STAFF REPORT

Agenda Item No.:	5
Work Plan:	Forest Resources Division
Topic:	Implementing Legislative Direction
Presentation Title:	Budgets for Adaptive Management Program and AMPC Research Agenda
Date of Presentation:	September 3, 2025
Contact Information:	Josh Barnard, Division Chief, Forest Resources Division, ODF, Josh.W.Barnard@odf.oregon.gov; Terry Frueh, Adaptive Management Program Coordinator, Forest Resources Division, ODF, Terry.Frueh@odf.oregon.gov; Stacey Detwiler, Adaptive Management Program Committee (AMPC) Co-chair Seth Barnes, AMPC Co-chair

SUMMARY

The department presents proposed budgets for the Adaptive Management Program and research projects per the Adaptive Management Program Committee's (AMPC) research agenda for the Board's consideration.

CONTEXT

The legislature directed the Board to set up an adaptive management program. The program helps inform future rulemaking and supports an application for a programmatic habitat conservation plan (HCP), and subsequent incidental take permits from NOAA Fisheries and the US Fish and Wildlife Service. The goal of the program is to use the best available science to assess the effectiveness of rules for achieving the biological goals and objectives described in the HCP.

BACKGROUND

In 2020, conservation and forest industry groups offered to revise the Forest Practices Act (FPA) and forest practice rules through a memorandum of understanding to include mediated discussions, known as the Private Forest Accord (PFA). Later that year, the Legislature passed SB 1602 which set helicopter pesticide application requirements and required the Governor to facilitate mediated sessions between conservation and forest industry groups. As a product of this collaborative process, the 2022 PFA Report was drafted and released by an author group comprised of representatives from those discussions. During the 2022 Legislative Session, SB 1501 and SB 1502 passed making substantial changes to the FPA and requiring the Board to incorporate the recommendations of the PFA Report into the forest practice rules through the adoption of a single rule package to support the development of the PFA habitat conservation plan (HCP) and prescribed two additional rulemaking efforts.

A key part of the rules is the Adaptive Management Program. In addition to the Board, this Program has two primary participants:

1. The AMPC develops the policy direction for the program.
2. The Independent Research and Science Team (IRST) oversees the research and monitoring to address the policy direction.

The Board approves the budgets for both the Program[1] and the AMPC's research agenda[2].

During the 2025 legislative session, the department was appropriated $4,500,000 to support the department's Adaptive Management Program and continued work towards a federally approved HCP as part of the PFA. This includes $1,400,000 to support operational costs, $20,000 for the Program's administrative costs at ODF, and $3,080,000 for the next round of research projects conducted by the IRST. The $3,080,000 is in addition to approximately $3 million already transferred to INR for research projects at the end of the 2023-25 biennium making approximately $6.1 million available for IRST research projects. Also, Governor Kotek issued a letter when signing the department's appropriation bill (Attachment 1) that may affect the timing of the disbursement of research project funds from the 2025-27 appropriation.

ANALYSIS

Per OAR 629-603-0130, the Board shall determine the budget for:

1. The IRST Housing Agency (Oregon State University's Institute for Natural Resources (INR)) and participation grants for the AMPC and the IRST; and,
2. The AMPC's research agenda.

The department, with input from INR, developed the budget (Table 1) for the IRST Housing Agency and participation grants for the AMPC and the IRST, for the Board's vote.

Table 1

Item	2-year Budget
IRST Housing Agency (INR)	$ 946,803
Participation grants for the AMPC & IRST*	$ 453,197
Total	**$ 1,400,000**

* Recommended participation grant awards, per OAR 629-603-0160, for the organizations that requested these grants are listed in Attachment 2.

The AMPC developed a research agenda per OAR 629-603-0200(5), the report of which (Attachment 3) was sent to the Board on July 8th, 2025. This agenda was based on scoping proposals developed by the IRST (Attachments 4 and 5),

The AMPC's estimated budget for the research agenda is summarized in Table 2.

Table 2. AMPC estimated research agenda budget.

[1] OAR 629-603-0130(2)
[2] OAR 629-603-0200(5)(d)

Project	Budget for 2025-2027 biennium	Total budget^
Road-Stream Hydrologic Connectivity&	$2.7 million	$5.4 million
Eastern Oregon Steep Slopes	$80,000	$80,000
Amphibians/other	TBD	TBD

^ Not to exceed numbers

& These budget numbers are for the baseline study per Question 1; subsequent rounds of sampling to develop the trends per Question 2 will be completed in the future.

The AMPC may amend the research agenda budget to include additional projects (e.g., Amphibians) for a Board decision later this biennium.

RECOMMENDATION

The department recommends the Board approve budgets for:
1. The IRST Housing Agency and participation grants for the AMPC and the IRST (Table 1); and,
2. The AMPC's research agenda (Table 2).

NEXT STEPS

The department will coordinate with the AMPC, the INR, and the IRST to complete work per the Board-approved budgets.

ATTACHMENTS

1. Governor Kotek's Senate Bill 5521 signing letter
2. Participation grant awards per organization
3. The Adaptive Management Program Committee's Research Agenda Report
4. Road-Stream Hydrologic Connectivity Scoping Proposal
5. Eastern Oregon Steep Slopes Scoping Proposal

Tina Kotek
Governor

July 24, 2025

The Honorable Tobias Read
Secretary of State
900 Court Street NE
Salem, OR 97310

RE: Senate Bill 5521

Dear Secretary Read,

Today I am signing Senate Bill 5521, which provides the budget for the Oregon Department of Forestry (ODF). I want to take this opportunity to share the direction I am giving the agency on the administration of a portion of the budget related to the Private Forest Accord (PFA).

Package 801 provides $6 million to ODF for the administration of the PFA effort to submit a consensus Habitat Conservation Plan (HCP) to the federal agencies charged with administering the Endangered Species Act. This one-of-a-kind effort by the State of Oregon, conservation organizations, and private forest landowners is well underway, and I appreciate the legislature's attention to this work. We cannot abandon this effort.

Of that $6 million provided, $3.1 million is intended for the next round of research projects at the Institute of Natural Resources (INR) and $2 million is intended for additional grants in the Small Forestland Investment in Stream Habitat (SFISH) fund. I understand that as of the end of the 2023-2025 biennium, approximately $2.8 million remains available from prior funding authorizations and will be used to continue research projects already being administered by the INR in support of the PFA.

Completing and submitting Oregon's HCP application that will meet requirements of the federal Endangered Species Act is a critical next step for ODF after a long engagement process with the PFA authors, interested parties, and constituencies. All allocated funding must support this effort before funds are applied to other PFA-related initiatives.

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With this in mind (and given that $2.8 million is already available for research related activities), I am directing ODF to hold the new allocations of $3.1 million targeting additional research projects and the $2 million for grants covered by the SFISH program until the HCP application is completed and submitted for review by the federal government. When that occurs, ODF should consult with my office on the timing and sequence for moving forward with the expenditures for these programs. That discussion can be accelerated if ODF finds a clear and present need for releasing a portion of the funds in order to directly support the completion of the state's HCP application.

Sincerely,

Governor Tina Kotek

cc: Speaker of the House Julie Fahey
Senate President Rob Wagner

TK:smg

Participation grant awards per organization

Adaptive Management Program Committee (AMPC)

Organization	Amount for 2025-27 biennium
Wild Salmon Center	$ 15,400
Oregon Small Woodlands Association	$ 15,400
Oregon Wild	$ 15,400
Oregon Forest Industries Council	$ 15,400
Coalition of Oregon Land Trusts	$ 15,400
Association of Oregon Counties	$ 15,400
Associated Oregon Loggers	$ 15,400
Cow Creek Band of Umpqua Tribe of Indians	$ 15,400
Total	$ 123,200

Independent Research and Science Team (IRST)

Organization	Amount for 2025-27 biennium
Kelly Burnett Consulting*	$ 60,000
USDA Forest Service	$ 54,000
Eagle Cap Press	$ 54,000
J Light Consulting	$ 54,000
Roering Geoscience	$ 54,000
MJ Furniss & Associates	$ 54,000
Total	**$ 330,000**

* Since member is co-chair of the committee for 2025-26 and has a higher workload, their grant award is higher.

Total for participation grants in 2025-27 $ 453,200

Adaptive Management Program Committee Research Agenda Report

July 7th, 2025

Contents

1. Introduction

The legislature directed the Board of Forestry (Board) to set up the Adaptive Management Program in 2022. The Program helps inform rulemaking[1] by using the best available science to assess the effectiveness of rules to achieve the Biological Goals and Objectives (BGOs) described in the Private Lands Aquatic Habitat Conservation Plan (HCP)[2].

The Adaptive Management Program includes two advisory bodies:

1. The Adaptive Management Program Committee (AMPC) develops the policy direction for the program, including the research questions.
2. The Independent Research and Science Team (IRST) oversees the research and monitoring to address the policy direction.

Every 2 years, the AMPC develops a Research Agenda that is based on the IRST's scoping proposals. This Agenda prioritizes the research projects, and specifies the budgets, key milestones, and timelines for these projects (see Appendix 1 for the relevant rule). The Board reviews this Agenda and votes on its budget. If additional funds remain available, then the AMPC may amend the Research Agenda to include additional projects[3] for a Board decision.

2. Research Agenda

The AMPC finalized this Research Agenda Report at their July 7, 2025, meeting and approved it unanimously by all 10 voting members.

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[1] OAR 629-603-0000(5)

[2] As of 07/07/2025 the private lands HCP was still in draft form, but the Adaptive Management Program and this research agenda were a negotiated requirement to meet commitments to USFW and NOAA Fisheries for the attainment of Incidental Take Permits.

[3] Note that the AMPC sent preliminary research questions on Amphibians to the IRST. However, there was insufficient time for the IRST to complete its scoping proposal, and thus the associated research is not included in this research agenda. This research may be later added to the research agenda through an amendment.

Table 1. Summary of Research Agenda

Priority	Project	Milestone	Completed (months since project start)
1	Road-Stream Hydrologic Connectivity Baseline Assessment and Sediment Modeling	Award contract	2-3
		Prep for field data collection	15-18
		Complete field data collection	27-30
		Complete data analysis & draft reports	42-46
		Complete final reports	48-50
2	Eastern Oregon Steep Slopes modified Rapid Systematic Map	Award contract	2-3
		Literature search and assessment	5-6
		Complete draft reports	7-8
		Complete final reports	9-10
?	Amphibians/other	TBD	TBD

Summary of Research Agenda Projects

This section outlines the AMPC decisions for the Research Agenda.

First Priority: Road-Stream Hydrologic Connectivity Baseline Assessment and Sediment Modeling Project[4]

The Road-Stream Hydrologic Connectivity Project will include these components[5]:

1) Pre-survey Options 1 & 2 to save time and money by using geospatial data to identify optimal field work for the study;
2) Sample stratification based on differences in ownership (large vs. small landowner[6]) and geography (eastern vs. western Oregon[7]);
3) Baseline assessment of road-stream hydrologic connectivity soon after the start of the new Forest Practices Act (FPA) rules; and,
4) Sediment modeling to assess trends in sediment delivery from roads to streams.

Knowledge Contribution:

- Assesses hydrologic connectivity between roads and streams, and models associated amounts of sediment delivery.
- Includes all the connectivity-only metrics listed in Option 1 of the scoping proposal, plus the modeled delivery of road sediment to streams.

[4] Scoping proposal found here.

[5] Note: The road connectivity research questions have three components (baseline, trends, and rule effectiveness); this research agenda proposal includes only the baseline component.

[6] OAR 629-600-0100(126)

[7] Eastern and western Oregon are distinguished in OAR 629-635-0220.

- Informs the development of performance targets and the effectiveness of road rules in achieving BGOs related to hydrologic disconnection and sediment delivery.

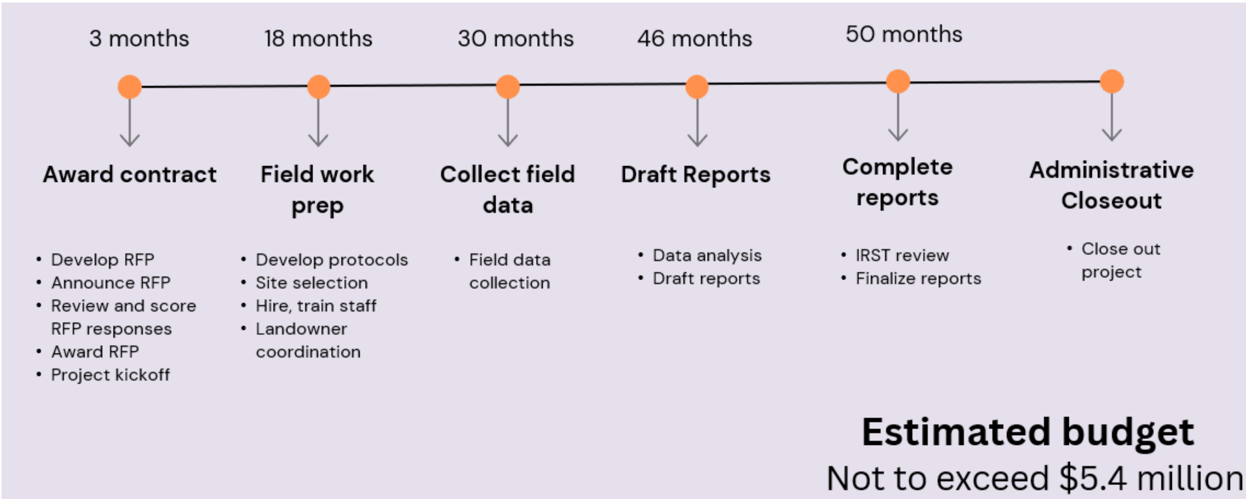


Figure 1. Timeline for Road-Stream Hydrologic Connectivity Baseline & Sediment Modeling Project

Use of Sediment Modeling Results

The AMPC believes the following quote provides important context for this work:

> "It is recognized that output from any road surface erosion model is not an accurate measure of sediment production or delivery at the scales of individual delivery points or individual road segments; however, models are useful for comparing trends in sediment production through time in response to changes in road conditions (Dubé et al. in press)." (Dubé et al., 2010)

Given this information, the AMPC will not use the results of sediment modeling that may come out of this project as an indication of measures of actual sediment amounts, individual sediment delivery points, or individual road segments. Sediment modeling results alone would not be used as the basis to recommend rule changes but could be used to inform future study or analysis.

