting the environmentally sound projects with the former, the ecological and economic values accrued, versus opportunities lost, became starkly apparent.

The intent of contrasting juniper management of the past with a more ecologically based, landscape scale approach emerging today is not to criticize that earlier work. Rather, it attempts to illustrate the values recovered by applying an ecologically based process of prioritizing and implementing land treatments that meet the needs of the land and needs of a burgeoning population. While the focus of this report is ostensibly western juniper, - its effects in the landscape, and its control - the deeper intent of this report is to encourage the recovery of rangeland health and function for all its inherent values.

Selection of the Area

The Crooked River watershed study area (see: Base Map OWEB Study Area) was selected for a set of reasons. Irrigators, domestic and municipal water users as well as recreationists depend on the watershed's optimal function for clean and reliable flows of water. The populations of salmon and steelhead in the lower Deschutes River, and those being re-introduced into the Crooked River watershed rely on the same quality, quantity and duration of flow. The watershed is a compact laboratory where landowners and agencies have been, and continue to actively control western juniper (Juniperus occidentalis). And since the watershed is representative of many landscapes, climates, vegetation types and diversity of public and private ownership in central and eastern Oregon, it is hoped this report has application in many other areas of the state (see map: OWEB Study Area with Land Status).


Base Map
OWEB Study Area
Ashwood
JEFFERSON
Mitchell
WHEELER
Grizzly
Antone
Dayville
GRANT
Prineville
Post
CROOK
Paulina
Brothers
DESCHUTES
Hampton
HARNEY
Riley
LAKE
Legend
Cities
Roads
Major Roads
Streams
CentralOregonLakes
County Boundaries
Study Area
0
5
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15
20
Miles
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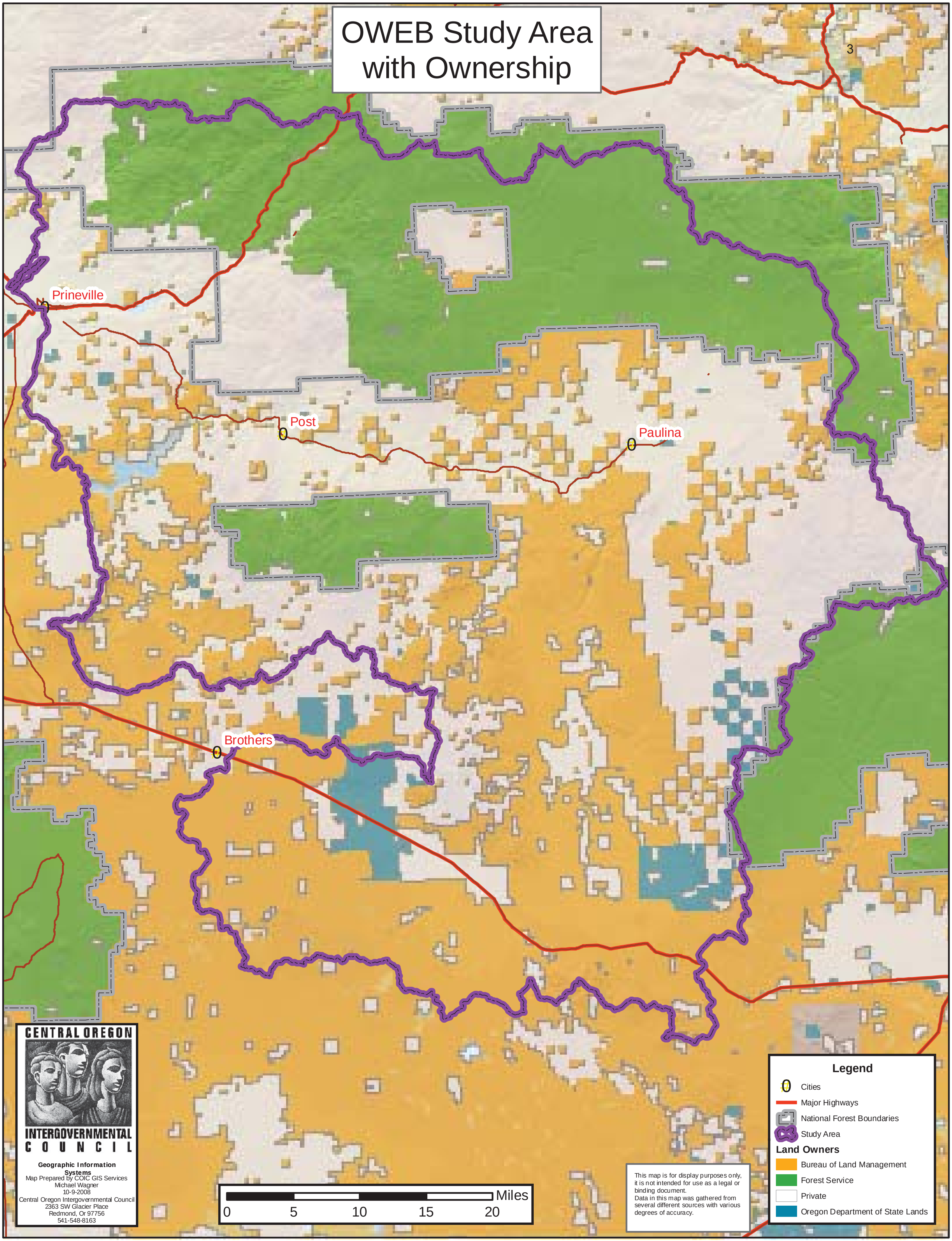
OWEB Study Area
with Ownership
3
Prineville
Post
Paulina
Brothers
Legend
Cities
Major Highways
National Forest Boundaries
Study Area
Land Owners
Bureau of Land Management
Forest Service
Private
Oregon Department of State Lands
0 5 10 15 20 Miles
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Method

In developing this report, CSR met with several local ranchers, individually and in groups; interviewed a number of state and federal agency representatives - including OSU Extension Service, Bureau of Land Management (BLM), US Forest Service (USFS), Natural Resource Conservation Service (NRCS) and OWEB. The Central Oregon inter-governmental Council collected and interpreted the graphic and tabular data used in the report. CSR reviewed currently available literature and relied heavily on the conversations with those mentioned above in interpreting the current on-ground situation.

Description of the Crooked River Watershed

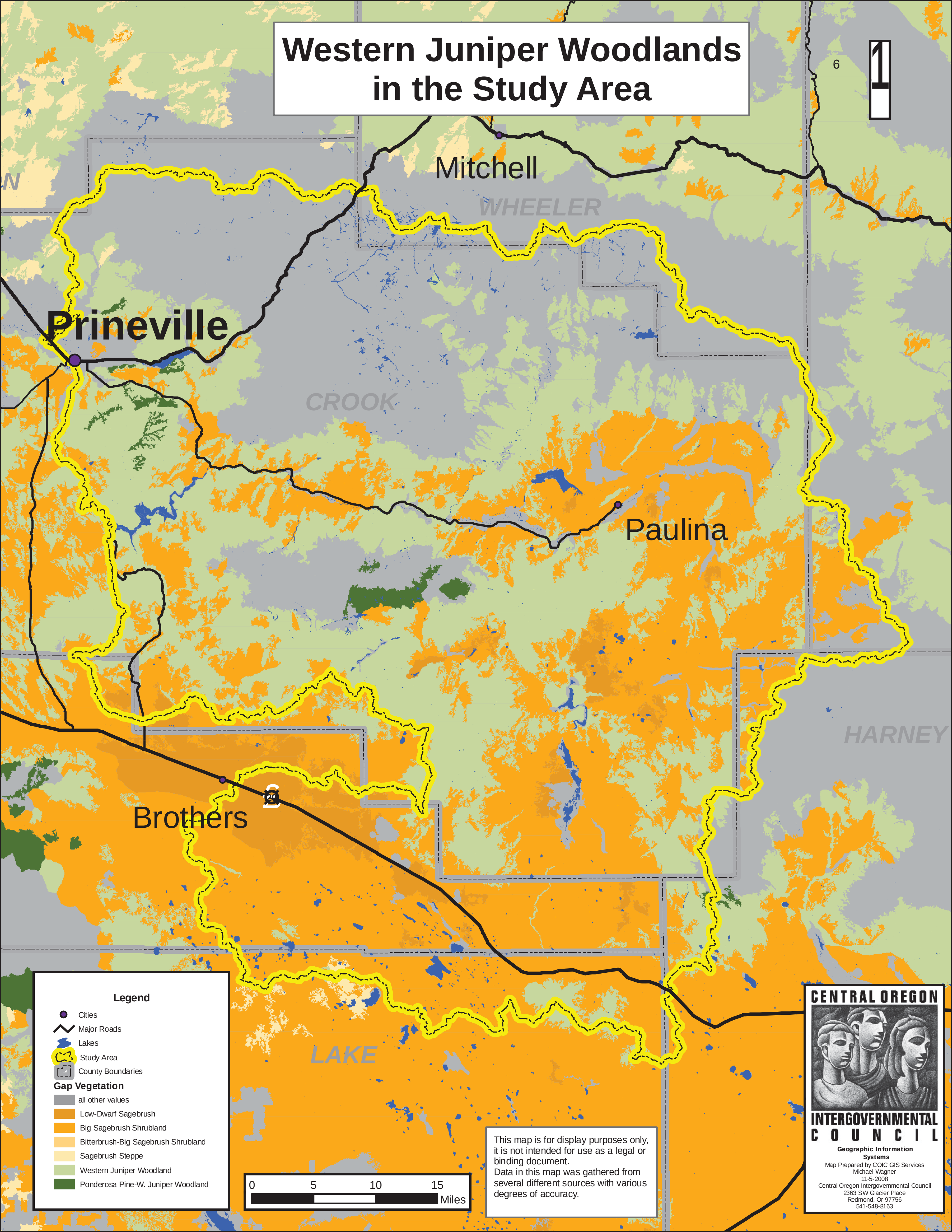
Location and Ecoregions

The Study Area is located in the Crooked River Watershed, Crook County, Oregon, in the geographic center of the State. The Crooked River watershed is defined, for purposes of this study, by the point of confluence of the Crooked River and McKay Creek, approximately three miles northwest of the City of Prineville. The study area lies between the Ochoco Mountains to the north and east, the Great Basin Geologic Province to the south, and the Deschutes River Plain to the west. The extreme southern part of the study area (part of the Great Basin) is included because of the hydrologic connection suggested by the USGS Hydrologic Unit Code (HUC) Map.