Second Priority: Eastern Oregon Steep Slopes Rapid Systematic Map Project[8]

The Eastern Oregon Steep Slopes Rapid Systematic Map Project is a detailed literature review to help inform the Board about hillslope processes in Eastern Oregon. The AMPC modified the original proposals by IRST in two ways:

1. Include a second reviewer to minimize bias; and
2. Extract data from the relevant studies and provide those data in a database for potential future analysis.

Knowledge Contribution:

[8] Scoping proposal found here.

Extracts data from reviewed documents to support quantitative and narrative synthesis about the state of, and important gaps in, knowledge regarding eastern Oregon steep slopes. This may exclude some of the gray literature, especially older studies or those from other states. The search and review process would be well documented for transparency and replicability.

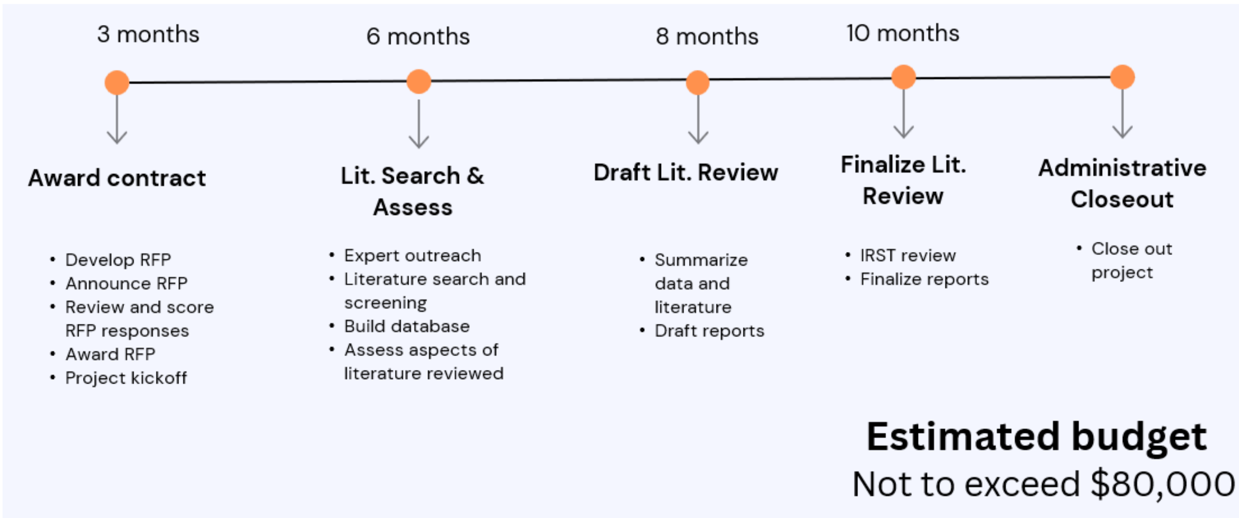


Figure 2. Timeline for Eastern Oregon Steep Slopes Rapid Systematic Map Project.

This Research Agenda provides the AMPC's direction for the IRST to implement the research. Although the details of this implementation are strictly the purview of the IRST[9], they may request input from the AMPC about unforeseen policy-relevant details of implementing this Research Agenda.

<u>Project Budgets</u>
Project budgets are based on the associated scoping proposals and are summarized in Table 2.

Table 2. Research Agenda budget estimates

Project	**Budget/year**	**Budget for 2025-2027 biennium**	**Total budget[^]**
Road-Stream Hydrologic Connectivity[&]	$1.4 million[#]	$2.7 million[#]	$5.4 million
Eastern Oregon Steep Slopes	$80,000	$80,000	$80,000
Amphibians/other	TBD	TBD	TBD

^ Not to exceed numbers
[&] These budget numbers are for the baseline study per Question 1; subsequent rounds of sampling to develop the trends per Question 2 will be completed in the future.
[#] Since there is insufficient information in the scoping proposals to determine these figures, a constant-rate expenditure is assumed.

[9] OAR 629-603-0200(6); Section 37(7)(a) chapter 33, Oregon Laws 2022; and Section 10.3.1.1 of the PFA Report.

Potential Research Agenda Amendments

The AMPC sent preliminary research questions on Amphibians to the IRST, and the AMPC anticipates coming back to the Board within 8-12 months to revise this Research Agenda. Additionally, work on an effectiveness monitoring strategy or other policy initiatives may arise that warrant amending the Research Agenda.

3. Conclusion & Next Steps

The AMPC requests that the Board approve the budget outlined above. Upon Board approval, the IRST will be notified they may proceed with Requests for Proposals for the research projects per this Research Agenda.

ODF, the AMPC, and the IRST will continue to provide Adaptive Management Program updates to the Board at least annually, and act upon the completed research project reports as specified in rule[10].

Reference

Dubé, K., A. Shelly, J. Black, and K. Kuzis. 2010. *Washington road sub-basin scale effectiveness monitoring first sampling event (2006-2008) report*. Cooperative Monitoring, Evaluation and Research Report CMER 08-801. Washington Department of Natural Resources. Olympia, Washington.

[10] OAR 629-603-0200(7, 8)

Appendix 1. Rules regarding the Research Agenda

OAR 629-603-0200(5)

(a) "The AMPC shall develop a multi-year research agenda that includes:
  - (A) Prioritized research projects;
  - (B) Key milestones for each research project;
  - (C) A timeline for progress on research projects; and,
  - (D) A comprehensive IRST budget, including annual budget for each year of each project."

(b) In prioritizing the research projects, the AMPC shall consider:
  - (A) Biennial appropriations from the legislature;
  - (B) Priorities outlined in OAR 629-603-0100(8);
  - (C) Research proposals received from the IRST per subsection (4)(e) of this rule;
  - (D) Board direction;
  - (E) Requirements for continuity of research projects under agreement or out for RFP review; and,
  - (F) Other information as appropriate.

Appendix 2. Finalized research questions

Hydrologic connectivity of roads research questions:

1. Baseline Report.
   a. What is the baseline status of hydrologic connectivity of roads prior to the implementation of the OFPA road rules effective Jan 1, 2024?
   b. How does the status of hydrologic connectivity differ based on landowner type and East/West region?
   c. How do particular elements of the regulatory framework (e.g. road location) or site characteristics (e.g. geology) contribute to hydrologic connectivity?
2. Trend Monitoring. What are the trends in the status of hydrologic connectivity of roads over 5-year intervals? These trends should be assessed for the same variables in question 1.
3. Determination of rule effectiveness. Within 25 years, to what extent are road rules associated with hydrologic disconnection effective at achieving biological goals and objectives?

Eastern Oregon Steep Slopes research questions:

Overarching Question: What impact do hillslope processes have on the covered species included in the draft HCP and their habitats in Eastern Oregon?

Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments?

Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Appendix 3. Work leading to the Research Agenda

The materials used in this Research Agenda were developed in these steps:

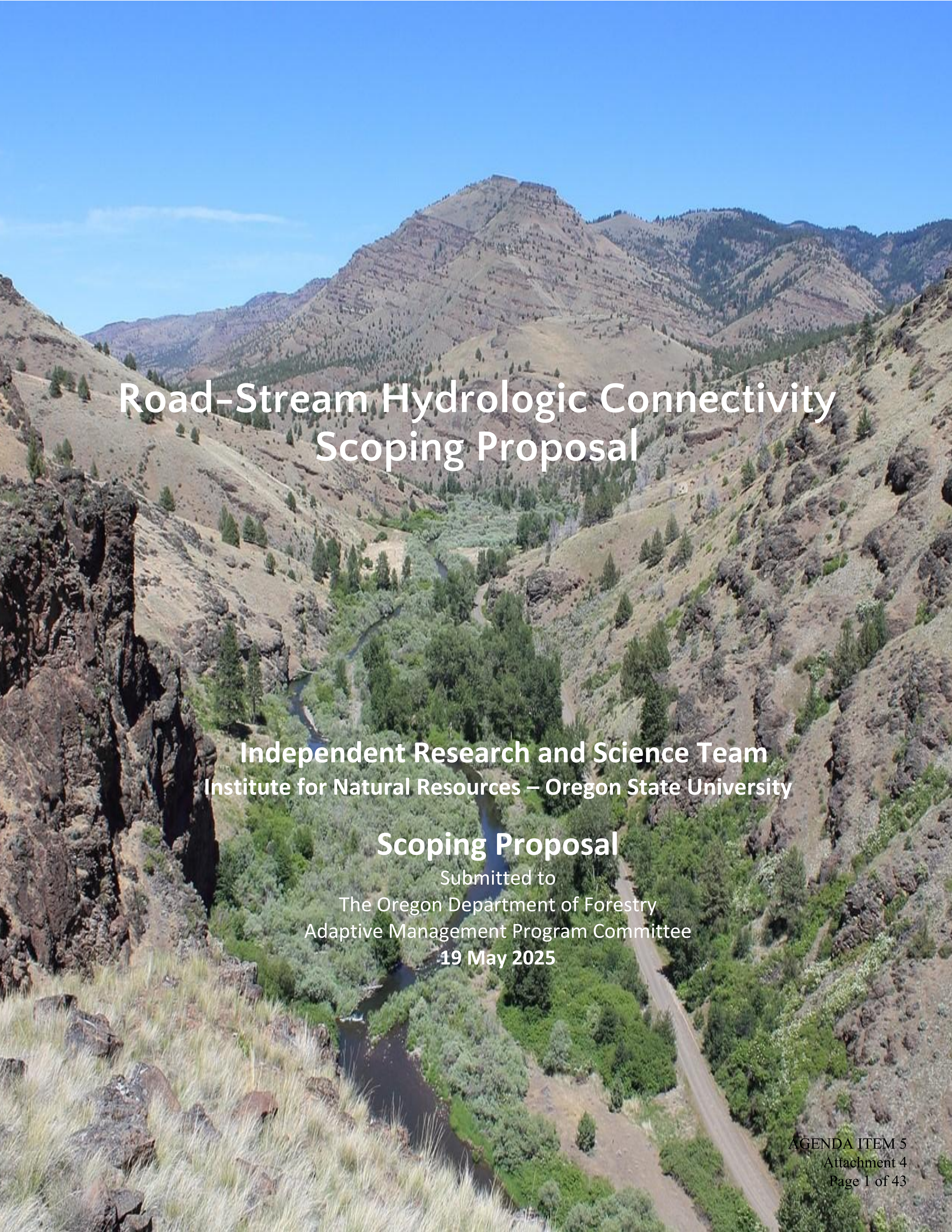
1. The AMPC developed preliminary research questions on two topics[11]:
   a. Road-stream hydrologic connectivity; and,
   b. Eastern Oregon steep slopes.
2. The IRST worked with the AMPC to hone the research questions into final, researchable formats. These finalized research questions are listed in Appendix 2.
3. The IRST developed scoping proposals that address the two sets of questions[12]. These scoping proposals include:
   a. A literature review;
   b. A preliminary estimate of the budget, and a timeline to complete the research project with specific deliverables; and,
   c. A preliminary description of research project requirements, scope of work including an estimate of the timeline and key milestones, and an estimate of the degree to which knowledge may be improved if the research proposal is implemented.

AMPC Process to develop the Research Agenda

The AMPC Co-chairs and ODF staff developed a survey to assess the AMPC members' preferences for the Research Agenda and then used that information to focus the conversation at their June 2, 2025, meeting. During this meeting, the AMPC discussed the IRST scoping proposals with the IRST Co-chairs, and then determined where there was consensus and what needed more conversation. The AMPC also formed a workgroup to work on an initial draft of this report that was subsequently reviewed and discussed by the full AMPC.

[11] These topics are specified in OAR 629-603-0100(8).

[12] Note that because the Biological Goals and Objectives and the associated metrics and targets are not yet complete, and the IRST could not complete a scoping proposal to address Question 3 from the road-stream hydrologic connectivity topic.



Road-Stream Hydrologic Connectivity Scoping Proposal

Independent Research and Science Team
Institute for Natural Resources – Oregon State University

Scoping Proposal

Submitted to
The Oregon Department of Forestry
Adaptive Management Program Committee
19 May 2025

Road-Stream Hydrologic Connectivity Scoping Proposal

19 May 2025

Authors

The Independent Research and Science Team

Prepared by

The Institute for Natural Resources

The Institute for Natural Resources' mission is to provide access to integrated, management-relevant information that informs discussions and decisions about the long-term stewardship of Oregon's natural resources. Institute for Natural Resources is an Oregon public universities institute located at Oregon State University and Portland State University.

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Disclaimer

This scoping proposal is submitted to the Adaptive Management Program Committee as a requirement of the Oregon Department of Forestry Adaptive Management Program rules (Chapter 629, Division 603).

The contents of this report reflect the views of the Independent Research and Science Team (IRST), which is solely responsible for the facts and accuracy of the material presented. This scoping proposal does not constitute a standard, specification, or regulation.

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Tables and Figures

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Abbreviations and Acronyms

AMPC	Adaptive Management Program Committee
AQI	Aquatic Inventories Program
AREMP	Aquatic and Riparian Effectiveness Monitoring Program
BGO	Biological, Goals, and Objectives
BLM	Bureau of Land Management
BMP	Best Management Practices
CMER	Cooperative Monitoring, Evaluation, and Research
FPR	Forest Practices Rules
FRIA	Forest Road Inventory and Assessment
GIS	Geographic Information Systems
GRAIP	Geomorphic Road Analysis and Inventory Package
HCP	Habitat Conservation Plan
HUC	Hydrologic Unit Code
INR	Institute for Natural Resources
IRST	Independent Research and Science Team
ISPRC	Independent Scientific Peer Review Committee
LiDAR	Light Detection and Ranging
NMFS	National Marine Fisheries Service
OAR	Oregon Administrative Rules
ODF	Oregon Department of Forestry
OSU	Oregon State University
PFA	Private Forest Accord
PIBO	PACFISH/INFISH Biological Opinion
QA/QC	Quality Assurance/Quality Control
RCA	Road Condition Assessment
READI	Road Erosion and Sediment Delivery Index

RFP	Request for Proposals
RMAP	Road Maintenance and Abandonment Plans
RSHC	Road-Stream Hydrologic Connectivity
QA/QC	Quality Assurance/Quality Control
WARSEM	Washington Road Surface Erosion Model
WEPP:Roads	Water Erosion Prediction Project: Roads

Executive Summary

The Independent Research and Science Team (IRST) was established to support the work of the Oregon Department of Forestry Adaptive Management Program Committee (AMPC) by developing research and monitoring options in response to AMPC-developed research question packages.

The AMPC submitted the following research questions related to road-stream hydrologic connectivity (RSHC):

1. Baseline report
   a. What is the baseline status of hydrologic connectivity of roads prior to the implementation of the OFPA road rules effective Jan 1, 2024?
   b. How does the status of hydrologic connectivity differ based on landowner type and East/West region?
   c. How do particular elements of the regulatory framework (e.g., road location) or site characteristics (e.g. geology) contribute to hydrologic connectivity?
2. Trend monitoring
   a. What are the trends in the status of hydrologic connectivity of roads over 5-year intervals? These trends should be assessed for the same variables in question 1.
3. Determination of rule effectiveness
   a. Within 25 years, to what extent are road rules associated with hydrologic disconnection effective at achieving biological goals and objectives?

The biological goals and objectives referenced in Question 3 are still under development as part of the Habitat Conservation Plan (HCP), therefore this scoping proposal focuses on the baseline and trend monitoring questions (Q1 and Q2).

The IRST reviewed the literature on RSHC, emphasizing the measurement and monitoring methods relevant for answering the AMPC's research questions. The following is a brief summary of key findings from the review:

- A number of RSHC models exist but the accuracy of modeled outputs depends on the quality of road and stream data as inputs.
- Numerous site-specific factors can influence connectivity and sediment delivery, so field data collection is still needed even when models are used.
- While water and sediment contributions from roads to streams have been quantitatively monitored over small areas, monitoring over broader spatial extents, such as for the area covered by the Oregon Forest Practice Rules (FPR), often necessitates using simpler, qualitative estimates of connectivity and/or modeling based on a small set of road characteristics.
- Monitoring over a broad area also means that a complete census of roads is typically infeasible, so some method for selecting a statistical sample will be necessary. The Dubé et al. (2010) study in Washington selected 60 four square mile land blocks and then collected data on all road segments within these.
- A sample of sub-watersheds rather than land blocks could better link RSHC monitoring results to effects on aquatic ecosystems.

- If accurate road and stream maps are available, efficiency can be gained by a pre-survey that:
  - First identifies and then collects field data on only the road segments with a higher probability of being connected to a stream; and
  - Characterizes essential metrics of road segments from available high-resolution digital elevation models, reducing field-data collection to a small set of variables.
- Although the ultimate purpose of the road connectivity rules is to reduce impacts on aquatic habitats and organisms, measuring impacts on those endpoints specific to the new road rules is likely infeasible given the large area involved, the cryptic nature of aquatic organisms, movement into the ocean by anadromous species, and multiple other confounding factors and mixed ownership patterns. Coordinating RSHC field sampling with existing habitat and population monitoring programs, however, could help understand these linkages in the future.

Based on the results of our literature review, we provide two primary survey options: 1) assessment of only the hydrologic connectivity between roads and streams, and 2) assessment of connectivity along with a modeled estimate of sediment delivery. In addition, we provide two pre-survey options, which could be added to test and improve the digital (GIS) road and stream data, helping to target where and what data are collected in the field. All options are summarized below (Table Ex-1).

Costs are highly dependent on the number of field sampling units. Dubé et al. (2010) determined that a sample size of 60 land blocks would provide sufficient statistical power for an accurate statewide estimate of RSHC, and so that sample size informs the lower end of our cost estimates. If AMPC desires to detect changes at the sub-state level (east/west, large/small landowners), the same number of samples would likely be required for each of these four strata, and so a four-fold increase is used as the upper bound for the cost estimates. Costs for Survey Options 1 and 2 may be reduced by implementing one or both of the Pre-survey options.

Table Ex-1. Summary of scoping proposal options, timeframes, costs, and knowledge contributions.

Option	Estimated Timeframe (months)	Cost	Knowledge Contributions
Survey Option 1: Hydrologic Connectivity Only	36 months	$1.1-$4.4 million (for baseline sample)	• Assesses only the hydrologic connectivity between roads and streams (no estimate of sediment contributions). • Characterizes the length of road segments identified as draining to streams by a number of measures (% of total, per stream mile, etc.). • Can inform performance targets and effectiveness of road rules at achieving BGOs related to hydrologic disconnection. • Faster and less expensive than Option 2 due to less field time and data processing.
Survey Option 2: Hydrologic Connectivity + Sediment Modeling	48 months	$1.35-5.4 million (for baseline sample)	• Assesses hydrologic connectivity between roads and streams and models associated amounts of sediment delivery. • Outputs would include all the connectivity-only metrics listed in Option 1, plus the modeled tons of road sediment delivered to streams. • Can inform the development of performance targets and the effectiveness of road rules at achieving BGOs related to hydrologic disconnection and sediment delivery. • Estimated time line is one year longer and costs are ~20% higher than Option 1.
Pre-survey Option 1: Digital Data Accuracy Assessment)	6 months	$10-30k	• Increases confidence that sampling locations selected are a relatively unbiased sample. • Reduces time and expense by limiting field data collection to road segments with a higher probability of connectivity.
Pre-survey Option 2: GIS-LiDAR Road Segmentation	8 months	$80k	• Reduces time and expense by limiting the data collected in the field on each road segment. • Improves the accuracy and consistency of road segment data.

1. Introduction

1.1 Background and Project Purpose

The Independent Research and Science Team (IRST) was established via Senate Bill 1501 as part of the Oregon Department of Forestry's Adaptive Management Program. The IRST supports the work of the Adaptive Management Program Committee (AMPC) by responding to AMPC-developed research questions packages. Per rule, and in consultation with the AMPC, the IRST refines preliminary research questions into final research questions, then develops scoping proposal(s) to address those questions. The scoping proposal(s) need(s) to include:

- A literature review that specifies the need for, or the type of, monitoring, research, commissioned studies, or other means of scientific inquiry necessary to answer the finalized research questions mentioned above;
- A preliminary estimate of the budget for each year of the research, and a timeline to complete the research project with specific deliverables; and,
- A preliminary description of research project requirements, scope of work including an estimate of the timeline and key milestones, and an estimate of the degree to which knowledge may be improved if the research proposal is implemented.

As per OAR 629-603-0200, the IRST develops requests for proposals (RFP) in an open, competitive process after the AMPC and Board of Forestry approve an AMPC research agenda that is based on IRST scoping proposal(s) (Figure 1).

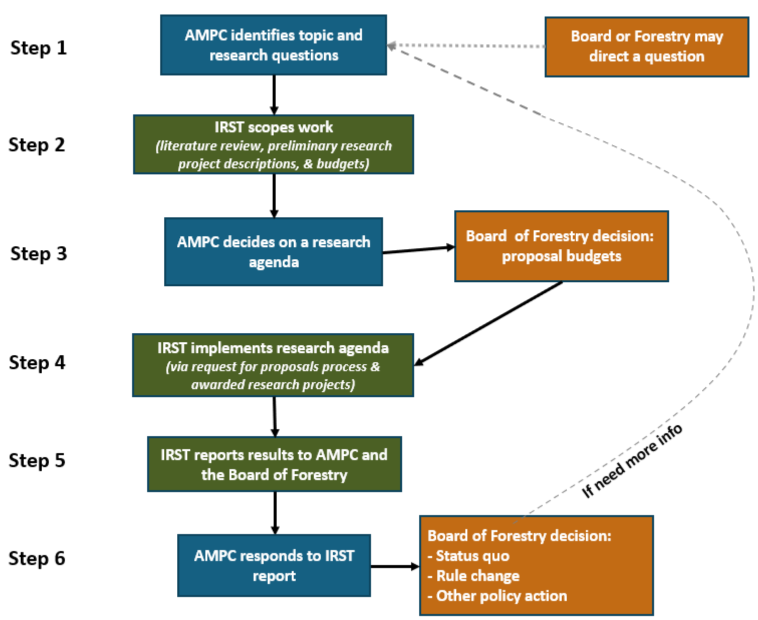

Figure 1. Adaptive Management Process.

1.2 Research questions

On June 24, 2024, the AMPC approved the finalized research questions package (Appendix A) pertaining to road-stream hydrologic connectivity (RSHC). The final questions were structured around baseline status and trend monitoring and determining rule effectiveness (Table 1).

Table 1. AMPC road-stream hydrologic connectivity research questions.

1. Baseline report	a. What is the baseline status of hydrologic connectivity of roads prior to the implementation of the OFPA road rules[1] effective Jan 1, 2024? b. How does the status of hydrologic connectivity differ based on landowner type and East/West region? c. How do particular elements of the regulatory framework (e.g., road location) or site characteristics (e.g., geology) contribute to hydrologic connectivity?
2. Trend monitoring	What are the trends in the status of hydrologic connectivity of roads over 5-year intervals? These trends should be assessed for the same variables in question 1.
3. Determination of rule effectiveness	Within 25 years, to what extent are road rules associated with hydrologic disconnection effective at achieving biological goals and objectives?

The biological goals and objectives (BGOs) referenced in question 3 are still under development as part of the Habitat Conservation Plan (HCP), therefore this scoping proposal focuses on the baseline and trend monitoring for RSHC. It is expected that further links to the BGOs will be considered by the AMPC as the HCP is finalized along with a broader effectiveness monitoring framework. However, there are potential opportunities to estimate the percentage reduction in RSHC through implementation of the OFPA Road Rules.

The Private Forest Accord Report (2022), which informed the development of HB1501 and the Adaptive Management Program, provided the following background on this request:

> *1. Baseline and Trend Monitoring for Hydrologic Disconnection: The methodology for the monitoring shall be based off of Dube et al. (2010) and Martin (2009). The purpose of the monitoring for hydrologic disconnection is to establish a baseline and to monitor and report the change in hydrologic connectivity over time as the FRIA is implemented. The overarching goal is to ensure that all forest roads and landings shall be hydrologically disconnected to the maximum extent feasible from waters of the state. The Adaptive Management Program Committee shall use the results of the baseline and trend monitoring to develop regional goals consistent with that monitoring. All hydrologic connectivity data should be public and shared as it becomes available to help focus goals, identify accomplishments, and inform statewide learning.*

[1] A summary of relevant OFPA road rules is provided in Appendix B.

2. Literature Review

Introduction

A large body of scientific literature details the impacts of forest roads on hydrologic processes. Reviews can be found in Dubé et al. (2004), the Private Forest Accord Report (2022), and Kastridis (2020). The factors controlling how overland flow and interception of subsurface stormflow by cutbanks concentrate runoff from roads and convey fine sediment and other materials to streams have been well studied using empirical and physically-based approaches. Rather than focusing on these well-studied impacts, this scoping proposal reviews relevant measurement and monitoring methods to answer the AMPC's research questions.