The Crooked River Watershed extends slightly beyond the Crook County boundary, into southern Wheeler, southwestern Grant, northwestern Harney and eastern Deschutes counties. The specific area of focus in the watershed is the sagebrush/juniper zone. This zone (see map: Western Juniper Woodlands in the Study Area) extends in an arc from the western edge of the watershed, north of Prineville, south to the vicinity of Brothers, Oregon and east (along the Post – Paulina Highway) to the Crook, Grant and Harney county conjunction, and north to the lower slopes of the Ochoco Mountains. The elevation of the watershed ranges from about 3,000 feet at the confluence of McKay Creek and the Crooked River to about 6,000 feet in the Ochoco Mountains on the northern and eastern boundaries of the watershed.

According to Anderson, Borman and Krueger (1998), in The Ecological Provinces of Oregon, the study area lies primarily in the John Day Ecological Province, an area consisting of …steeply and intricately dissected hills interspersed with isolated buttes, extensive plateaus and…valleys.

Thorson et al., as cited in USGS (2003), in adapting to a hierarchical system (defined in Omernik, 1995) of ecoregion classification developed for the United States, included Anderson's John Day Ecological Province in the Blue Mountains Ecoregion which is broadly defined as a complex of mountain ranges, lower and more open than the neighboring Cascades and Northern Rockies. Like the Cascades, and unlike the Northern Rockies, the Blue Mountains are mostly volcanic in origin. That part of the Blue Mountain ecoregion in which the study area lies, several sub-regions are identified. They include: the John Day/Clarno Uplands, the John Day/Clarno Highlands, the Mesic Forest Zone and the Cold Basins. In addition, based on USGS Hydrologic Unit mapping, a small portion of the Northern Great Basin, (the eastern extension of Anderson's Mazama Province) specifically Pluvial Lake Basins and High Lava Plains Ecoregions have been included in the study area. The focus of this study, in the context of Thorson's Blue Mountain Ecoregion, is the John Day/Clarno Uplands - the sagebrush/juniper zone of the Crooked River Watershed.


Western Juniper Woodlands
in the Study Area
Mitchell
WHEELER
Prineville
CROOK
Paulina
HARNEY
Brothers
LAKE
Legend
Cities
Major Roads
Lakes
Study Area
County Boundaries
Gap Vegetation
all other values
Low-Dwarf Sagebrush
Big Sagebrush Shrubland
Bitterbrush-Big Sagebrush Shrubland
Sagebrush Steppe
Western Juniper Woodland
Ponderosa Pine-W. Juniper Woodland
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Geology and Landforms

The geologic history of the study area is distinctly volcanic. (see map: Geology of the Study Area) The bedrock material, overlaying the deep, ancient John Day and Clarno Formations, in the northeastern part of the area consists primarily of Miocene basalts that covered the area 5 to 15 million years ago (ma). These basalts are part of the Picture Gorge subgroup of the Columbia Flood Basalts that flowed from fissures near Mitchell, Oregon. The western half of the study area is made up of clastic rocks, tuff, and andesite flows originating from the eruptions of the Cascades and Round Butte, and from the Wildcat (40 ma) and Prineville (29.5 ma) caldera eruptions. More recent basalt flows, occurring in the extreme southwestern part of the area, originated from eruptions of Newberry Crater and other volcanic activity associated with the Brothers Fault Zone. The southeastern quadrant of the study area is a complex of basalts, ash-tuffs and sedimentary rocks of diverse origin.

During the Columbia Flood Basalt activity, the topography of the area was low-lying with little topographic relief - explaining the current widespread distribution and elevational uniformity of the flows. Since that period, plate tectonic-driven uplift and faulting, concurrent with active stream down cutting, has produced the, highly dissected nature of the region's terrain - the cap rock, mesas, plateaus and canyons encountered today.

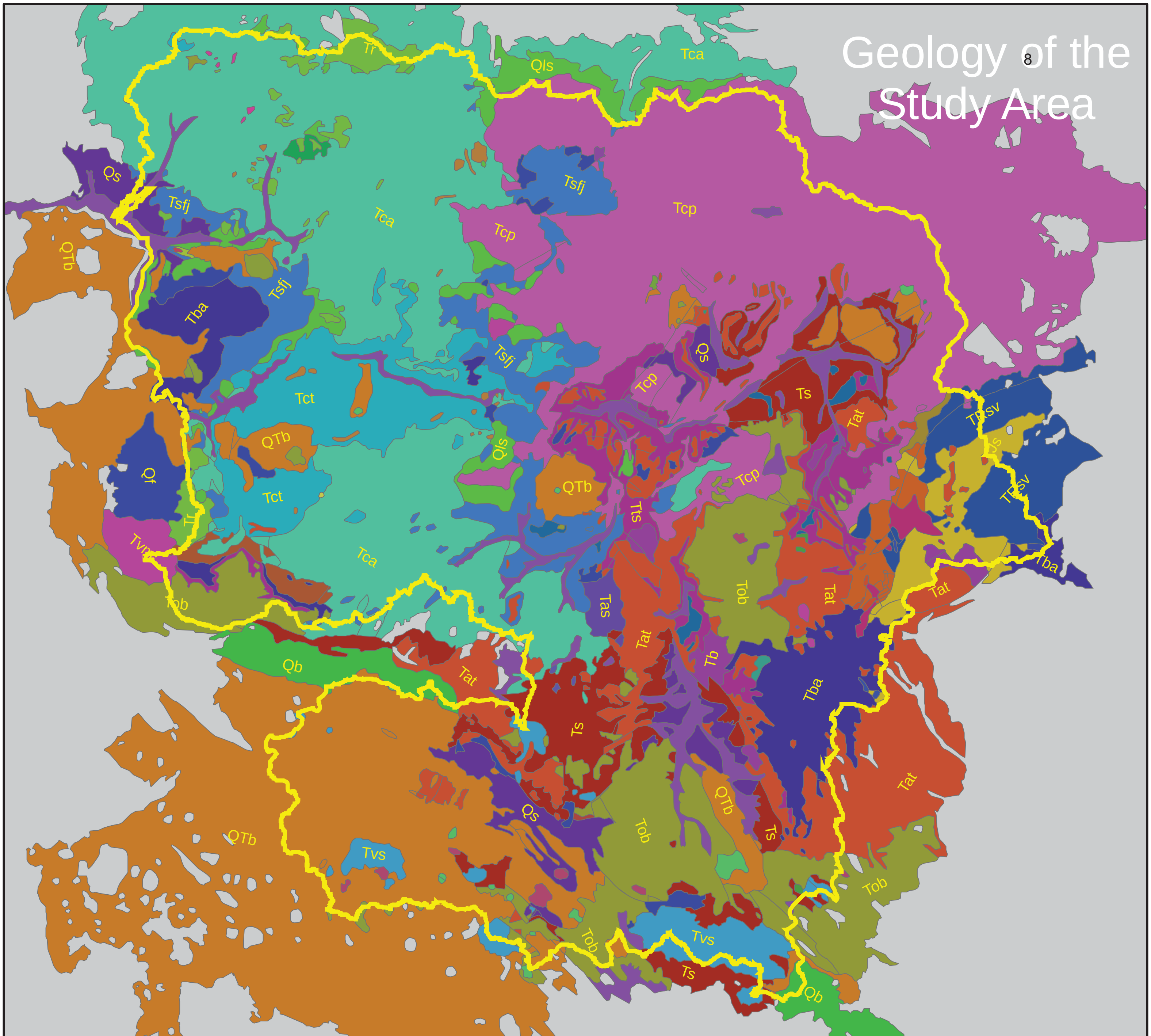
The more recent volcanic activity of Newberry Crater and Mount Mazama has left a veneer of aerially deposited ash and pumice across the local landscape.

Soils

The soils of the study area (above the floor of the Crooked River valley) are commonly stony and shallow (< 20 inches deep) or moderately deep (20 to 40 inches deep) over basalt or tuffaceous bedrock. In areas of heavy pumice deposition soils are moderately deep to deep (> 40 inches) and stone-free. Soil textures in the area range from fine clays, where John Day or Clarno Formation material has been exposed by stream down cutting, to medium and coarse textured where of volcanic ash and pumice deposits exist. Often, deep depositions of wind-worked pumice or northeast-facing (leeward) slopes. The soils on slopes below plateaus and mesas are generally colluvial in nature (containing talus and cliff debris) and are often strewn with boulders shed by the collapsing cap rock where the less resistant underlying material has been eroded away.

Climate

The study area lies just north of the extreme northwest corner of the Great Basin. The climate is semiarid and most (about 70 percent) of the annual precipitation occurs in fall, winter and spring. The annual precipitation ranges from about 10 inches at Prineville to over 30 inches at the crest of the Ochoco Mountains (see: Precipitation Map).