The literature review began with reports from Dubé et al. (2010) and Martin (2009), as these studies were cited in the Private Forest Accord (2022) as methods to follow. In contrast to the Eastern Steep Slopes Scoping Proposal, the IRST did not conduct a systematic review due to the limited timeframe and the existence of relatively recent and comprehensive reviews. Most reviewed literature was drawn from two resources: 1) a literature database maintained by the NW Forest Plan Aquatic and Riparian Effectiveness Monitoring Program (AREMP 2025a), and 2) literature compiled for the Trees to Tap report (Souder et al. 2020). These documents were initially screened by INR staff, and those that were deemed potentially relevant were reviewed by IRST members and INR staff to extract salient information. IRST members used their professional knowledge to identify additional documents to supplement this effort. In total, this literature review including scanning or integrating information across approximately XX publications.

Assessing connectivity between roads and streams requires a standardized definition (Furniss et al. 2000). The Oregon Forest Practices Rules (FPR) define hydrologic disconnection as "the removal of direct routes of drainage or overland flow of road runoff to waters of the state" (OAR 629-600-0100 (71)). However, the Oregon Forest Practices Rules (FPR) lack a definition of hydrologic connection. On 6 March 2025, the IRST accepted the following as its working definition of road-stream hydrologic connectivity (RSHC): "A road segment is considered hydrologically connected where surface runoff from road cuts, ditches, running surfaces, and fills exhibits a continuous surface flow path to a natural stream channel." This definition was derived from the IRST's literature review and is used throughout the scoping proposal.

We reviewed the literature for methods of RSHC effectiveness monitoring that examined: 1) only the Hydrologic connection of water runoff between roads and streams, hereafter referenced as Hydrologic connectivity; 2) sediment inputs from roads to streams; 3) runoff and sediment effects on aquatic habitats; and 4) runoff and sediment effects on populations of aquatic species. The primary interest of AMPC appears to be the Hydrologic connections between roads and streams; however, the third question references achieving BGOs, which include both runoff and sediment as related to covered species habitat requirements. Given the AMPC questions and the Dubé et al. (2010) and Martin (2009) examples, the literature review prioritized methods for measuring or estimating connectivity. However, we also reviewed methods for estimating sediment inputs and impacts to habitat or aquatic species. Because of the overlap in methods among connectivity and sediment monitoring and habitat/population monitoring, the literature review was collapsed into two corresponding sections.

The full literature review is in Appendix C. Here we summarize the key takeaways considered in the developing the options presented in Section 3. The takeaways are organized under three principal aspects of option design: ways to measure connectivity, statistical sampling designs, and assessment of results.

Key Takeaways

Measurement

- A number of very site-specific factors can have a large influence on connectivity and sediment delivery, so field verification of conditions is still considered essential.
- Observer bias was substantial in field assessments of RSHC even with extensive training. Thus, enhanced standardized training and coordination in the field are recommended.
- Field measurement of connectivity and modeling of sediment are possible at a state-wide scale as demonstrated by Dubé et al. (2010). However, direct field measurements of sediment production and delivery from a census of road segments across a broad spatial extent, such as the area covered by the FPA, is infeasible.
- Numerous site-specific factors can influence connectivity and sediment delivery so that quantifying field covariates is essential for exploring relationships between RSHC and local conditions.
- Availability of models and improvements in remote sensing methods and GIS data may reduce the amount of field work needed, particularly when relative estimates of RSHC are sufficient.
- RSHC data to be collected under FRIA may complement but not fulfill the effectiveness monitoring needs for numerous reasons.

Sampling Design

- For large areas of interest, monitoring for RSHC requires sampling rather than a census of all roads.
- Because of the focus on hydrologic processes, most studies sampled and/or assessed based on hydrologic units, such as sub-watersheds; however, Dubé et al (2004) and Martin (2009) documented reasons to sample by land grids.
- Past studies have consistently determined that most impacts from RSHC are associated with relatively few road segments. These "high probability of delivery" segments can be identified and characterized using existing GIS data and modeling tools before going to the field. This focuses field data collection, potentially decreasing sampling costs or cost-effectively increasing sample size. However, applying such "pre-survey" approaches depends on the quality of GIS roads and streams data available.

Assessment

- Although the ultimate purpose of the road connectivity rules is to reduce impacts on aquatic habitats and organisms, measuring such impacts specific to the new road rules is likely infeasible given the large area involved, the cryptic nature of aquatic organisms, movement into the ocean by anadromous species, and multiple other confounding factors and mixed ownership patterns. Coordinating RSHC field sampling with existing habitat and population monitoring programs, however, could help understand these linkages in the future.
- Accurate estimates of the *absolute* amounts of sediment delivered to streams is infeasible over large areas. However, field measurement of road characteristics coupled with erosion and delivery modeling can provide *relative* measures of sediment inputs.
- Although most studies have addressed Hydrologic connectivity and sediment delivery together, connectivity can be addressed alone and would save on both field work and analysis resources.

- Dubé et al. (2010) were able to compare their connectivity and sediment results to Washington performance target ranges from prior agency work, however, performance targets have not been developed for Oregon.

3. Scoping Proposal Options

3.1 Introduction

Based on the results of our literature review, we provide options for RSHC status and trend monitoring (AMPC Questions 1 and 2). We do not address the full breadth of potential effectiveness monitoring approaches (Question 3) for habitat or populations. Rule effectiveness can be inferred from status and trends monitoring of RSHC and the likely reduction through time. More specific BGOs, monitoring metrics, and performance targets that would be necessary to quantitatively assess effectiveness are not finalized through a fully executed HCP. Thus, the options presented here are intended to support the eventual development of achievable targets for lowering RSHC through time.

Below we describe two primary survey options: 1) assessment of only the Hydrologic connectivity between roads and streams, and 2) assessment of connectivity with a modeled estimate of sediment delivery. We also provide two pre-survey options. These could be added to test and improve the digital (GIS) roads and streams data that will be used in planning the field survey, helping to better target where and what data are collected in the field.

3.2 Survey Options

Survey Option 1: Hydrologic Connectivity

Approach

This option documents the connectivity of surface runoff from roads to streams without collecting the parameters and other data required to model road-related sediment production and transport. The length of road-related features (e.g., road tread, road cuts, ditches, fill slopes) that capture and deliver water to streams will be measured in the field-for status and trend reporting. Based on GIS analysis, points of connectivity to natural water bodies (e.g., wetlands, lakes) other than streams, as defined in the Oregon Forest Practice Rules (FPR), will be included if these can be identified comprehensively in advance of or in conjunction with initial fieldwork.

Sampling Design

The two sampling approaches considered are the land-grid–based road census approach used by Dubé et al. (2010) and an approach that targets road segments most likely to have a high degree of RSHC. The latter approach would be watershed-based, sampling within 12th code hydrologic units (HUC 12) that have significant private forestland ownership. The watershed-based approach entails a pre-survey step to identify the road segments with a high probability of delivering sediment using a GIS-based road-stream proximity assessment.

Either approach will require a large random sample to provide valid statistical data to draw inferences and detect trends across the state of Oregon. The sample could be stratified by landowner type (large/small) and geography (eastside/westside). These four sampling frames are hereafter referred to as "strata." A statistical power analysis will be necessary to determine the sample size needed for each stratum and sampling period to reliably evaluate the baseline status and detect trends.

Numerous sampling designs are possible for trend analysis, including paired, unpaired, and rotating panel designs.

Data Collection Methods

We envision data collection methods similar to the field protocol of Dubé et al. (2010), as described in Watershed Professionals Network (2009) with potentially more recent updates (e.g., Bohle and Dubé 2016). Field crews will drive roads included in the sample and use GPS to spatially record features indicating various types and levels of connectivity (such as the five types in Dubé et al. (2010)). Crews will measure variables describing and affecting pathways for delivery of runoff from each sampled road segment. Typical variables would include ditch lengths, road segment slope, and road surface type. Field crews will be sufficiently trained to competently reduce within- and among-observer errors to within specified tolerances (TBD) and a QA/QC program will be developed to quantify data collection variability.

Baseline Status and Trend Analysis

As part of this study, summary statistics will be calculated on each measured variable related to RSHC for each reporting unit (e.g., all the roads in a watershed or land grid). The baseline status will be summarized by strata (landowner class in each geo-region). Depending on the sampling approach, the summarized baseline status would be something like the length of connected road over total road length (or sampled area) or length of actually connected road per length of potentially connected road.

To establish the pre-PFA baseline status for Hydrologic connectivity, ODF records of road work completed since January 2024 will be used. New FPRs went into effect in 2024, including the FRIA process that directed large landowners to begin, as soon as possible, identifying and remediating high conservation value sites. These are areas known to have road stream connectivity or chronic sedimentation. Small landowners are exempt from FRIA but must conduct a Road Condition Assessment (RCA) for roads used in active harvest operations. Data from FRIA and RCA would help identify road segments affected by these post-rule changes, which then could either be dropped from the sample or assumed connected in the baseline.

AMPC question 2 requests a trend analysis at 5-year intervals, which seems reasonable given the 20-year timeframe of the FRIA process and the remediation of the worst roads in the first five years. The request for a specific design of repeated sampling through time would be integrated into the Request for Proposals.

Reporting

The baseline status of Hydrologic connectivity at each sampling interval, and trends over time between intervals, will be reported for each stratum. Potential metrics include:

- Total road length draining to streams.
- Density of roads and road length draining to streams (road miles/sq mi).
- Percent of road network draining to streams.
- Miles of roads delivering to streams per miles of stream.
- Average percentage of high probability road length delivering to streams.

- Characteristics of delivering road segments, including the portion of road cross section that is connected to streams.
- Presence of or delivery to adjacent wetlands and lentic water bodies (i.e. lakes).
- Regression plot of the estimated percentage of roads that meet current BMPs vs. percentage of high probability road length delivering to streams.

Landowner-specific information collected in the sample will not be identified in any reporting and will be held confidential.

Timeline

Determining baseline status for this project should entail 6–12 months to prepare for sampling, one or two field seasons to collect field data, and 6–12 months for data analysis. The final report on baseline status results would be expected in about 3 years from project initiation.

For trends, the sampling interval will likely be at least 5 years and the duration at least 20 years. The 3-year timeline projected for the baseline status will apply for each iteration of trend sampling, but with some time savings likely in subsequent sampling periods.

Table 2. Timeline for Option 1.

Task	Who	Estimated Time Needed (months)
Administrative Start up (i.e., contracting, etc.)	OSU/INR	2
Initial planning	IRST & Contractor	1
Site selection & screening,	Contractor	4
Recruitment & training of field teams	Contractor	6
Landowner permissions and access coordination	Contractor	2
Field sampling	Contractor	10
Data analysis & report writing	Contractor	8
IRST review	IRST	1
Final report	Contractor	1
Administrative closing	OSU/INR	1
Total		**36**

Costs

There is insufficient information to estimate sampling densities needed for different levels of statistical certainty or the potential cost differences between alternative sampling approaches at this time. Thus, costs and precision related to the Dubé et al. (2010) study are assumed to provide an adequate basis for this scoping proposal. Dubé sampled 60 land blocks, which they estimated would provide a statistical power of 80% to detect a change of 30% in delivering road length on a statewide basis.

CMER recorded an overall cost of $878,000 for the Dubé study (which probably did not include some additional CMER staff time). Using an inflation calculator for 2007 (midpoint of the 2006–2008 monitoring effort) to 2025 provides an overall cost equivalent of $1.35 million. Based on the line-item budget in the pilot study (Raines et al. 2005), not collecting and analyzing data needed for the sediment modeling is estimated to reduce the costs by 20%, resulting in a cost estimate of approximately $1.1 million for the baseline sampling event. Raines et al. (2005) estimated costs would be approximately 25% less for a second round of sampling after five years resulting in an estimate of $800,000 for each of the second and subsequent iterations.

If AMPC desires to detect changes at the sub-state level (east/west, large/small landowners) with a similar amount of statistical power, the same number of samples may be required for each of these strata. Thus, four strata may require 240 sampling units and cost approximately $4.4 million for the initial sampling iteration.

Other factors affecting costs:

- Field time, including travel between sites and rigor of field measurements.
- Whether field data collection can target only the road segments likely to be connected i.e., proximate to streams versus a complete census of roads in the sample.
- Whether road segments can be characterized from high-resolution LiDAR, reducing the metrics for which data collection in the field is required.
- The number of strata for which hydrologic connectivity is to be estimated.
- Sampling frequency.

Knowledge Contribution

- Assesses only the hydrologic connectivity between roads and streams (no estimate of sediment contributions).
- Characterizes the length of road segments identified as draining to streams by a number of measures (% of total, per stream mile, etc.)
- Result metrics, all based on the length of road segments identified as draining to streams, would include: total length, percent of road network, length per mile of stream.
- If additional road characteristics are collected (cutslope vegetation, road surface type), connectivity could additionally be reported by these categories.
- Can inform the development of performance targets and effectiveness of road rules at achieving BGOs related to hydrologic disconnection.
- Cannot support quantitative targets or effectiveness for sediment-related BGOs, although a more qualitative assessment of sediment could be inferred from levels of hydrologic connectivity but with a lower level of confidence than Option 2.
- Faster and less expensive than Option 2 due to less field time and data processing.

Survey Option 2: Hydrologic Connectivity Plus Modeled Estimates of Sediment Delivery

Approach

This effort expands the field sampling, analysis, and reporting of Survey Option 1 to include modeled estimates of sediment generated by roads and delivered to streams both episodically and annually.

Field Methods

The field methods for this option require data collection to support modeling the estimated amounts of sediment generation and delivery. Raines et al. (2005) describes the types of variables for which field data will be collected. These include variables such as road surface, road age, and cut slope vegetation coverage. Other needed variables (e.g., road traffic or maintenance activities) may be derived from landowner interviews. The exact variables will depend on the model selected.

Baseline and Trend Analysis

Similar to Survey Option 1, with the addition of all variables that relate to the generation and delivery of sediment to streams (e.g., surfacing, traffic, age, cut slope vegetation coverage), and a modeled estimate of the amount of sediment delivered by the surveyed road segments per year. Estimates of sediment delivered could be stratified across landowner type and region and analyzed through time as the FPRs are implemented.

Reporting

Reports will include the baseline status of hydrologic connectivity plus sediment delivery at each sampling interval, and trends over time between intervals, for each stratum. The following metrics will be included in addition to those in Survey Option 1:

- Density of sediment delivery to streams (tons/sq mi/year).
- Volume of road sediment delivered to streams per mile of stream (tons/stream mi/year).
- Characteristics of high delivery road segments (surfacing, traffic, etc.).
- Sediment delivery to adjacent wetlands and lentic water bodies that may store/divert delivery to streams.
- Expected sediment delivered by certain levels of storm/meltwater runoff events.

Landowner-specific information collected in the sample will not be identified in any reporting and will be held confidential.

Timeline

Determining the baseline for this project should be the same as for Option 1, requiring 6-12 months to prepare for sampling. However, field sampling and data analysis will take longer than for Option 1 given the need to collect and analyze sediment data. Thus, two seasons will likely be necessary to collect field data, and 15 months for data analysis. The final report for baseline results would be expected in about four years from project initiation.

For trends, the sampling interval will likely be at least five years and the duration at least 20 years. The four-year timeline projected for the baseline will apply for each episode of trend sampling, but with some time savings likely for subsequent sampling periods.

Table 3. Timeline for Option 2.

Task	Who	Estimated Time Needed (months)

Administrative Start up (i.e., contracting, etc.)	OSU/INR	2
Initial planning	IRST & Contractor	1
Site selection & screening	Contractor	4
Recruitment & training of field teams	Contractor	6
Landowner coordination & interviews	Contractor	4
Field sampling	Contractor	12
Data analysis & report writing	Contractor	15
IRST review	IRST	1
Final report	Contractor	2
Administrative closing	OSU/INR	1
Total		**48**

Cost

Costs are estimated based on the Dubé et al. (2010) study, similar to Option 1. To establish a statewide connectivity baseline with sediment modeling would cost an estimated $1.35 million. Subsequent iterations on five-year intervals would cost approximately 25% less, resulting in an estimate of $1 million for each round of sampling. If AMPC desires to detect changes at the sub-state level (east/west, large/small landowners) with a similar amount of statistical power, the same number of samples may be required for each of these strata. Thus, four strata may require 240 sampling units and cost approximately $5.4 million for the initial sampling iteration. Costs may be reduced if field data collection can target only the road segments likely to be connected and if road segments can be characterized from high-resolution LiDAR data, reducing the metrics for which data collection in the field is required.

Knowledge Contribution

Same as for Survey Option 1, except that Option 2:

- Assesses hydrologic connectivity between roads and streams and models associated amounts of sediment delivery.
- Outputs would include all the connectivity-only metrics listed in Option 1, plus the modeled tons of road sediment delivered to streams.
- Includes additional road characteristics needed for sediment modeling (cutslope vegetation, road surface type, traffic levels) that will be reported by road length.
- Provides a baseline status estimate in approximately four years after project initiation. An initial trend estimate could likely be available five years after the baseline.
- Can inform the development of performance targets and the effectiveness of road rules at achieving BGOs related to hydrologic disconnection and sediment delivery.
- Estimated time line is one year longer and costs are ~20% higher than Option 1.

3.3 Pre-survey Options

Pre-survey Option 1: Assessing Roads and Streams Digital Data

Approach

As described in Options 1 and 2 above, one potential way to boost sampling efficiency would be to preselect and sample only road segments with a high probability of being hydrologically connected, using either a simple distance buffer or one of the RSHC models. However, the utility of these locations for field work and eliminating potential sampling bias will depend on the accuracy of the stream and road data used to identify field sampling locations.

ODF's hydrography layer derived from LiDAR and ODF's transportation layer (both available from their GIS Data Hub) are considered the most comprehensive coverages available for private forestland in Oregon. However, the accuracy of the layers is not well quantified. Thus, using these layers to guide sampling for RSHC may introduce an unknown level of bias into estimates. For example, road locations that are inaccurate could result in higher or lower estimates of the true probability of RSHC.

Here, we propose to quantify and address potential biases of inaccurate hydrography or transportation layers through validation sampling. If the existing ODF transportation and hydrography layers have a desired level of accuracy, estimates of baseline status and future RSHC will have lower levels of bias. Conversely, if either layer is less accurate than desired, these will need to be improved or cannot be used to preselect road segments for field data collection in Survey Options 1 and 2.

Developing an improved transportation layer, for example, could be achieved by interpreting LiDAR data or by a field-mapped census. It may also be possible to draw on the complete census of roads being developed by large landowners through the FRIA process, but that census will not be available until January 1, 2029 and excludes small landowners.

Two time periods are proposed for assessing the accuracy of ODF's hydrography and transportation layers.

- A state agency, INR, or other organization could validate and estimate accuracy prior to publishing the Request for Proposal (RFP) for the Roads Questions.
- Alternatively, validation sampling could be incorporated into the RFP as an additional project component.

In either case, if the accuracy of the layers is lower than desired, additional mapping of roads and streams may be necessary in the geographic areas (e.g., sub-watersheds) selected for study. The sooner this is determined, the greater the certainty in approach as well as cost and time estimates for Survey Options 1 and 2 above.

Timeline

Evaluation of the hydrography and transportation layers could be undertaken prior to publishing a full survey RFP or as part of the full survey RFP before sending crews to the field. We estimate it will take one to three person-months of effort to complete, with a likely overall timeline of three to six months. If improved roads or streams layers are desired, a separate timeline for that work would need to be developed.

Cost

We estimate it will take one to three person-months of effort to complete at a cost per person-month of about $10,000, yielding a total cost estimate of $10,000 - $30,000. Testing (and possibly improving) these layers may also decrease costs of the full Survey Options 1 and 2 by reducing the amount of field sampling needed.

If this initial assessment shows a need to develop improved transportation or stream layers, that will require a separate cost estimate. We cannot develop that additional cost estimate until the initial evaluation of data quality is completed.

Knowledge Contribution

Estimating the accuracy of these layers could enhance the sampling design by reducing required sample sizes, facilitating selection of a relatively unbiased sample of field sites, and allowing use of the methods described in Survey Options 1 and 2 that target field sampling at the road segments most likely to be hydrologically connected. These benefits are possible only if the existing transportation and stream layers are deemed sufficiently accurate or are improved after evaluation.

Pre-survey Option 2: GIS-LiDAR Road Segment Analysis

Approach

Identifying road segments and measuring the associated attributes needed for RSHC analysis and sediment modeling takes considerable time in the field. The literature suggests that GIS (desktop) analysis prior to fieldwork could be used to generate road segments and properties from publicly available airborne LiDAR data. The goal of this option would be to test whether such an approach improves the accuracy and efficiency of road segment creation and the quantification of segment characteristics needed for RSHC analysis.

After overlaying the ODF road network atop airborne LiDAR, flow routing algorithms and other GIS tools could be used to distinguish road segments and attribute those segments with estimates of relevant properties, including length, slope, configuration, ditch width/position, cut slope height, tread width, and other geometric data. Field crews could then focus on documenting site-specific information such as road surfacing.

This approach would require workflow development and testing before adoption and rollout for field crews. Also, some legacy (or older) LiDAR datasets have lower point density, thus testing would be necessary to determine whether data limitations exist. Field validation would also be needed to assess the accuracy of this approach.

Timeline

A detailed timeline for this pre-survey option is presented below (Table 4).

Table 4. Timeline for Pre-survey Option 2.

Task	Who	Estimated Time Needed (months)
Administrative start up (i.e., contracting, etc.)	OSU/INR	2
Initial planning	IRST & Contractor	1
LiDAR data acquisition and initial processing	Contractor	1
Terrain analysis and feature extraction	Contractor	1
Identification of road features	Contractor	1
Road extraction, testing, and refinement	Contractor	2
Post-processing, vectorization, and characterization	Contractor	2
IRST review	IRST	1
Final report	Contractor	1
Administrative closing	OSU/INR	1
Total		**13**

Cost

Eight months of contractor time would be needed, and assuming a cost of $10,000 per person-month, the estimated cost for this option is $80,000.

Knowledge Contribution

This option has the potential to reduce the time (and funding) needed for field crews to collect geometric data and instead focus their efforts on acquiring other relevant data. It is anticipated there would be cost savings and/or an expansion of the number of sample sites or length of roads assessed for RSHC.

3.4 Options Summary Table

The two primary survey options and two pre-survey options differ in time required, cost, and knowledge contributions (Table 5).

Table 5. Summary of scoping proposal options, timeframes, costs, and knowledge contributions.

Option	Estimated Timeframe (months)	Cost	Knowledge Contributions
Survey Option 1: Hydrologic Connectivity Only	36 months	$1.1-$4.4 million (for baseline sample)	• Assesses only the hydrologic connectivity between roads and streams (no estimate of sediment contributions). • Characterizes the length of road segments identified as draining to streams by a number of measures (% of total, per stream mile, etc.). • Can inform performance targets and effectiveness of road rules at achieving BGOs related to hydrologic disconnection. • Faster and less expensive than Option 2 due to less field time and data processing.
Survey Option 2: Hydrologic Connectivity + Sediment Modeling	48 months	$1.35-5.4 million (for baseline sample)	• Assesses hydrologic connectivity between roads and streams and models associated amounts of sediment delivery. • Outputs would include all the connectivity-only metrics listed in Option 1, plus the modeled tons of road sediment delivered to streams. • Can inform the development of performance targets and the effectiveness of road rules at achieving BGOs related to hydrologic disconnection and sediment delivery. • Estimated time line is one year longer and costs are ~20% higher than Option 1.
Pre-survey Option 1: Digital Data Accuracy Assessment)	6 months	$10-30k	• Increases confidence that sampling locations selected are a relatively unbiased sample. • Reduces time and expense by limiting field data collection to road segments with a higher probability of connectivity.
Pre-survey Option 2: GIS-LiDAR Road Segmentation	8 months	$80k	• Reduces time and expense by limiting the data collected in the field on each road segment. • Improves the accuracy and consistency of road segment data.

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5. Appendices

Appendix A. AMPC Research Questions Package

Finalized research questions

These finalized research questions were approved by the AMPC at the June 24 2024 AMPC meeting.

4. Baseline report
    d. What is the baseline status of hydrologic connectivity of roads prior to the implementation of the OFPA road rules effective Jan 1, 2024?
    e. How does the status of hydrologic connectivity differ based on landowner type and East/West region?
    f. How do particular elements of the regulatory framework (e.g., road location) or site characteristics (e.g. geology) contribute to hydrologic connectivity?
5. Trend monitoring
    b. What are the trends in the status of hydrologic connectivity of roads over 5-year intervals? These trends should be assessed for the same variables in question 1.
6. Determination of rule effectiveness
    b. Within 25 years, to what extent are road rules associated with hydrologic disconnection effective at achieving BGOs?

Preliminary Research Questions Package: Contextual Information

The remainder of this document provides contextual information that details the context for the preliminary research questions, as required by rule[2]. The following are organized per the elements in this rule.

B.1 The type of research[3]
This research is of type OAR 629-603-0100(1)(a): *"Conduct effectiveness monitoring by assessing the degree to which the rules facilitating particular forest conditions and ecological processes achieve the biological goals and objectives. This assessment may include evaluation of cumulative effects."*

B.2 The rule, biological goals and objectives (BGOs), or other issue being studied[4]
Note that the most recent version of the BGOs is in the Dec. 2022 draft HCP. The BGOs will be finalized within the HCP due Dec. 31, 2027.The BGOs are listed below with those applicable to these questions in bold italic:

[2] OAR 629-603-0200 (3)(a)

[3] OAR 629-603-0200(3)(a)(A)

[4] OAR 629-603-0200(3)(a)(B)

"***Overarching Goal:*** *Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats.*

Goal 1: *Provide clean water and substrate for the covered species.*

- ***Objective 1.1** - **Forest practices near streams minimize sediment delivery.***
- *Objective 1.2 – Slope Retention Areas reduce episodic sediment delivery to fish-bearing streams.*
- ***Objective 1.3** – **Road runoff directly to streams is minimized.***
- ***Objective 1.4 – Roads are not a significant source of episodic sediment delivery to streams.***

Goal 2: *Shade and watershed processes controlling stream temperature provide cool water compatible with the needs of the covered species.*

- *Objective 2.1 – Forest practices maintain stream shade sufficient to support desired cool water temperatures on fish-bearing streams.*
- *Objective 2.2 – No-harvest RMAs maintain stream shade sufficient to support desired cool water temperatures for covered amphibians.*
- *Objective 2.3 – Forest practices near non-fish-bearing perennial streams do not notably increase water temperatures in fish-bearing streams.*

Goal 3: *Stream network connectivity satisfies freshwater habitat needs for covered species.*

- *Objective 3.1 – Road crossings on fish-bearing streams are passable by the covered fish species.*
- *Objective 3.2 – Forest practices maintain the hydrologic continuity of stream-associated wetlands and stream-adjacent seeps and springs to stream habitats.*
- *Objective 3.3 – Timber harvest maintains stream-associated connectivity in riparian areas along non-fish streams sufficient to support covered amphibians.*

Goal 4: *Riparian areas function to support complex habitats for the covered species.*

- *Objective 4.1 – Mature, complex riparian forests are fostered in no-harvest zones of RMAs.*
- *Objective 4.2 – Forest practices within tree retention areas of RMAs promote delivery of large wood.*
- *Objective 4.3 – Designated Debris Flow Traversal Areas function to deliver large wood to fish-bearing streams.*
- *Objective 4.4 – Forest practices maintain stream-associated wetlands and stream-adjacent seep and spring habitat for amphibians."*

<u>B.3 The objective of the research</u>[5]

[5] OAR 629-603-0200(3)(a)(C)

1. To assess the current (baseline) status and trend of roads that are hydrologically connected to streams, and how those vary with practice, region, landowner type, and other relevant strata.
2. Determine the effectiveness of road rules associated with hydrologic disconnection at achieving BGOs.