Legend

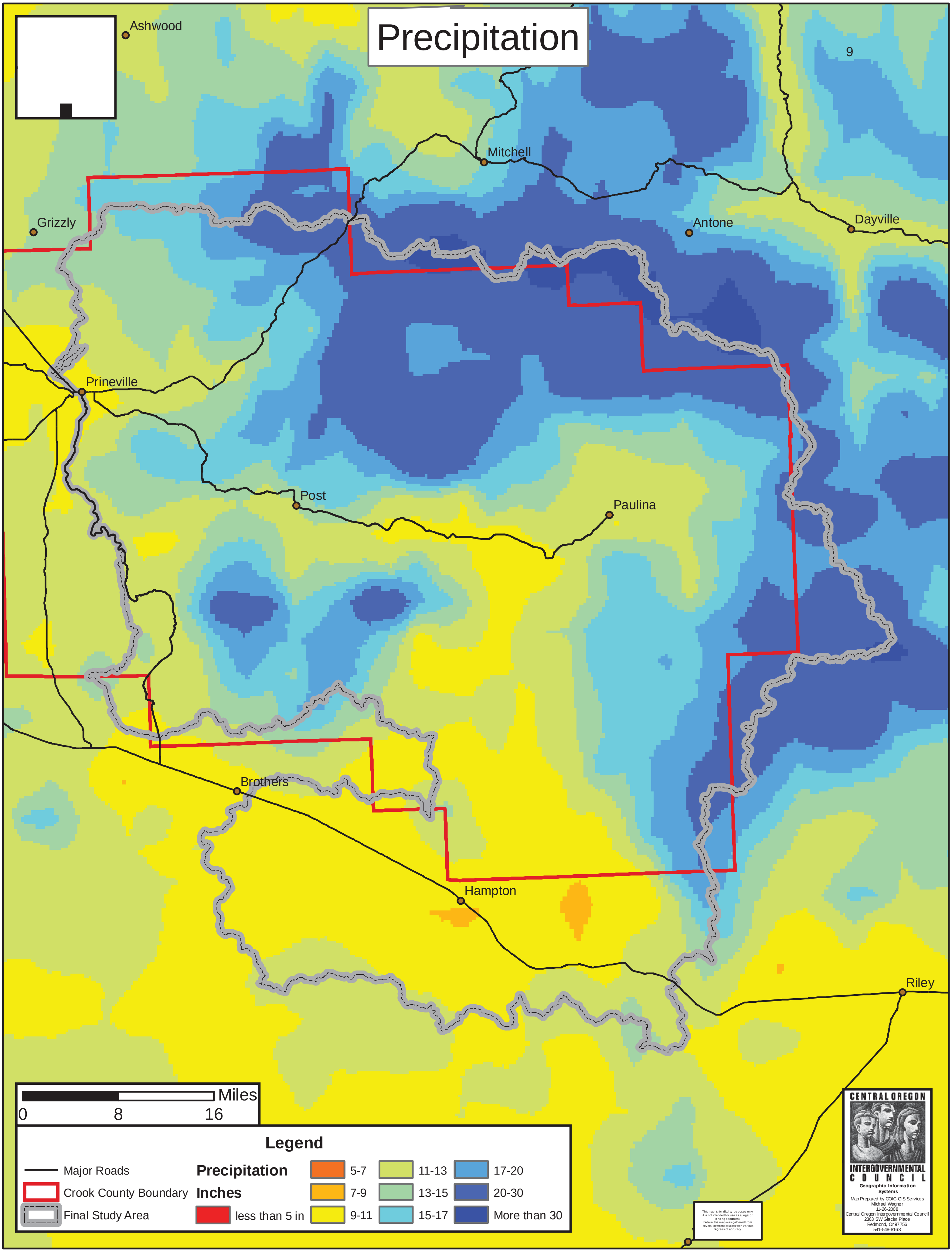
- Final Study Area

Study_area_Geology

- all other values

MAP UNIT, DESCRIPTION_

- Js, SEDIMENTARY ROCKS (JURASSIC)
- Ks, SEDIMENTARY ROCKS (CRETACEOUS)
- Pzs, SEDIMENTARY ROCKS; PARTLY METAMORPHOSED (PALEOZOIC)
- QTb, BASALT (PLEISTOCENE AND PLIOCENE)
- QTba, BASALT AND BASALTIC ANDESITE (PLEISTOCENE AND PLIOCENE)
- QTg, TERRACE AND PEDIMENT GRAVELS (PLEISTOCENE AND PLIOCENE)
- QTp, PYROCLASTIC ROCKS OF BASALTIC AND ANDESITIC CINDER CONES: BASALTIC AND ANDESITIC EJECTA
- QTs, SEDIMENTARY ROCKS (PLEISTOCENE AND PLIOCENE)
- QTvm, MAFIC VENT DEPOSITS (PLEISTOCENE; PLIOCENE; AND MIOCENE?)
- Qal, ALLUVIAL DEPOSITS
- Qb, BASALT AND BASALTIC ANDESITE (HOLOCENE AND PLEISTOCENE)
- Qf, FANGLOMERATE (HOLOCENE? AND PLEISTOCENE)
- Qgf, GLACIAL DEPOSITS (PLEISTOCENE)-GLACIOFLUVIAL DEPOSITS
- Qls, LANDSLIDE AND DEBRIS-FLOW DEPOSITS (HOLOCENE AND PLEISTOCENE)
- Qpl, PLAYA DEPOSITS (HOLOCENE)
- Qs, LACUSTRIAN AND FLUVIAL SEDIMENTARY ROCKS (PLEISTOCENE)
- Qt, TERRACE; PEDIMENT; AND LAG GRAVELS (HOLOCENE AND PLEISTOCENE)
- Qyb, YOUNGEST BASALT AND BASALTIC ANDESITE (HOLOCENE)
- TRPsv, SEDIMENTARY AND VOLCANIC ROCKS, PARTLY METAMORPHOSED (TRIASSIC AND PERMIAN)
- TRPzs, SEDIMENTARY ROCKS; PARTLY METAMORPHOSED (TRIASSIC AND PALEOZOIC)
- TRsv, SEDIMENTARY AND VOLCANIC ROCKS (UPPER? TRIASSIC)
- Tas, ANDESITE AND DACITE AND SEIDMENTARY ROCKS (MIOCENE? AND OLIGIOCENE)
- Tat, SILICIC ASH-FLOW TUFF (LOWER PLIOCENE AND UPPER MIOCENE)
- Tb, BASALT (UPPER AND MIDDLE MIOCENE)
- Tba, BASALT AND ANDESITE (MIOCENE)
- Tc, COLUMBIA RIVER BASALT GROUP AND RELATED FLOWS (MIOCENE)
- Tca, CLASTIC ROCKS AND ANDESITE FLOWS (LOWER OLIGIOCENE?; EOCENE; AND PALEOCENE)
- Tcp, PICTURE GORGE BASALT (MIDDLE AND LOWER MIOCENE)
- Tct, PREDOMINANTLY TUFFACEOUS FACIES OF CLARNO FORMATION (LOWER OLIGOCENE? AND EOCENE)
- Tct?, PREDOMINANTLY TUFFACEOUS FACIES OF CLARNO FORMATION (LOWER OLIGOCENE? AND EOCENE)
- Tob, OLIVINE BASALT (PLIOCENE AND MIOCENE)
- Tp, PYROCLASTIC ROCKS OF BASALTIC CINDER CONES (LOWER PLIOCENE? AND MIOCENE?)-BASALTIC AND ANDESITIC EJ
- Tps, PYROCLASTIC ROCKS OF BASALTIC CINDER CONES (LOWER PLIOCENE? AND MIOCENE?)-SUBAQUEOUS PYROCLASTIC RO
- Tr, RHYOLITE AND DACITE DOMES AND FLOWS AND SMALL HYPABYSSAL INTRUSIVE BODIES (MIOCENE TO UPPER EOCENE?
- Trb, RIDGE-CAPPING BASALT AND BASALTIC ANDESITE (PLIOCENE AND UPPER MIOCENE)
- Ts, TUFFACEOUS SEDIMENTARY ROCKS AND TUFF (PLIOCENE AND MIOCENE)
- Tsf, RHYOLITIC TUFF; TUFFACEOUS SEDIMENTARY ROCKS; AND LAVA FLOWS (LOWER MIOCENE; OLIGIOCENE; AND UPPERM
- Tsfj, JOHN DAY FORMATION OF EAST-CENTRAL OREGON (LOWER MIOCENE, OLIGOCENE, AND UPPERMOST EOCENE?)
- Tts, TUFFACEOUS SEDIMENTARY ROKCS; TUFFS; PUMICITES; AND SILCIC FLOWS (MIOCENE)
- Tvi, MAFIC VENT AND INTRUSIVE ROCKS (EOCENE?)
- Tvm, MAFIC AND INTERMEDIATE VENT ROCKS (PLIOCENE? AND MIOCENE)
- Tvs, SILICIC VENT ROCKS (PLIOCENE; MIOCENE; OLIGOCENE AND EOCENE?)
- Twt?, WELDED TUFFS AND TUFFACEOUS SEDIMENTARY ROCKS (UPPER? AND MIDDLE MIOCENE)
- water, WATER BODIES


Precipitation
Ashwood
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Dayville
Prineville
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Paulina
Brothers
Hampton
Riley
Miles
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16
Legend
Major Roads
Crook County Boundary
Final Study Area
Precipitation
Inches
less than 5 in
5-7
7-9
9-11
11-13
13-15
15-17
17-20
20-30
More than 30
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Temperature extremes range from a low of -35ºF to a high of 119º. Freezing temperatures (32ºF) can occur anywhere in the study area in any month of the year.