B.4 A brief description of the context of the research question[6]

The following direction was provided in the PFA Report and provides the foundation for these research questions:

> *"4.3.5 Hydrologic Connectivity in Forest Practice Rules (FPR) Revisions and Proposed Inventory Processes*
>
> *Hydrologic connectivity occurs where road and ditch runoff is delivered to the natural stream channel system. Roads can generate overland flow due to the relatively impermeable surface of the road prism and can also intercept interflow at cut slopes, effectively converting subsurface flows to surface flows. When these surface flows have a continuous flow path between the road prism and a natural stream channel, hydrologic connectivity occurs (Furniss et al., 2000, pp. 5-6). As Furniss et al. describe, "a hydrologically connected road becomes part of the stream network" (pp. 5-6).*
>
> *Hydrologically connected roads can deliver increased runoff, sediment, and chemicals associated with roads, such as spills or oils generated on the road surface or cut slope. At the watershed scale, connections between roads and streams can also alter the drainage density of the watershed and change runoff frequency and magnitude (See Furniss et al., 2000; Weaver et al., 2015).*
>
> *The Authors agree that the goal of disconnecting roads and streams is to minimize sediment delivery, hydrologic change, and risk of road pollutants entering waters of the state."*
>
> 4.3.10 Development of Monitoring Requirements
>
> *The Independent Research Science Team (IRST) created under the PFA shall design and oversee baseline and trend monitoring for hydrologic disconnection. Compliance monitoring will be conducted through the Department's process.*
>
> 1. ***Baseline and Trend Monitoring for Hydrologic Disconnection:*** *The methodology for the monitoring shall be based off of Dube et al. (2010) and Martin (2009). The purpose of the monitoring for hydrologic disconnection is to establish a baseline and to monitor and report the change in hydrologic connectivity over time as the FRIA is implemented. The overarching goal is to ensure that all forest roads and landings shall be hydrologically disconnected to the maximum extent feasible from waters of the state. The Adaptive Management Program Committee shall use the results of the baseline and trend monitoring to develop regional goals consistent with that monitoring. All*

[6] OAR 629-603-0200(3)(a)(D)

hydrologic connectivity data should be public and shared as it becomes available to help focus goals, identify accomplishments, and inform statewide learning."

B.5 Other information the AMPC deems necessary for the IRST's work[7]

1. It is essential to maintain the role of the regulatory framework (the OFPA) throughout the design and implementation of studies, including the following considerations:
    a. There are two stratum classifications:
        A. FPA regions, of which there are two - East and West of the Cascade Mountains.
        B. Landowner classifications in the FPA (of which there are two, each with a different regulatory framework for roads) – 1) small forestland owners (RCA); 2) large forestland owners (FRIA).
    b. Assessments should differentiate Type F, SSBT, and N streams, but the design need not be stratified by stream type. Additional attributes listed in Dube et al. (2010) should also be considered.
2. The AMPC wants to know how metrics of interest (e.g., sediment delivery from roads) compares with background levels.
3. Ideally, the baseline would be for the effective date for the road rules (Jan. 1, 2024); however, the AMPC recognizes that it will take time to refine and scope the research questions, decide on the research agenda, develop and then award the RFP.
4. Research should include field data.
5. When assessing effectiveness of rules, it would be helpful to understand results both individually and cumulatively.
6. This entire research question package would be very complex, long, and expensive to implement as a single research project. Thus, the AMPC would appreciate the IRST dividing up this research question package into discrete projects and developing scoping proposals (per OAR 629-603-0200(4)) for each one.

[7] OAR 629-603-0200(3)(a)(E)

Appendix B. Road rules relevant to the IRST's work on hydrologic connectivity

This document provides the rules that are relevant to the work of the Adaptive Management Program regarding hydrologic connectivity of roads, along with clarifying summaries where needed. These rules are provided to help the IRST develop a scoping proposal per OAR 629-603-0200(4)(c) in the context of the question package from the AMPC with the finalized research questions. Clarifications are added via comments. Parts of rules that are irrelevant to hydrologic connectivity have been omitted for brevity and focus.

OAR 629-625-0000 Purpose

(3) The purpose of the road construction and maintenance rules is to establish standards for locating, designing, constructing, and maintaining efficient and beneficial forest roads;…; identifying active and inactive roads that … contribute sediment to waters of the state, to correct conditions; and to vacate roads, rock pits, and quarries that are no longer needed in manners that provide the maximum practical protection to maintain forest productivity, water quality, and fish and wildlife habitat.

(4) To achieve the goals of the division, all roads will be designed, constructed, improved, maintained, or vacated to:

- (a) Prevent or minimize sediment delivery to waters of the state;
- (f) To the maximum extent practicable, hydrologically disconnect forest roads and landings from waters of the state;

OAR 629-625-0300 Road Design

(3) The department shall publish Forest Practices Technical Guidance that explains how to avoid and prevent potential impacts to fish, wildlife, habitat resources, and waters of the state, in support of the following rules:

- (g) OAR 629-625-0330(1) to explain how to implement rules to hydrologically disconnect forest roads and landings from waters of the state.

OAR 629-625-0320 Water Crossing Structures

(10) Construction of Water Crossings. In the construction of water crossings, operators shall do the following:

- (b) Runoff, Erosion and Sediment. Operators shall control runoff, erosion, and sediment through the following actions:
  - (A) Include a site-specific erosion and sediment control plan as part of a written plan prior to beginning work. This plan must include, but is not limited to:
    - (i) A site plan with a description of the methods of erosion or sediment control;

(iii) Measures to disconnect road surface and ditch water from all typed waters and lakes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, marshes, wetlands, inlets, and canals.

OAR 629-625-0330 Drainage

(1) All active, inactive, and vacated forest roads and landings shall be hydrologically disconnected to the maximum extent practicable from waters of the state to minimize sediment delivery from road runoff and reduce the potential for hydrological changes that alter the magnitude and frequency of runoff. Operators shall locate drainage structures based on the priority listed below. When there is a conflict between the requirements of sections (2) through (7) of this rule, the lowest numbered section takes precedence and the operator shall not implement the later numbered and conflicting section.

(2) Operator shall not install cross-drains and ditch-relief culverts in a way that causes stream diversion.

(3) Operators shall not concentrate road drainage water into headwalls, slide areas, high landslide hazard locations, or steep erodible fill slopes.

(4) Operators shall not divert water from stream channels into roadside ditches.

(5) Operators shall install drainage structures at approaches to stream crossings to divert road runoff from entering the stream. If placement of a single drainage structure cannot be placed in a location where it can effectively limit sediment from entering the stream, then additional drainage structures, road surfacing, controlling haul, or other site-specific measures shall be employed so that the drainage structure immediately prior to the crossing will effectively limit sediment from entering the stream. Operators may also use best management practices to manage sediment at the outflow of the drainage structure nearest to the crossing.

(6) Operators shall provide drainage when roads cross or expose springs, seeps, or wet areas.

(7) Operators shall provide a drainage system that minimizes the development of gully erosion of the road prism or slopes below the road using grade reversals, surface sloping, ditches, culverts, water bars, or any combination thereof. For new road construction, operators shall use out sloping to the maximum extent practicable when site-specific conditions allow for its safe and effective use.

OAR 629-625-0600 Road Maintenance

(1) The purpose of this rule is to protect water quality and ensure hydrologic disconnection of roads from waters of the state to the maximum extent practicable by timely maintenance of all active and inactive roads. Road surface must be maintained as necessary to:

(a) Minimize erosion of the surface and the subgrade;

(b) Minimize direct delivery of surface water to waters of the state;

(c) Minimize sediment entry to waters of the state;

(d) Direct any groundwater that is captured by the road surface onto stable portions of the forest floor;

(e) Ensure properly functioning and durable drainage features; and

(f) For existing roads with inboard ditch, avoid overcleaning of ditch lines.

OAR 629-600-0100(71) "Hydrologic disconnection" means the removal of direct routes of drainage or overland flow of road runoff to waters of the state.

Note: there is no rule-based definition of hydrologic connectivity.

Appendix C. Literature Review

For our literature review, we considered relevant measurement and monitoring methods for road-stream hydrologic connectivity (RSHC) that focused on: 1) simply the Hydrologic connection of water runoff between roads and streams; 2) sediment inputs from roads to streams; 3) runoff and sediment effects on aquatic habitats; and 4) runoff and sediment effects on aquatic species populations. Given the AMPC questions and the Dubé/Martin examples, we focused on methods for measuring or estimating Hydrologic connectivity and sediment inputs, but we also include information on a few studies and monitoring programs that include RSHC-related habitat and species metrics. Because of the overlap in methods between connectivity/sediment monitoring and habitat/population monitoring, the review has been collapsed into two corresponding sections.

Hydrologic Connectivity and Sediment Delivery Monitoring

In a forested landscape, runoff and associated chronic sedimentation are primary concerns from road-stream connectivity on aquatic species; thus, several methods have been devised to characterize these processes. Predictive models have emerged from this knowledge base and are increasingly used to estimate water and sediment inputs from roads to streams in a wide array of geologic and ecological settings (Fu et al. 2010). The literature tends to address hydrological connectivity and sediment delivery together, with the former being an element of and precursor to the latter. Martin (2009) is an exception in that only connectivity was measured.

Measuring RSHC

To characterize RSHC, roads are typically divided into segments that drain to a common point and share other related characteristics (e.g., surfacing, traffic, slope). All the efforts reviewed based their data collection and analyses on road segments, although their delineation methods varied.

Field methods

For the Dubé et al. (2010) study, Hydrologic connectivity was determined visually by field crews using a flow chart protocol (Watershed Professionals Network 2009). Six categories of connectivity were recorded in the field assessment: 1) none; 2) direct delivery; 3) 35% delivery; 4) 10% delivery sediment plume reaching or nearly reaching a stream; 5) direct via gully or from road structure; or 6) a road paralleling a stream within 20 ft. They implemented a quality assurance/quality control (QA/QC) protocol and found observer differences to be substantial, which they addressed through further training and mixing of teams. Martin (2009) did not describe RSHC determination methods, however, they are assumed to be similar to those used by Dubé et al. (2010). For modeling sediment delivery, field crews measured numerous aspects of delivering road segments, such as slope, surfacing, maintenance level, ditch conditions, cutslope conditions, and vegetation.

Several field methods have been developed to improve accuracy of estimates of sediment contributions to streams from RSHC, by directly measuring sediment outputs from road segments. These include tipping buckets, sediment traps, and visual observations of runoff turbidity (Skaugset et al. 2011). Logistics limit actual field sampling of sediment to relatively small areas. Thus, monitoring sediment delivery at the scale envisioned by AMPC has generally been done using models with various levels of field calibration.

GIS/Remote Sensing

Remote sensing and GIS analysis have been increasingly used to identify and characterize forest roads and RSHC. Given the limitations of optical imagery in dense, closed canopy forests, much of the relevant literature focuses on airborne LiDAR, which can penetrate canopy and achieve moderate-to-high 'bare earth' point density.

Several studies have tested the ability of airborne LiDAR data to map road networks and demonstrate that airborne LiDAR can be used to map road networks with high accuracy (Kardoš et al. 2024), including abandoned/deactivated roads (Beck et al. 2015; White et al. 2010). Early efforts involved manual GIS work to map road surfaces from LiDAR-derived coverages, but recent studies highlight the efficacy of automated tools for road network extraction (Even and Ngo 2021; Ferraz et al. 2016; Wiskes et al. 2023). GIS tools using LiDAR enable the quantification of road geometry, such as segment length, width, slope, cutbank height, and more, with high accuracy (Hatta Antah et al. 2021; Pradhan and Ibrahim Sameen 2020). A multitude of studies have used GIS tools to map and quantify road-stream hydrologic connectivity by using flow routing algorithms to intersect road drainage flow paths with stream layers and drainage features (Benda et al. 2019; Roelens et al. 2018). These RSHC approaches have been applied in steep as well as gentle settings and can be used to generate maps of connected road systems or revise existing maps of road-stream connectivity to inform field surveys and facilitate validation (Benda et al. 2016). GIS analysis has been shown to be effective for assessing road status (e.g., active, abandoned) and quality (e.g., structural condition, surface geometry, ditches) over relatively large areas, which greatly reduces the need for extensive field surveys (Waga et al. 2020a, 2020b).