The Cascade Range exerts a strong influence on the local climate. The mountain range lifts the moisture-laden westerly winds from the Pacific resulting in their cooling and subsequent condensation and precipitation on the range's west slope and at high elevations. In the 30 to 35 mile distance between the Cascades crest to the central Oregon plateau the average annual precipitation decreases from more than 65 inches to less than 9 inches. Having released its moisture, the dry air warms as it descends the east slope of the Cascades, increasing its evaporative capacity, rapidly depleting soil moisture and dehydrating vegetation.

Most summer precipitation comes in the form of strong convectional storms derived from pulses of warm moist air drawn northward from the Gulf of Mexico along the lee of the Sierras and Cascades. The intense cloudbursts or "waterspouts" associated with these storms produce rainfall rates exceeding the infiltration rates of many local soils, especially where plant cover is reduced or is naturally sparse. Subsequently, local streams and their riparian areas must often endure the fast and often destructive surges of concentrated overland flow from deteriorated uplands. Frequently, these strong convectional storms produce numerous lightening strikes but little moisture – making fire an historically significant influence in the plant community dynamics of the region.

In winter, the area is generally influenced by the cool, moist maritime-polar air mass - its temperature moderated by the relative warmth of the Pacific Ocean as it traveled south from the polar region. Winter nighttime temperatures can often be very cold as the air, chilled by high elevations and snow and ice fields sinks from the peaks of the Cascades to pool in the lower valleys. This frigid air often lifts the relatively warm air in the valleys creating a temperature inversion with the warmer air aloft. Some speculate that the upper elevational extent of western juniper (its timberline) coincides with the average wintertime cold air/warm air boundary of these inversions. Occasionally winter temperatures drop precipitously when continental-polar air, driving southward from the Arctic interior and the Canadian prairies, breaks over the Continental Divide and is channeled southward between the Cascades and the Rockies.

The Fate of Water in this Setting

This landscape owes its character to ancient volcanism, the stress and uplift of plate tectonics and to the ash and pumice deposition from recent volcanic activity. In a geologic setting as diverse as the Crooked River Watershed, the fate of water is often difficult to predict. Where the columnar basalts underlie the soil, water can percolate into the underlying fractured bedrock, recharging the deep water table or aquifers without any observable effect on local surface water flow. In this setting, efforts to recover hydrologic function (improving infiltration, reducing overland flow and moderating excessive transpiration), may not always result in increased seep, spring or stream flow in, or adjacent to the treatment area.

During Miocene flood basalt activity (15 to 5 ma), many thousands of years may have passed between the periods of basalt flow. During those quiescent periods, soils developed on the basalt surfaces. Subsequent basalt flows buried those soils. These buried soils often create a discontinuity between the flows that can restrict the deep downward percolation of water. Where exposed by stream downcutting or road cuts, these buried soils are often associated with seeps and springs that flow from the basalt walls.

Conversely, in areas where ancient sediments and volcanic tuff are exposed at the soil surface or underlie thin basalt caps, seep, spring and stream flow is often common. Efforts to restore seep, spring and stream flows in this geologic setting are frequently successful because of the relatively impermeable nature of the material and its tendency to retard the deep percolation of soil water.

The landscape's processing of water received as rainfall and snowmelt, as just described, is a moot point where juniper has become the dominant vegetation. Here, the essential processes of watershed function are often restricted or negated by juniper's ability to intercept precipitation and actively transpire soil water.

Potential Native Vegetation

Thorson, in USGS (2003), describes the John Day/Clarno Uplands as a sagebrush-grassland vegetation type where western juniper has expanded markedly during the 20th century due to a combination of climatic factors, fire suppression and [the removal of fine fuels] by grazing pressure.

The potential native vegetation of the sagebrush/Western juniper zone in the study area is expressed in a number of plant communities occurring in the 10 to 12 inch and 12 to 14 inch precipitation zones (PZ) on a variety of soils, slopes and aspects. In his journal, an early pioneer wrote "…this country was, certainly, as fine a country then as a stockman could wish to see. The hills were clothed with a mat of bunchgrass that seemed inexhaustible" (as noted by Nielsen-Pincus, 2008). Occasional, low intensity fires (lightening- and aboriginal-caused) were common in the region and fire was an important ecological process (USDI BLM, 2001). These fires are believed to have maintained an open grass/shrub/juniper mosaic across the upland landscape. Immediately following a fire, herbaceous vegetation (grasses and forbs) commonly dominated the burned area. Over time shrubs grew from being a subordinate component of the plant community to becoming co-dominant and eventually becoming dominant if fire did not intervene. It would be considered normal for juniper to increase its numbers and influence on the site, with the eventual dominance we see today if it were not for the fact that the fire return intervals were typically 20 to 50 years for these sites (Miller, 2005). That was, until the removal of fine fuels by poorly managed, or un-managed grazing and fire suppression had their return interval-extending effects.

Surrounding the edge of the Ochoco Creek/Crooked River Valley floor at Prineville, the south- and west-facing slopes of hills and plateaus are in the 10 to 12” PZ, and a mesic soil temperature regime. The potential native plant communities in this zone are comprised predominantly of Wyoming big sagebrush (Artemisia tridentata var. wyomingensis), with antelope bitterbrush (Purshia tridentata) in some areas, with bluebunch wheatgrass (Pseudorogneria spicata), Thurber needlegrass (Achnatherum thurberianum), and bottlebrush squirreltail (Elymus elymoides) and a variety of forbs. Western juniper occupied a minor part of the landscape, being restricted to rim rock and rock outcrops on these slopes where they escaped fire. On north- and east-facing slopes in this zone, soils are deeper (pumice accumulation) and temperatures cooler. The plant communities were generally comprised of Wyoming big sagebrush, blending to mountain big sagebrush (Artemisia tridentata var. vaseyana), bluebunch wheatgrass and Idaho fescue (Festuca idahoensis), with juniper, once again, being a minor component in the landscape.

Basin wildrye (Leymus cinerius) is believed to have been the dominant plant on the deep, well-drained alluvial soils of the draws, swales and intermittent drainages and on the terraces above the frequently flooded riparian areas of perennial streams.

Ascending in elevation, to the north and east, along the lower slopes of the Ochoco mountains up to the ponderosa pine, Douglas fir and larch zones, and south to the boundary of the John Day Ecological Province and the Great Basin, the annual precipitation increases to 12 and 14 inches. Soil temperatures transition with this increase in elevation, from mesic to frigid except on the warmer south- and west-facing slopes. In this zone, mountain big sagebrush was the dominant shrub and Idaho fescue, prairie junegrass (Koleria macrantha) and bluebunch wheatgrass were common. Western juniper was present in the landscape but was restricted to rock outcrops, boulder fields and shallow soils where fire was restricted by a lack of ground fuels.

Riparian areas associated with perennial streams in the area were dominated by a complex of sedge/rush/grass, hardwood and willow communities. The mix and proportions of the vegetation components being dependent on complex combination of site features. These include soils, soil drainage and aeration, slope, landform and stream channel characteristics that control stream velocity, and erosion/deposition potential of a stream reach. In specific instances cottonwood gallery forests were an important community along many of the region’s perennial streams and rivers. It is important to note, however, that while some stream reaches were capable of supporting woody vegetation, others were not. Woody vegetation was not, historically, part of the vegetation in all stream reaches. The riparian areas on the lower terraces of low gradient stream reaches where soils are fine-textured, often saturated and poorly aerated are commonly dominated by sedges and rushes and will not support cottonwood, alders, willows or other hardwoods (Rosgen, 1996).

Current Vegetation

In central Oregon western juniper woodlands where the juniper canopy exceed 10 percent are estimated to have expanded from 314,000 acres in 1936 to 964,000 acres in 1988 (Gedney et al. 1999). In The Biology, Ecology and Management of Western Juniper (Miller et al. 2005), the authors state that western juniper woodlands now occupy about 3.7 million acres of Oregon, while others estimate that juniper now occupies 6 to 9 million acres of the state - a ten-fold increase in the last 130 years. It is estimated that juniper continues its expansion at the rate of 3 to 5 percent per year (Miller, 2005). In Crook County, the extent of western juniper woodlands and savannas is estimated to have increased from 27% of the land area in 1936, to 60% in 2005 (Azuma et al. 2005). In-fill by young juniper in existing juniper stands and savannas, and encroachment into open sagebrush/grass communities continues, more or less unabated.

Since the time of European settlement in the 1860's, the changes in plant communities have been significant and widespread. The suppression of fire, the cessation of aboriginal burning and the removal of fine fuels by unmanaged livestock grazing combined to remove this major environmental driver from the plant community dynamics of the region. Active fire control has promoted the expansion of western juniper, away from fire-safe sites (rim rock, etc.), into open, once fire-prone sites and has also led to the downslope expansion of ponderosa pine into the sagebrush/grass communities, resulting in a additional loss of this vegetation type.

Throughout the area, deep soils in valley bottoms, where basin wildrye had been the dominant vegetation, were converted to haylands where cereal rye was grown for livestock forage. Farming traditions have changed and rye is no longer commonly grown. Many of these former hay field were seeded to introduced forage grasses, predominately crested wheatgrass (Agropyron cristatum) and intermediate wheatgrass (A. intermedium). Abandoned fields not seeded to perennial cover are now dominated by gray rabbitbrush (Chrysothamnus nauseosus) and big sagebrush, often with a dense understory of Sandberg bluegrass and/or cheatgrass (Bromus tectorum). Western juniper is aggressively invading these lands.

In stark contrast to the potential native plant communities described earlier, a large portion of the once extensive sagebrush/grass communities are dominated by western juniper. The negative effects of this conversion on watershed health and function, wildlife and fisheries and economic use are significant since juniper out-competes native shrubs, grasses and forbs for space, water, nutrients and sunlight. The result of juniper's competitive success are large expanses of fully occupied stands of juniper where the interspaces between the trees are bare and the erosion potential (on slopes) exceeds, by an order of magnitude (ten times), that of intact sagebrush/grass communities (e.g., 1,000 lbs./acre vs. 100 lbs./acre) (Buckhouse and Gaither. 1982)

Land Use

Livestock grazing was the major use of the lands in the watershed from the time of European settlement in the 1860's until the 1930's. Initially cattle were the predominant form of livestock grazing the area. Sheep were introduced in the early 1880's and by the turn of the century, the numbers of sheep, cattle and horses (used in farming) were high. The effects of heavy grazing use was taking its toll on plant communities in the uplands and valley bottom meadows and grasslands. Nielsen-Pincus (2008), citing Buckley, 1992; USDA –USFS 1998b and Elmore and Bestcha, 2005, stated that prior to 1885, floodplains were dominated by bunchgrass, wildrye, and sedges and that streams were perennial and not incised. After 1903, stream channels were described as entrenched and the floodplains were dominated by sagebrush. This period of channel incision is believed to have been caused by the interaction between high grazing pressure, climate (drought followed by intense summer storms) and the loss of beaver.

Currently, irrigated agriculture is the dominant land use in the broad valley bottoms surrounding the City of Prineville. Here, irrigation for forage and specialty crop production is dependant on water stored in the Ochoco Reservoir and Prineville Reservoir on the Crooked River. Upstream of the Prineville Reservoir, irrigation of valley bottoms for livestock forage (hay and pasture) production is almost exclusively dependent on stream diversion.

Aside from limited timber harvest in the watershed, one of the most influential forms of land use under way in the watershed, and in the study area most especially, is the ostensibly unrestrained subdivision of large ranches and the subsequent scatterings of rural (often isolated) housing. Among the effects of this development are the fragmentation of plant communities and wildlife habitats, soil disturbance leading to weed invasion, and the increasing risk of fire hazard - placing structures and lives in harm's way (adding to fire control costs and risks to firefighter's safety). Many of these landowners, understandably, view western juniper as esthetically valuable and oppose efforts of juniper control.

Juniper Encroachment

History and Cause

Western juniper, according to Axelrod (in Munz 1964), belongs to a group of plants defined as the Madro-Tertiary Geoflora, one of three major plant assemblages that have maintained their character since the early Cenozoic (75 ma). The Neotropical-Tertiary Geoflora, a broad-leafed evergreen group that occupies the southeastern part of the North American continent, bound this group on the south. The Arcto-Tertiary group of mixed deciduous hardwoods (aspen, alder and birch) and conifers (spruce, fir, etc) occupies the northern, temperate half of the continent. Between these two groups, centered in southwestern North America, is the Madro-Tertiary Geoflora, named after the Sierra Madre range of northern Mexico, where many of its relics exist. The Conifer Woodland Element of this group is represented by pinyon pine (Pinus edulis, P. monophylla, etc.), juniper (Juniperus occidentalis, J. utahensis, etc.), serviceberry (Amelanchier alnifolia), mountain mahogany (Cercocarpus spp.), oceanspray (Holodiscus discolor), antelope bitterbrush (Purshia tridentata) and snowberry (Symphoricarpus spp.). As summer precipitation diminished, during the dry Pliocene Epoch (5 to 2 ma) plants of this group adapted to the current summer drought and cold wet winter climate of the semi-arid intermountain west. The northern expansion of western juniper, which may have been halted or reversed during the Pleistocene (the last Ice Age), appears to be continuing today - into the rim of the Columbia Basin in north central Oregon and south central Washington.

Anderson, Borman and Krueger (1998) stated their belief that the preponderance of juniper around Prineville and the lower Crooked River… is likely due to the huge seed source from junipers that blanketed the nearby pumice-soil area (Mazama Province) that extends from the Redmond and Bend area east to about Hampton.

Juniper does not tolerate fire. In the past, its distribution was limited primarily to landforms and soils that did not support fire and were isolated from historic fire return intervals. Rimrock, lava blisters, scree slopes, and boulder fields are typically the landforms where juniper is protected from fire. Relatively un-productive soils, like the droughty pumice soils and the claypan soils of eastern Oregon tend to support long-term juniper survival because or their limited amount of fine- and ladder fuels and infrequent fire.

However, the general reduction of fire in the landscape is allowing juniper to spread beyond its pre-European settlement extent and traditional habitats, as described earlier. This expansion appears to be the result of a number of factors working in combination including the introduction of, and season-long grazing by, large numbers of domestic livestock in the late 1800's and early 1900's. This uncontrolled grazing reduced fine fuels and significantly reduced the frequency, extent and effect of naturally occurring fire. A period of mild and wet climatic conditions in the late 1800's and early 1900's coincided with post-European settlement promoted juniper's expansion. And the aggressive use of sophisticated fire suppression policy and techniques (Miller 2005), spurred, in large part by the increase of dispersed home-building in the sagebrush/juniper zone have cemented juniper's occupation of the landscape.

In addition, the cessation of widespread aboriginal burning has had a significant influence on the expansion of western juniper (Dr. Lee Eddleman, OSU Rangeland Ecologist, personal communication, 2002). Eddleman further noted that the two primary mechanisms of seed dispersal supporting juniper expansion are 1) birds that the ingest seeds, dispersing them in their droppings throughout the environment, and 2) overland flow and concentrated runoff in rills, gullies, and ephemeral drainages that contribute to the downslope transport of seed.

The Effects of Juniper Encroachment

Encroaching into sagebrush steppe communities, riparian areas, and other lands, juniper competes aggressively with native vegetation for water, space, sunlight, and soil nutrients. Understanding the effects of juniper encroachment is important step in developing treatment objectives, determining alternative actions and selecting treatment methods. The effects of juniper encroachment may be biological and abiotic (i.e. physical: pertaining to soil, water, air, etc.) depending on the density and duration of the encroachment.

Miller, et al. (2005) described the effects of juniper encroachment in the stages of woodland succession in three phases. Phase I, the early stage of encroachment, is characterized by young (usually less than 40 old), actively growing trees that are a subordinate component of the plant community. In this phase, juniper appears to have no negative effects on the physical or biological functions of the site. In Phase II, maturing juniper is an actively growing co-dominant component of the plant community. At this point, juniper is beginning to compete with other plants in the community – most often shrubs are the first group in the community to weaken and die from of competition. The effects of Phase II encroachment are primarily biological. The transition into Phase III, according to Miller, is the point when the maturing trees affect the physical condition of the site (i.e., bare soil resulting from plant mortality, soil crusting, overland flow, soil erosion, etc.). The following physical and biological effects of encroachment are significant:

- The percentage of rain and snow intercepted in the juniper canopy is equivalent to the percentage of juniper canopy cover (e.g. a juniper canopy of 20 percent equals the interception of about 20 percent of the precipitation). The intercepted rain and snow, evaporates or sublimates (changes from a solid to gas phase without going through the liquid phase) back to the atmosphere.

- Precipitation through-fall (i.e. water reaching the soil surface through the tree canopy) generally occurs only after rain events that exceed 0.30 inches or more. Storm events of 0.30 inches or greater in this climatic zone are uncommon.

- Sixty to 75 percent of annual precipitation in central and eastern Oregon occurs during the fall, winter, and spring. Through interception and the use of soil water, juniper reduces soil moisture recharge and vegetation growth of other plants.

- Juniper is capable of transpiring (consuming) soil water during any month of the year - significant point since because native vegetation depends on soil water stored during the dormant period (fall, winter, and early spring) for initiating growth in the spring.

- Increasing juniper dominance results in the die-off of shrubs and a reduction or die-off of native grasses and forbs. The ensuing loss of shrubs, grasses, and forbs reduces species richness and diversity results in a loss of habitat value (cover, forage) for many wildlife species as well as a loss of forage for livestock.

- Increasing juniper dominance in stands of aspen (Populus tremuloides) and mountain mahogany (Cercocarpus ledifolius) often causes these important species to weaken and eventually die.

- Reduction or die-off of vegetation in the canopy interspaces of juniper stands results in a loss of protective plant cover, contributing to overland flow and soil erosion. According to Buckhouse and Mattison (1980), Buckhouse and Gaither (1982), Gaither and Buckhouse (1983), and Miller et al. (2005), erosion rates on encroached sites can be as much as an order of magnitude (ten times) greater than on similar sites without juniper.

- Canopy interception, diminished infiltration rates, increased overland flow, and increased transpiration, in certain soil and geologic settings, significantly reduce seep, spring and stream flow.

- The loss of species diversity diminishes the function of the basic ecological processes of nutrient cycling and energy flow.

- Juniper encroachment into sage grouse habitats provides perches for avian predators, often causing sage grouse to abandon these areas.

Briefly stated, juniper encroachment and eventual dominance alters the hydrologic cycle, which is the ability of the soil to capture, store, and safely release water (Barrett, 1981), drying seeps, springs and streams in much of the region, and short-circuiting nutrient cycling and ecosystem energy flow - reducing a site’s productive potential, biological diversity, wildlife habitat quality, and forage value.