Modeling

Numerous models have been developed to estimate runoff and sediment yield from forest roads. Two types of models are generally used: empirical and physical process-based (Elliot et al. 2009; Fu et al. 2010).

Empirical models apply relationships describing sediment production and delivery derived from research on road erosion (e.g., WARSEM [Washington Road Sediment Estimation Model, Dube et al. 2004], USLE/RUSLE [Universal Soil Loss Equation/Revised] (Dissmeyer and Foster 1980), GRAIP and GRAIP-lite [Geomorphic Road Analysis and Inventory Package] (Black et al. 2012; Cissel et al. 2012; Nelson et al. 2014). The GRAIP and most other of the empirical models predict road to stream hydrologic connectivity, sediment production and delivery to streams, downstream sediment accumulation, risks of shallow landslides caused by roads, gully initiation risk below drain points, and risks to road-stream crossings (Black et al. 2012; Cissel et al. 2012). The NW Forest Plan Aquatic and Riparian Effectiveness Monitoring Program (AREMP; Dunham et al. 2023) used the GRAIP-lite model to assess RSHC and sediment delivery. These empirical models all use similar basic inputs on road characteristics to estimate sediment production from surface erosion.

Physical process-based models simulate the finer scale subprocesses that determine runoff, such as infiltration, routing, and soil cohesion. They can use regionalized parameters for inputs and can provide estimates of sediment production from individual road segments (e.g., WEPP:Road [Water Erosion Prediction Project] (Elliot 2013), DHSVM [Distributed Hydrology Soil Vegetation Model] (Wigmosta et al. 2002), and whole watersheds (e.g., READI [Road Erosion And Delivery Index]) (Benda et al. 2019).

Tests of both types of models using field-measured sediment production show they can provide reasonable relative delivery estimates over multiple sampling locations, but that they may be inaccurate for individual locations, sometimes by large amounts (Bohle and Dubé 2015; Dubé et al. 2011; Faubion 2020; Fu et al. 2010; Skaugset et al. 2011). Calibrating the models with local sediment production data can improve the accuracy of estimates (Bohle and Dubé 2015). Despite issues with accuracy, models are useful for generating relative estimates of sediment production, which can identify road segments with the highest probability of delivering the most water and sediment to streams. Relative estimates can also be used as a proxy for measuring change in sediment inputs, for example, where efforts have been made to reduce RSHC.

Sampling Design

Spatial Sampling

For field-based studies or field-calibrated models, if the area of interest is small it may be possible to collect measurement on the complete road network (a full census). However, when field-based methods are desired over a large area selecting samples based on a predetermined design will be necessary, given costs and time constraints. Raines et al. (2005) (the pilot study for Dubé et al. 2010) considered sampling by Washington sub-basins (average area 6.26 mi^2), but rejected that idea because statewide mapping was incomplete. Instead, they opted for six square mile sample units based on aggregating quarter sections from the general land survey (Dubé et al. 2010 reduced these units to four square miles). A potential benefit was that sections were more likely to follow property lines creating efficiencies with landowner contacts. However, effects on aquatic systems may be better characterized using subwatersheds, which have been mapped at multiple spatial scales for the entire state of Oregon (https://geohub.oregon.gov/datasets/oregon-geo::12-digit-hu-subwatershed/explore).

For larger areas, it may not be necessary to sample depending on the information desired and whether accurate and comprehensive mapping is available for both roads and streams. For example, AREMP was able to model RSHC for all roads in their area of interest with the uncalibrated GRAIP-lite model based on a compilation of agency road inventories. However, the only road condition change categories available consistently included road segments that were active or decommissioned, thus limiting the detail of the results. FRIA will create another example of a census approach in which large landowners are required to conduct a complete inventory of their roads, but the information collected will be limited.

Covariates / Sampling Stratification

Road-stream hydrologic connectivity and sediment delivery have been found to be influenced by both human-caused factors (e.g., location, surfacing, traffic) and environmental factors (e.g., slope, soils, geology, rainfall patterns) (Kastridis 2020). Covariates reflecting such factors can be either explicitly integrated into the sampling design or data about these can be collected during field work and analyzed post hoc. The former increases chances that statistically-based conclusions can be generated but also increases the sample size needed for each covariate.

AMPC question 1b asks how results vary by OFPA landowner type, which are divided into large (>5,000 acres) and small landowners, and by OFPA geographic region (east/west). Dubé et al. (2010) did not stratify by ownership types but encountered challenges aggregating sufficient blocks in more fragmented non-industrial ownerships and in obtaining landowner permissions. As a result, ~95 percent of their sampled area came from industrial and state/local government owners. They also weighted their sampling by three geographic regions (Coastal/Spruce, West of Cascade Crest, East of Cascade Crest), which were based on performance targets established by these regions in prior watershed analyses. Their overall sample design considered the proportion of eligible lands within each of these zones.

Cabrera et al. (2016) stratified by more specific environmental variables, such as granitic and volcanic geologies, found significantly different base erosion rates. Sheridan et al. (2013) stratified by stream size because the same amount of sediment in a small stream has a greater potential to affect biota compared to that amount of sediment in a larger stream.

Temporal Sampling

Timing of sampling is critical for establishing baseline status and trend estimates of RSHC. Dubé et al. (2010) faced a number of related challenges, which are likely to be similar for the Oregon AMP process. First, the time it takes to get a baseline sampling effort executed is one such consideration. The original vision in Washington was to have a first sample before significant work on Road Maintenance and Abandonment Plans (RMAP) had been accomplished, a second sample mid-way through RMAP efforts, and a third sample after RMAP was completed. However, the first sample was not collected until 2006/2007, five years after the Washington road upgrade process was underway. Our Oregon effort may be able to use records from the FRIA process or landowner interviews to identify improvements made between the implantation of the new rules and our sampling date. These post-rule improved road segments could either be dropped from the sample or assumed connected for the baseline. Timing and budgetary constraints have delayed the follow up sampling to Dube et al. (2010), which was intended to show trend and efficacy. It is now scheduled to occur in 2028, well after RMAP completion in 2021 (CMER 2023).

Repeated sampling needs to match the time scale of processes of interest that are driving change. Sampling intervals that are too short may capture the effects of processes that are not relevant to answering the AMPC questions or result in redundant data collection for periods where the processes of interest are relatively static. Sampling intervals that are too long may miss important variability and delay information useful for decision making.

Assessment

Measurement and sampling choices should be driven by determining how to ultimately assess the data. The main studies we reviewed have used relatively simple metrics. For RSHC, Dubé et al. (2010) reported connected road length (both per square mile and per mile of stream), whereas for sediment, they used the WARSEM model to estimate tons of delivered sediment/year/mile of stream. Dubé et al. (2010) also used performance target ranges from prior agency work that were established from the low-medium categories of an expert rating of watersheds for aquatic risk.

The AREMP measured changes in modeled connected road length by subwatershed (HUC12). Sediment delivery values were divided by the subwatershed area to account for subwatersheds of varying size (km/km2). The sediment model was not calibrated for local geology, climate, or other influences; thus, results were interpreted as relative.

FRIA will simply report on road length in each of their categories, transitioning from “not meeting” to “meeting” standards. The ODF Compliance Monitoring Program will also be assessing road conditions on randomly sampled sites; metrics are currently under discussion, however, no measure of RSHC is included at this point.

Studies have generally found that a relatively small percentage of the road network (1%–25%) is hydrologically connected to streams (Benda et al. 2019; Coe 2006; Dubé et al. 2010; Faubion 2020; Martin 2009).

Habitat and Population Monitoring

The Oregon FPR HCP is designed to minimize and mitigate take of the species of concern through the provision of adequate habitat. Studies linking particular habitat attributes and the effects on aquatic and riparian species are too numerous to discuss here. More relevant to this effort are monitoring and assessment programs that have been developed based on habitat-species links. A few ongoing state and federal government programs monitor aquatic habitat indicators and/or species populations in the northwestern United States. Through the Aquatic Inventories Program (AQI), the Oregon Department of Fish and Wildlife (ODFW) has been collecting aquatic and riparian habitat data for 27 years in westside wadeable streams (ODFW 2019, 2025). Aquatic and riparian monitoring has also been occurring on federal lands on the east (PIBO 2025; Roper et al. 2019) and west (AREMP 2025; Dunham et al. 2023) sides of the state.

Measurement

ODFW's AQI collects information on culverts and substrate particle size by 6 classes (including fines). They also conduct fish population surveys for juvenile and spawning salmonids. The AREMP and PIBO tested aquatic organism surveys but found that their sampling intensity was not sufficient to reliably detect changes. AREMP/PIBO habitat metrics most closely related to RSHC effects include pool-tail crest fines and the distribution of substrate particle sizes along stream bed transects.

Spatial and Temporal Sampling Design

All three programs (ODFW, PIBO, AREMP) use a rotating panel design to balance the benefits of having more sites (better for status assessments) with repeat visits to sites (better for trend assessment). ODFW uses four panels with different repeat intervals: annual, 3-year, 9-year, and sites that are only visited once. The sites are selected from 1st–3rd order streams on a 1:100,000-scale map as stratified by five monitoring areas. The sample size is large enough to allow post hoc analyses by ownership class. AREMP uses a hierarchical random sample based first on HUC12 subwatersheds, then on sites within them selected from the 1:100,000 NHD streams layer. The original plan was to sample 50 subwatersheds per year on a five-year repeating cycle. Financial and logistical constraints have pushed the repeat cycle to eight years. Identifying more watersheds and sites initially was important because sites had to be delayed or dropped due to fires and other unanticipated circumstances. On the eastside of the Cascade crest, the PIBO program also samples a randomly selected subset of HUC12s on a repeating cycle but only samples at one location at the lowest point in the stream network on federal land.

Assessment

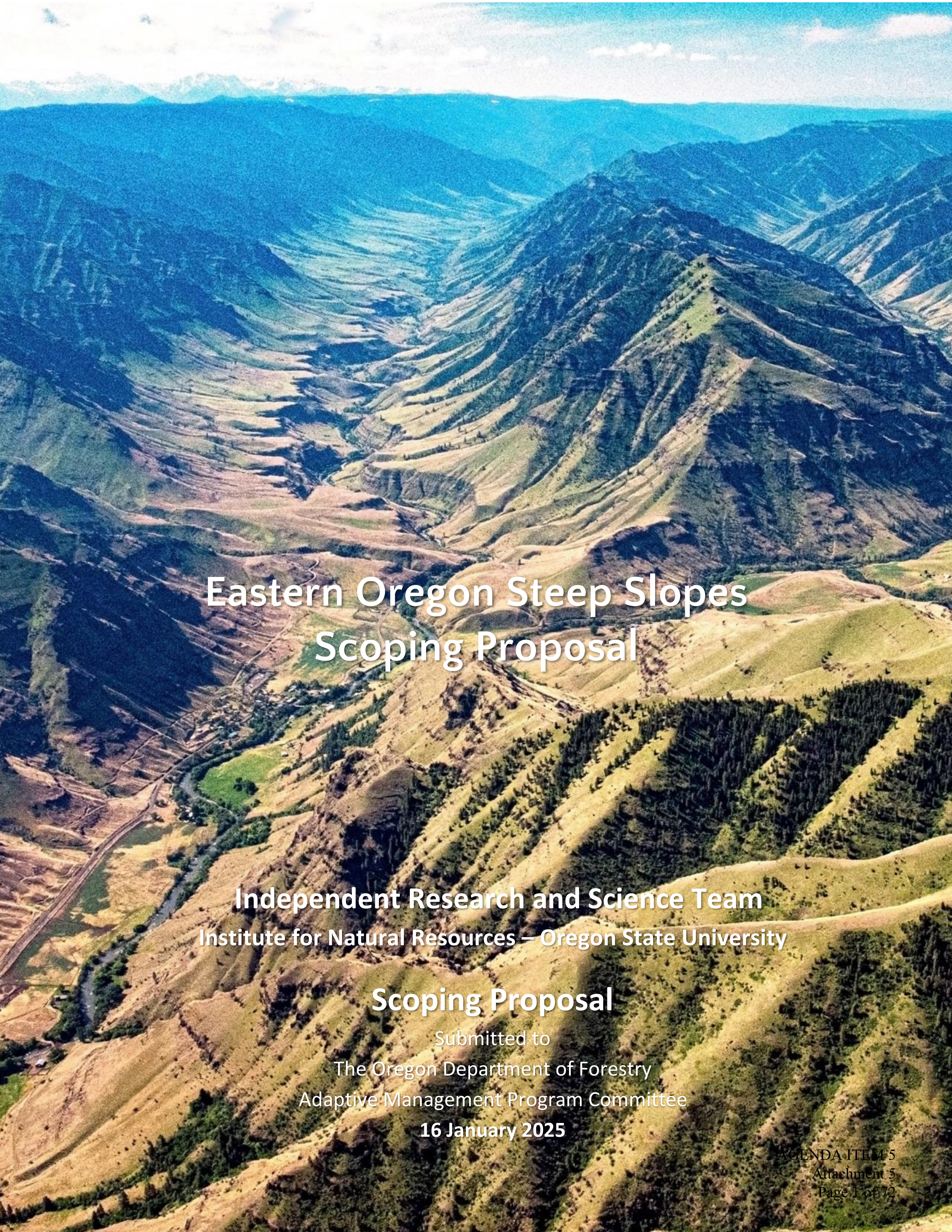
Using linear statistical models, the ODFW (2019) analyzed the first 12 years of ODFW habitat data and generally found no trends for fine sediment in riffles; however, positive or negative trends were observed in other habitat variables. Twelve years is a relatively short time period to expect such changes.