Anticipating the Benefits of Juniper Control

The benefits expected from juniper control are proportionate to site potential, the degree of juniper encroachment, and the length of time the site has been subject to the effects of occupation

- Reducing the interception of precipitation by the tree canopy allows rain and snow to reach the soil surface where its capture (infiltration) is most probable.

- Controlling juniper encourages the establishment of seedings or the re-occupation of the site by native grasses, forbs, and shrubs

- Slash (limbs, etc.) left on the site moderates soil temperature, humidity and air flow, creating ideal conditions for seed germination and seedling establishment.

- Re-occupation of the treated area by native vegetation or the establishment of seeded grasses, forbs and shrubs significantly increases plant cover, reducing the amount of bare ground. This cover, together with the accumulation of plant litter and increased soil organic matter, will increasing promote the infiltration of rain and snowmelt over time.

- The timing, amount and duration of stream, spring and seep flow can, in the right geologic setting, be expected to improve as the problems of interception and restricted infiltration are corrected.

- Removing juniper, the principal cause of dormant- and early-growing season transpiration, will allow the soil's capacity to store water to be better utilized - increasing the amount of soil water available for plant growth in the spring.

- Re-occupation of the site by diverse and productive native plant communities will restore habitat values for many wildlife species and increase forage available for livestock grazing. Carefully designed seedings of introduced species can have similar beneficial effects.

In summary, by increasing the opportunity for precipitation to reach the soil surface and protecting the soil surface with vegetation, infiltration will improve over time – increasing water storage in the soil profile. When that water capacity is exceeded, surplus water may flow laterally beneath the soil surface, supporting seep, spring, and stream flow or it may percolate into fractured bedrock, recharging groundwater. With the removal of the principal cause of winter and spring water loss, soil water is more dependably available for native or seeded species when growth initiates in the spring.

Scope, Scale and Purpose of Past Treatments

A History of Juniper Control

The information in this section regarding activities in the study area was gathered in interviews with staff members of state and federal agencies involved in juniper management, and with local ranchers who are actively controlling juniper on their own lands. Additionally, GIS maps and tables were provided by BLM, USFS and OWEB with the assistance of the Central Oregon Intergovernmental Council (COIC) in Redmond Oregon. Individuals interviewed or who provided maps and tabular data for this report include: Dr. Tim Deboodt (OSU Extension, Prineville) John Swanson (BLM, Prineville), Chris Mundy (NRCS, Redmond), Nancy Wiggins (BLM, Prineville), Tori Kurtz (USFS, Prineville) and Courtney Shaff (OWEB, Salem). Ranchers interviewed include John Breese, Bill McCormack, Kurt McCormack, Pete Jamison, J.W. “Just Wonderful” Hart, Rance Kaster, and John Jackson.

The exact extent of lands on which juniper control has been done over the years is difficult, if not impossible, to calculate. There has been a broad array of treatments used with varying degrees of success. This section describes the history of juniper control in the area and outlines the evolution of thought in approaching this aspect of land treatment. Misinterpretation of the information collected in interviews or from submitted materials, if any, is the authors doing.

The earliest treatments recalled by those interviewed were completed in the 1950’s and 60’s by Oregon Department of Fish and Wildlife (ODFW) and BLM. The objective of these projects was to improve winter deer habitat – opening up stands of juniper to increase the production of antelope bitterbrush, an important shrub in deer winter diet. Chaining, a radical method of treatment was commonly used. Chaining employed long lengths of heavy ship anchor chains, often with short lengths of railroad rails welded to it, which, when dragged between two heavy crawler tractors, uprooted juniper and sagebrush and deeply scarified the soil surface. Commonly, the treated areas were seeded with bitterbrush seed and/or crested wheatgrass seed. Bureau of Land management/ODFW chaining ended in the mid- to late-60s, in large part, because of public outcry at the unsightly and often geometrical scarring of the landscape.

During the 1970’s, juniper control efforts increased significantly as agencies and landowners grew aware of the loss of livestock forage resulting from the effects of juniper expansion and infill in the region. Project objectives at that time were primarily livestock forage-based. The two most common methods of juniper control during the period were: 1) falling individual trees with chainsaws, leaving downed trees on site, and 2) uprooting and piling trees with crawler tractors equipped with dozer blades. Dozed piles were often burned. This “push and pile” method proved very destructive to the soil surface and to the desirable vegetation in the project areas. Valuable surface soils were often removed, as were the native grasses, shrubs and forbs. The exposed sub-soil was opened to weed invasion. As a result raindrop impact on bare soil, soil crusting and overland flow and erosion were common. Dr. Lee Eddleman (Rangeland ecologist, OSU) conducted research on the soil erosion associated with this method of treatment and, based on his findings, recommended that this practice cease, which it did, for the most part, in the early 1990's. This method of control continues to a limited degree on some private lands, however, the treatment areas are often seeded to grasses and forbs and shrubs immediately following the initial control. Where this follow-up is not practiced, the results are devastating.

Federal cost-share programs, the Agricultural Conservation Program (ACP) and Long Term Agreements (LTA), administered by USDA Agricultural Conservation and Stabilization Service (ASCS, now the Farm Service Agency) with technical support from the Soil Conservation Service (SCS, now NRCS) shared the costs of juniper projects, among many other sorts of conservation projects (range seeding, livestock water developments, etc.) on private lands. These programs accelerated juniper control in the study area, and throughout the West. Varying degrees of quality in the planning and implementation of these federally-supported projects led to correspondingly varied outcomes. In some cases the design and implementation of these projects formed around the nucleus of today's concepts of rangeland health - recognizing that each part of the landscape contained its own unique set of environmental variables that needed to be addressed, and that not every acre or landform should be treated. Post-treatment grazing management was recognized by some as being essential to realizing the full benefit of the treatment. Other projects, less carefully designed, applied or managed, were simply "juniper kills" where no real environmental improvement was realized or different, but equally problematic, issues were created.

In the late 1980's, federal funding for projects on private lands was either reduced or terminated. At the same time there seemed to be a parallel loss of interest or commitment by land management agencies (BLM and USFS) in aggressive, large-scale juniper control efforts. Landowners, agency staffs and others were frustrated with the lack of financial or managerial support while seeing the growing need for accelerated land treatment.

During that time, word began to spread among landowners and agency staffs about the research into juniper's consumptive use of soil water being conducted by Dr. Rick Miller (OSU Rangeland Ecologist). His research indicated that a mature juniper was capable of transpiring soil water at the rate of 25 to 35 gallons of soil water per day. There seemed, to some, to be an acceleration in juniper control activity throughout the region, as word of these findings increasingly spread. The belief was that controlling juniper would keep moisture received from precipitation on-site; grass production would increase; dried springs would begin to flow, and intermittent streams would start to flow year-round. However, without attention to soil surface conditions and a thorough understanding of plant community dynamics and the need for post-treatment management, the response was not always as hoped. After a period of 3 to 4 years (the time it takes the downed trees to shed their leaves), the interception and loss of precipitation by the tree canopy was significantly reduced and the loss of soil water to transpiration by juniper had significantly declined. However, because other needs of the site were not always considered, these anticipated moisture savings were sometimes converted to overland flow and soil loss, and/or invasive weeds overtook many sites. In the mesic soil temperature zones, cheatgrass and other introduced winter-annuals (medusahead, mustard, etc.) took advantage of open, nutrient-rich soil conditions, overtaking many sites.

In 1991, Bedell et al. published the Watershed Management Guide for the Interior Northwest; in which a new view to land treatment was offered to landowners and agencies. The publication was issued in response to the widespread frustration of range professionals, hydrologists and some landowners who were watching the steady, cumulative loss of sagebrush /grass communities and the further desiccation of rangeland watersheds. The publication focused on recovery of the basic hydrologic functions of rangeland watersheds: the capture, storage and safe release of precipitation (Barrett, 1981) in the arid and semi-arid areas of the region. In addition to a review of the currently known aspects of upland and riparian hydrology, typical rangeland practices (brush management, range seeding, and juniper management) were discussed with regard to their individual effects on watershed function. Evidence suggests this publication provided the impetus for a resurgence of activity in juniper management and in the kinds, extent and quality of projects conducted in the region.

In 1994, the National Research Council published Rangeland Health by Busby, et al. A compendium of scientific knowledge relating to rangeland management, the publication presented an environmentally sound, scientifically supported approach to the classification, management and monitoring of the Nation's rangelands. Critical to the utility of the publication was the analysis and discussion of the concept of rangeland watershed function, led by Dr. John Buckhouse (OSU Rangeland Hydrologist). According to Buckhouse (2009), the core of the publication was the scientific background documenting the utility of the concept of the capture, storage and safe release of water in rangeland ecosystems. The publication provided useful, scientifically supported guidance in the future management and repair of rangeland ecosystems.

Seizing the opportunity presented by the publication of Rangeland Health to employ current, ecologically sound science in the management of the Nation's publicly-owned rangelands, the Secretary of the Interior, in 1995, commissioned the development the of the BLM's Standards for Rangeland Health. As part of that effort, Pellant, et al. (2005) drafted the publication Indicators of Rangeland Heath, that outlines a process for assessing the components of rangeland health and function: hydrologic function, biologic integrity and soil stability. This process forms the basis for the site inventory, project design and monitoring described in the OWEB publication: Western Juniper Management: A Field Guide (Barrett. 2007)

Treatment objectives on federally administered lands began to shift from the forage- and deer winter range-based objectives of the past, and from erosion control, to objectives addressing the recovery of hydrologic function (infiltration and soil water storage) and watershed health.

In the ensuing years, state, federal and private efforts have increased in size and scope. The NRCS Environmental Quality Incentive Program (EQIP) and the Wildlife Habitat

Improvement Program (WHIP) have offered financial incentive and assistance in juniper management projects on private lands. OWEB began funding juniper management projects through numerous small grants and larger capital expenditures. Recently, OWEB has provided funding support for larger cooperative projects in the area. BLM has accelerated its involvement in large-scale projects in cooperation with private landowners. Project scale has evolved from “postage stamp” treatments ranging in size from 20 to 60 acres in the 1960’s to the 1990’s to larger, landscape scale treatments, involving cooperative effort on the part of state, federal and private entities. BLM’s South Prineville Reservoir Watershed Project, encompassing approximately 20,000 acres of public land and 4 ranches is one such example of these cooperative projects. According to John Swanson (Personal communication. 2008), the over-arching goal in this case is the attainment of “watershed health”.

Facilitating the cooperative efforts underway in the study area, the Wyden Amendment (Public Law 105-277, Section 323 as amended by Public Law 109-54, Section 434) authorized BLM and Forest Service to enter into cooperative agreements to benefit resources within watersheds on BLM-administered and National Forest System lands. The amendment authorizes the two agencies to enter into these cooperative agreements with willing Federal, Tribal, State, and local governments, private and nonprofit entities, and landowners to conduct activities on private lands. The requirements for the use of these funds are: a) protection, restoration, and enhancement of fish and wildlife habitat and other resources, b) reduction of risk for natural disaster where public safety is threatened, or c) a combination of both where public resources values were complemented. For budgetary or other reasons, the implementation of the provisions of this amendment has languished in recent years.

The Scale of Treatments

Records made available by the Bureau of Land Management, U.S Forest Service, Natural Resources Conservation Service and OWEB indicate a wide variety in the acres of juniper treatment in the study area, and in the objectives of those treatments:

Agency	Period of Record	Total Acres Treated	Ave. Treatment Acres	Range in Treated Acres	Stated Treatment Objective
USFS	1970 - 2000	1,407 ac. ***	8 ac.	<1 – 67 ac.	Pre-comm. Thinning
BLM	1969 - 2003	114,000 ac.	223 ac.	2 – 20, 450 ac.	Fuels Reduction
NRCS	2002 - 2008	4,697 ac.	160 ac.	50 – 400 ac.	Rangeland Health **
OWEB	2003 - 2008	1,523 ac.	100 ac.	20 – 80 ac *	Watershed Function
Total	1970 - 2008	121,627 ac			

Table 1. A summary of state and federal activity, or technical/funding support, in juniper control in the Crooked River Watershed: based on a review of the records provided. See footnote.

The above summary, derived primarily from Excel Spreadsheets, is, as spreadsheets are, cryptic. The back story, not available from the spreadsheets, is important: what protocols, if any, were used in determining the need for treatment, in designing and implementing treatments, in designing post-treatment management and in monitoring treatment effectiveness? Were these treatments ecologically based in their nature, or were they "juniper kills"?

In follow-up conversations with the various agency representatives, these questions were asked. In the case of the Forest Service, the silviculturalist who currently selects areas for treatment considers: 1) the ecological potential of the site(s) using published plant association guides and personal knowledge of the area; 2) site recovery potential, and 3) economic feasibility. This final step (step 3) is likely to prioritize sites in Phases I and II for treatment, and few, if any in Phase III (Miller, 2005) sites. Post-treatment management is applied on a "case by case basis". As is common to all agencies, long-term effectiveness monitoring is seldom, if ever, conducted.

The Bureau of Land Management uses the assessment method (Interpreting Indicators of Rangeland Health) developed by BLM, Agricultural Research Service (ARS), NRCS and USGS. The method detailed in this publication identifies 17 environmental indicators that address ecosystem function in three specific areas: hydrologic function, soil stability and biotic integrity. According to conversations with BLM representatives, this assessment method is to be applied in all juniper (and other land treatment) project assessments, design and implementation since the time of its adoption in the late 1990's. Post-treatment management is applied on a case by case basis. Long-term effectiveness monitoring is seldom conducted.

* OWEB Small Grant Projects; does not include 11,800 acre Cooperative Project (Ant Creek) on BLM/Private Lands. ** Assumed. *** Forest Service indicates data record accounts for only about 25% of the total acres treated.

NRCS employs an elaborate, time-tested planning process in providing its technical support to private landowners. The process involves an inventory of land resources; a determination of landowner objectives, and the development of treatment alternatives to address the conservation needs of the property that are both practical and economically feasible. Most juniper treatments involving NRCS on private lands are financially supported through the EQIP (Environmental Quality Incentive Program) or WHIP (Wildlife Habitat Improvement Program) administered by NRCS. Implementation monitoring, to determine if projects were completed in accordance with design, is conducted on all projects. Long term monitoring is seldom conducted.

OWEB juniper management projects, most commonly funded through its Small Grant Program are designed by local Soil and Water Conservation Districts (SWCD) or Watershed Council (WC) field personnel. Until the publication of the OWEB Western Juniper Management: A Field Guide, there was no prescribed method of site assessment or project design for these projects. Recent OWEB-funded field schools on the use and application of methods set forth in the publication were conducted for SWCD and WC personnel. Implementation monitoring, to determine project completion in accordance with design is conducted on all projects. Long term monitoring is not often conducted.

No records exist for all of the juniper control efforts on private land. While many projects are applied with public technical and/or financial assistance, significant acreages have been, and are being treated by landowners at their own initiative and cost. Interviews with landowners indicate that a wide array of treatment methods are used. They also indicate that the triggers for treatment, the planning process used and the application of post-treatment management are as variable as the individuals conducting the work.

Among the many advances made in the art and science of rangeland management in the last 30 has been the recognition (or recollection) of the importance of hydrologic function in the biological health, social value and economic use of rangeland watersheds. As described earlier, rangeland treatments in the study area are beginning to shift from single use objectives to ones that address basic ecological functions (hydrologic function, nutrient cycling and energy flow) as common and underlying objectives of treatment.

In spite of the increasing awareness of the scale and cost in the loss of the sagebrush biome to western juniper encroachment, there is a highly dispersed and eclectic mix of opposition to juniper control. This opposition is based on aesthetics for many, on environmental issues for some and on economic rationale for others. While this opposition is frustrating to many resource professionals, it should be the stimulus for land managers, landowners and resource scientists to isolate their facts and develop a strong, technically sound and, most importantly, understandable public message about the need for this work. Just as fast wolves make for fast elk: good critics can promote excellence in professional and scientific performance.

The Emerging Science

For many years, the only records of change in site-specific, or landscape-scale hydrology resulting from juniper control were the anecdotal records of ranchers and resource professionals who were witnessing the effects of those treatments. They could perceive the reduced interception of rain and snow by the tree canopies. They saw the effects of improved infiltration rates at the soil surface and fewer instances of overland flow and soil erosion. They noticed the increasing flows in seeps and springs and the re-emergence of long-forgotten meadows in, or down slope of the areas treated. While this anecdotal record overflows with evidence of this cause and effect scenario, it was not supported by measurement and systematic documentation published in the scientific literature.

Beginning in the early 1970's, and continuing to the present, researchers (Gifford, Tausch, Pierson, Buckhouse, Eddleman, Miller, Bates and others) began to quantify the effects of juniper on surface hydrology (infiltration, overland flow, erosion and sediment yield, etc.) and to document the results of their research. Most commonly, the positive effects on surface hydrology resulting from juniper treatment (i.e., increased herbaceous cover and decreased surface erosion) were substantiated. However, the findings of this work showed mixed results when anticipating increased yields of surface water of seeps, springs and streams… understandably so, since the subsurface hydrology of these broken systems had been ignored. The barrel must be filled - from the bottom up - before it can overflow!

In 1994, Dr. John Buckhouse (OSU Rangeland Hydrologist) established a long-term, OWEB-funded, paired watershed study in the Jensen and Mays Creek watersheds, tributaries of the Crooked River, within the area of focus of this report. These neighboring drainages were selected for this study because of their proximity to each other, their similar size, aspect, soils, vegetation, juniper density and subsurface geology. The juniper in Mays Creek drainage was cut. The Jensen Creek drainage (the control) was left untreated. To date, this paired watershed study has yielded important information on the subsurface hydrology in this semi-arid system. Deboodt (2008) documented surface and subsurface hydrologic changes associated with the removal of encroached juniper. Increases in infiltration, with a corresponding reduction in overland flow, were an immediate result. Soil moisture storage at moderate depth increased significantly and rapidly. Shallow groundwater test wells installed in both watersheds show significant increases in groundwater storage. Spring flow volume and duration of flow in the treated watershed (Mays) has also increased dramatically. The ephemeral stream flow in the treated watershed is not expected to change in the immediate future, but a shift to an intermittent flow regime is anticipated as groundwater storage continues to increase.

Looking Forward in a Changing World

Climate Change

The Crooked River Watershed, like the rest of the West, has seen enormous change in the 150 years since European settlement began. This report has attempted to outline some of the environmental changes and their cause(s) that have taken place since that time. But more, and perhaps deeper, change is on the way. The on-going and increasingly influential change in climate could affect the watershed significantly. The increasing population in the region along with its accompanying demands for space and water will underscore the importance of western watersheds and their function. Our choices are few: we can either prepare for these changes, or react once they arrive in full force and effect.

The changes expected as the climate continues to warm seem, on the surface, to be rather pleasant: warming winter temperatures and a general shift from mid-elevation snow to rain. Other than the mud, what's the problem? The shift from winter snow to rain has the potential to increase winter runoff. Rather than the release of snowmelt in late winter and spring, water, un-absorbed by the watershed, will quickly leave the system. Other than the erosion of upland soils and streambanks and sediment depositition in streambeds, it may as well not have rained at all! On juniper dominated sites, the water that does enter the soil profile is more likely to be transpired by the trees during the warming winter months.

Winter-annual weeds like cheatgrass, medusahead and mustards flourish in the kind of warmer and wetter conditions anticipated. If, as expected, they increase in density, production and distribution resulting from these changes, they present an increasing fire risk - serving as additional fuels throughout the sagebrush/grass/juniper zone. The risk of large, fast-moving fires like those seen in the cheatgrass ranges of northern Nevada may become commonplace. The real concern in the region, however, is that these fires will be working new ground – full of shrubs and trees that will give rise to catastrophic, stand converting conflagrations. Adding complexity and risk to this potential situation is the scattered, low density development of private homes beyond the Prineville urban growth boundary in the juniper dominated landscape of the watershed.

The landscape-scale reduction of juniper by unnaturally hot fires means the loss of important shrubs like sagebrush and bitterbrush. Deep-rooted perennial grasses that survive the first fires will weaken over time and die out as fire becomes increasingly frequent. Idaho's Snake River Plain is a vast and current example of this scenario.

This insult to the already heavily damaged watersheds of the region will further reduce the ability of these land to capture, store and safely release the limited amounts of moisture they receive. The timing of runoff can be expected to shift from late winter and early spring; the runoff rates higher and more immediately connected to the precipitation event; sediment loads, supported by eroding uplands and streambanks, can be expected to increase significantly, and the duration of stream flow will shorten.

An Ecological Approach

Rather than promoting the "restoration" of the landscape - to one of the many visions of a pre-Columbian condition - this report proposes an approach meant to regain ecosystem functions within the capabilities of each unit of the landscape - addressing the complex interactions of climate soil, geology, water, plants, animals and man. Unfortunately, this report cannot address the sustainability of much of the current landscape. Many of these lands have crossed thresholds that will require enormous resource inputs to regain site function, productivity and resilience before sustainability can be contemplated.

As stated by Charles Mann in his recent book 1491 "…we should not set our sights on rebuilding an environment from the past but concentrate on shaping a world to live in for the future." Implicit in this is a full appreciation of the stresses arising between the currently available supply of basic resources, the future demands on, and for, those resources, and the basic ecological precepts that bear on landscape function and productivity.

Describing an ecological approach, at the landscape-scale, to watershed "restoration" can be as complicated as anyone wants to make it. However, the approach so far implied in this report has, at its roots, a number of user-friendly sources which include: A Watershed Management Guide for the Interior Northwest (Bedell, 1991), Rangeland Health (Busby, 1994) Oregon Standards for Rangeland Health and Guidelines for Grazing Management (USDI, 1996), Interpreting Indicators of Rangeland Health. Technical Reference 1734-6 (USDI, 2005) and Western Juniper Management: A Field Guide (OWEB, 2007). Each publications addresses, from various perspectives, three pivotal processes whose understanding is necessary in assessing, attaining and monitoring rangeland health. These processes: hydrologic function, nutrient cycling and energy flow, when applied in a systematic way, can answer critical questions regarding the health and function of rangeland ecosystems. Using this approach, the results can be stepped directly into management actions and effectiveness monitoring at various scales: at the range site or plant community level and at the watershed level. The fundamental assumption in this approach is that when functioning "properly" – at optimum functional levels – water for fish, habitat for wildlife and to meet the social and economic needs of society can, within the land's capability, can be expected.

Hydrologic function always heads the list because without water, there are no other issues. Hydrologic function consists of three processes (Pirsig, 1974). First, the capture of water where it falls - considers interception by vegetation canopies and infiltration of water into the soil profile. Second, the storage of captured water in the soil profile, which is then available for plant use. Third, the safe release of water from the site through plant use, through lateral flow to seeps, springs and streams and/or to ground water. Soil condition and its relative health are essential in the consideration of this process. Note that the discussion of the hydrologic function does not distinguish between a watershed's structural components (the uplands, the riparian/wetland areas and the aquatic zone), rather it focuses on the process as a whole - throughout the watershed.

The energy flow component addresses the conversion of sunlight energy, through photosynthesis, into energy useable by the plant and its downstream consumers in the food chain (i.e. primary and secondary consumers) until it is eventually dispersed in the environment through respiration and decomposition (Gershuny, 1983. Considered in assessing the function of this component are the kinds and amounts of vegetation, plant community diversity, the photosynthetic period (or the duration of photosynthetic activity relative to the potential photosynthetic period) and the plant's availability to consumers.

Nutrient cycling involves the movement of essential elements and inorganic compounds between the soil and organisms (plants, animals, insects, microorganisms) in an exchange between organisms and their environment. Among the features considered in assessing nutrient cycling are plant community diversity (with attention to root occupancy of the available soil profile), plant litter distribution and breakdown, soil erosion (the loss of organic matter, plant nutrients, etc.) and the duration of nutrient sequestration by the plant community.

At the Landscape-scale

What is the landscape-scale? It depends, as always, on whom you ask and on their particular point of interest. If their interest is migratory, like the Inter-state deer herd on the Oregon-California border they hold a definition of a landscape bounded by the range of that herd. An avian biologist, struggling to maintain or recover sage grouse habitat, will define the landscape as the area consisting of the necessary breeding, nesting, brood-rearing and winter habitats within the range of a certain sage grouse population. OWEB, on the other hand, is in the ideal position - the catbird seat - in which the concept of "landscape-scale" is almost a non-issue. Until the surface waters of central and eastern Oregon leave the state by way of the Columbia and Klamath River systems or the atmosphere, these waters reside in discreet, "stackable" watersheds. The identification of surface water issues relating to things like irrigation, domestic, municipal and industrial use or to fish and wildlife, in this Russian Doll-like structure is self-informing. Dysfunctional watersheds exclaim themselves. Water quality and quantity and the timing and duration of flow are direct and discernable indicators of the location and cause(s) of watershed issues. By working upstream, through descending stream order (3^{rd} Order streams, to 2^{nd} Order and 1^{st} Order), much in the way fish passage is addressed, will expose the location and cause(s) of watershed issues. Using this process to winnow out priority watersheds where watershed enhancement opportunities exist, Watershed Councils, Soil and Water Conservation Districts and other entities can address the landscape-scale issue.

Conclusion

The juniper-dominated lands of central and eastern Oregon are being squandered. The resources on which Oregon depends are being lost, and the environmental quality and resilience of its landscape are threatened. While many private landowners and state and federal agencies are attempting to do their part in slowing juniper encroachment and in-fill or reversing its detrimental effects, a much more concerted effort is needed.

The results of scientific investigation, along with decades of practical experience and observation relating to the management of rangeland watersheds, gives us confidence in our understanding of the basic ecological needs of these lands and their repair and maintenance. We should be able to move forward comfortably in carrying out this important mission.

Identifying commercial uses for juniper wood products will provide incentive to private landowners to harvest the juniper on their lands, which when accomplished with attention to the ecological needs of the landscape, will help accelerated the essential job of watershed repair. In addition, family-wage jobs throughout the chain of supply may be generated by this new industry.

Watershed Councils, Soil and Water Conservation Districts and other agencies are in the position to, if they have not done so already, prioritize watersheds for treatment in the recognition that, small or large, projects will coalesce in time and the beneficial, cumulative effects will be realized. Perhaps one outcome to be anticipated from this approach is that land management agencies and local, state and federal officials will recognize the deeper social need for healthy, functioning landscapes including, but more than, wildlife habitat, fish and recreation.

The Oregon Watershed Enhancement Board is in a position to support further research in the science of watershed function and repair and to aggressively promote, and actively fund environmentally sound projects. OWEB is, as well, ideally situated in its place in state government to promote an understanding of the importance of healthy, functioning watersheds and attendant values among legislators, policy and decision makers and influential non-governmental organizations and groups - and is encouraged to actively fulfill this role.

The scale of work to be accomplished, not only in the study area but throughout central and eastern Oregon is enormous. No one agency or entity possesses the funds or skills to carry out the work necessary to repair this most fundamental of infrastructures. But by combining the commitment and resources of the potential participants and beneficiaries - landowners, industries, agencies, NGOs, the public, the legislature, the Congressional delegation – the effort can begin in earnest.

Recommendations:

- Apply a strategy of watershed enhancement that addresses the whole watershed and addresses all components of the watershed: uplands, riparian/wetland areas and the aquatic zone.

- Encourage individual Watershed Councils and Soil and Water Conservation Districts to identify priority watersheds within their respective jurisdictions and to actively address whole watershed repair in those priority area.

- Focus initial whole watershed enhancement efforts in watersheds with the greatest recovery potential.

- Actively promote and support cooperative watershed maintenance and repair by landowners, NGO's and state and federal agencies at the landscape scale.

- Continue to provide ecologically based field training to state, federal and local agency personnel, funding organizations and landowners.

- Promote the involvement of qualified specialists (hydrologists, soil scientists, rangeland ecologists, wildlife biologists and others as appropriate) to give technical assistance to SWCDs and Watershed Councils in the pre-application phase of project development intended for OWEB Grant Funding.

- Actively promote, and continue to support research in the effects of juniper encroachment and treatment on the surface and subsurface hydrology in the semi-arid regions of Oregon.

- Promote the dissemination of the results of this, and future research, in formats useful to landowners, policy makers and the influential public.

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