In a study examining only the first five years of data, Anlauf-Dunn and Jones (2012) compared distributions of habitat values to minimally-disturbed reference conditions and found median fine sediment values at or above reference thresholds, whereas coarser gravel values were below reference.

A study by Al-Chokhachy et al. (2016) tested for a linkage between sediment delivery predicted by the GRAIP model with PIBO instream sediment data. Although they found a positive relationship, it was highly variable across sites, which they attributed to differences in topography, geology, and other human-caused sources (off road vehicle trails, cattle grazing, forest management). In their associated literature review, they found only eight studies that attempted to link streambed fine sediment to road measures and only one that found a strong (but again variable) relationship. Similarly, whereas (Dunham et al. 2023) found declines in active road miles over 25 years, along with declines in modeled connectivity/sediment, and instream fine sediment, they cautioned against expecting high correlation given the variety of factors that can influence in-channel sediment.

Summary

A summary of the key takeaways from this review is provided in the Literature Review section in the main body of the document.



Eastern Oregon Steep Slopes Scoping Proposal

Independent Research and Science Team

Institute for Natural Resources – Oregon State University

Scoping Proposal

Submitted to

The Oregon Department of Forestry

Adaptive Management Program Committee

16 January 2025

Eastern Oregon Steep Slopes: Scoping Proposal

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Authors

The Independent Research and Science Team

Prepared by

The Institute for Natural Resources

The Institute for Natural Resources' mission is to provide access to integrated, management-relevant information that informs discussions and decisions about the long-term stewardship of Oregon's natural resources. Institute for Natural Resources is an Oregon public universities institute located at Oregon State University and Portland State University.

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Photo by Ellen Bishop, IRST Member

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Disclaimer

This scoping proposal is submitted to the Adaptive Management Program Committee as a requirement of the Oregon Department of Forestry Adaptive Management Program rules (Chapter 629, Division 603).

The contents of this report reflect the views of the Independent Research and Science Team (IRST), which is solely responsible for the facts and accuracy of the material presented. This scoping proposal does not constitute a standard, specification, or regulation.

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Tables and Figures

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Abbreviations and Acronyms

AMPC	Adaptive Management Program Committee
BGO	Biological, Goals, and Objectives
CEE	Collaboration for Environmental Evidence
CMER	Washington State's Cooperative Monitoring, Evaluation, and Research Committee
EMC	California's Effectiveness Monitoring Committee
HCP	Habitat Conservation Plan
INR	Institute for Natural Resources
IRST	Independent Research and Science Team
OSU	Oregon State University
PFA	Private Forest Accord
ROSES	RepOrting standards for Systematic Evidence Syntheses

Executive Summary

The Independent Research and Science Team (IRST) was established to support the work of the Oregon Department of Forestry Adaptive Management Program Committee (AMPC) by responding to AMPC-developed research question packages. The AMPC-submitted research questions pertaining to steep slopes in eastern Oregon are:

Overarching Question: What impact do hillslope processes have on the covered species included in the draft HCP and their habitats in Eastern Oregon?

- Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments?
- Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Only those amphibians and fish species identified in Section 1.4 of the Private Forest Accord (PFA) Report (2022) are considered "covered species," as defined for use in developing a Habitat Conservation Plan (HCP) consistent with USFWS and NMFS (2016), and thus are relevant to the overarching question. Road impacts on shallow rapid slides were not considered for the primary and secondary focus questions. Similarly, other hillslope processes unrelated to mass wasting were excluded for the secondary focus question.

The IRST was asked to prepare a research scoping proposal framing how these questions could be addressed using literature reviews, which would assess the robustness of conclusions based on the literature and identify key gaps that may prompt the need for additional research. Through the Institute for Natural Resources (INR) – the housing agency of the IRST – the IRST conducted a scoping review to characterize the potential amount and nature of the existing scientific literature. It was intended, not as a comprehensive literature review, but as a necessary first step to support the development of a research proposal package that will inform the AMPC and Board of Forestry decisions about the utility of soliciting a further literature review or research via requests for proposals.

Traditional searches considered 45 documents from two document repositories, two documents contributed from IRST members, several documents found through the Google search engine, and citations within these. Seven predetermined searches were performed across three electronic literature database sources. Of the thousands of documents retrieved through searches for the scoping review, 39 documents were found to have potential relevance to the research questions.

Primary Focus. Twenty of the 39 documents were deemed potentially relevant to the primary focus question and included content on hillslope processes, specifically shallow rapid slides; three of these documents were studies focused in eastern Oregon and two additional documents were focused in eastern Washington.

Secondary Focus. Four of the 39 documents, none of which targeted eastern Oregon or Washington, were deemed potentially relevant to the secondary focus question and included content on mass wasting processes apart from shallow rapid landslides, such as deep-seated earthflows, slumping, and soil bulking debris flows. One document included mention of aquatic species and fire. All four were also identified as potentially relevant to the primary focus question.

Of the 39 documents, 19 were identified as potentially relevant to hillslope processes related to mass wasting on forested lands in semi-arid environments but did not explicitly include forest harvest-related practices.

The scoping review yielded insights on the literature review process and content that could be valuable for the AMPC when considering future work and for those designing and conducting that work. Insights on content are summarized here:

1) The approach used to search and review the literature identified few documents that directly addressed the research questions, and only Fitzgerald and Clifton (1997) explicitly examined mass wasting in eastern Oregon.
2) Many of the potentially relevant documents reported mass wasting in northeastern Oregon, southeastern Washington, and Idaho following an intense storm event in February 1996.
3) Landslide inventories generally indicated that fewer landslides and debris flows occur in arid and semi-arid environments east of the Cascade Mountain Crest compared to west of the Crest.
4) Although not well characterized in the literature for eastern Oregon, the factors there associated with the initiation and runout of shallow rapid slides and other mass wasting processes appear similar to those in western Oregon. These factors include slope steepness and heavy precipitation.
5) The effects of changing climate and weather patterns on precipitation events and thus mass wasting in eastern Oregon are unclear but may be important for evaluating landslide susceptibility and risk to covered species. Halofsky and Peterson (2017) report that climate change impacts to precipitation, plant communities, and wildfires in eastern Oregon may contribute to increasing mass movement susceptibility.
6) Shallow rapid landslides were associated with timber harvest in environments similar to eastern Oregon. However, the influence of timber harvesting on landslide and debris flow characteristics (e.g., number, size, runout distance) in semi-arid environments is less well studied and understood than in westside forests.
7) Watershed analyses in eastern Washington, Idaho, and western Montana included landslide inventories and explicitly examined the role of forest management on landslides. These landslide inventories may be a source of information to address the research questions if a future review occurs.
8) The impacts of debris flows and other hillslope processes on habitat characteristics or their influence on demographics and persistence of covered amphibian and fish species in eastern Oregon has not been researched extensively. Limited studies identified in the scoping review examined changes to in-stream habitat conditions following mass wasting events. Other studies from semi-arid regions broadly infer habitat responses to changes in sediment levels related to climate change, forest management practices, and in particular the frequency, extent and severity of wildfires (e.g., Goode et al. 2012, Halofsky et al. 2017, Luce et al. 2012). The eastside watershed analyses may contain information on fish habitat as related to mass wasting, but this has not yet been explored.

Based on the results of this scoping review, four options are presented to address the AMPC research questions: (1) a full systematic mapping review following the Collaboration for Environmental Evidence

(CEE) process; (2) a more rapid systematic mapping review following the corresponding CEE advice; (3) a standard but less rigorous descriptive review; and, (4) no further searching or literature review. The four options differ in time required, costs, and knowledge contributions. However, the knowledge contributed from each of the first three options in Table I should sufficiently characterize the state of science and gaps in understanding to help inform policy discussions regarding steep slopes in eastern Oregon.

Table ES-1. Summary of scoping proposal options timeframes, costs, (excluding indirect costs and administrative startup and closeout time), and knowledge contributions.

Option	Timeframe	Cost	Knowledge Contribution
Full systematic map	12–18 mo.	$50,000-$100,000	Extracts data from reviewed documents to support quantitative and narrative synthesis about the state of and important gaps in knowledge regarding eastern Oregon steep slopes. Compiles any existing empirical databases for future use. Further describe differences between eastern and western Oregon in the drivers of mass wasting processes and what is known about covered species habitat vulnerabilities in eastern Oregon.
Rapid systematic map	4–8 mo.	$20,000-$50,000	Extracts data from reviewed documents to support quantitative and narrative synthesis about the state of and important gaps in knowledge regarding eastern Oregon steep slopes. This may exclude some of the gray literature, especially older studies or those from other states. The search and review process would still be well documented for transparency and replicability but relying only on one or two reviewers without consistency checking could increase bias.
Descriptive review	3–6 mo.	$15,000-$30,000	Provides a reasonable collation of the literature on steep slopes in eastern Oregon based primarily on peer-reviewed literature. It is unlikely to capture much of the gray literature, especially older studies or those from other states. The searching, screening and review methods would not be as thoroughly documented, so would be less transparent and replicable. A narrative synthesis of findings would result but would be more limited than for the rapid systematic mapping option.
No further searching or review	0 mo.	N/A	Provides only the characterization and summary of the literature garnered from this scoping effort (Section 2.5 Content Insights, Appendices B, C, and D) and does not identify knowledge gaps. The search for literature conducted for this scoping review was not exhaustive and was not intended to be a full synthesis of existing information relative to the research questions.

1. Introduction

1.1 Background and Project Purpose

The Independent Research and Science Team (IRST) was established via Senate Bill 1501 as part of the Oregon Department of Forestry's Adaptive Management Program. The IRST supports the work of the Adaptive Management Program Committee (AMPC) by responding to AMPC-developed research questions packages. Per rule, and in consultation with the AMPC, the IRST refines preliminary research questions into final research questions, then develops scoping proposal(s) to address those questions. The scoping proposal(s) need(s) to include:

- A literature review that specifies the need for, or the type of, monitoring, research, commissioned studies, or other means of scientific inquiry necessary to answer the finalized research questions mentioned above;
- A preliminary estimate of the budget for each year of the research, and a timeline to complete the research project with specific deliverables; and,
- A preliminary description of research project requirements, scope of work including an estimate of the timeline and key milestones, and an estimate of the degree to which knowledge may be improved if the research proposal is implemented.

As per OAR 629-603-0200, the IRST develops requests for proposals (RFP) in an open, competitive process after the AMPC and Board of Forestry approve an AMPC research agenda that is based on IRST scoping proposal(s). See Figure 1.

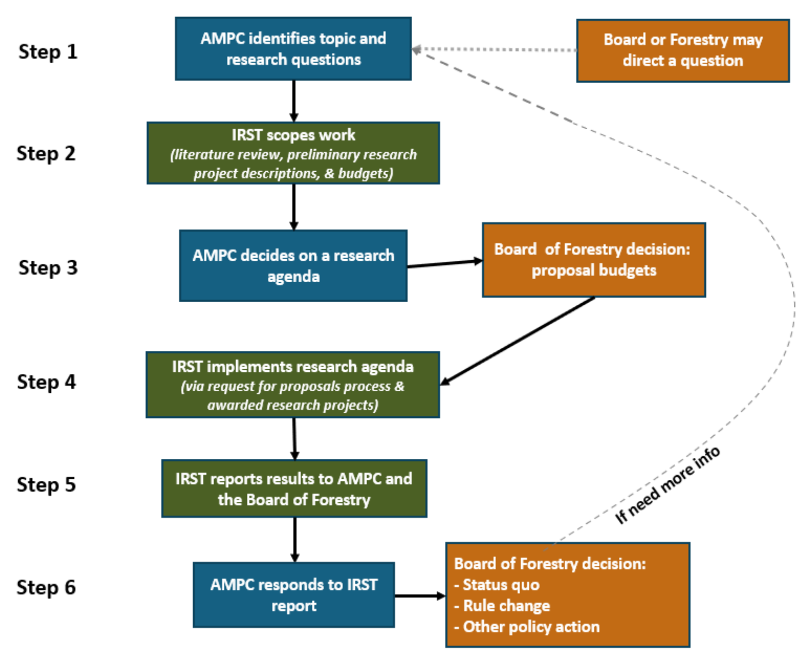

Figure 1. Adaptive Management Process.

With these requirements, the purpose of this effort was to conduct a scoping review that provides an initial characterization of the potential amount and nature of existing literature in relation to the AMPC research questions (see Section 1.2) and to determine if there is enough to warrant a full literature review through the required RFP process.

1.2 Research Questions

On July 11, 2024, the AMPC submitted the research questions package (Appendix A) pertaining to the geographic region [1] of Eastern Oregon. The IRST was asked to address the questions using literature reviews, assess the robustness of conclusions based on the literature, and identify key gaps that may prompt the need for additional research.

Overarching Question: What impacts do hillslope processes have on the covered species in the draft HCP and their habitats in Eastern Oregon?

- Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments?
- Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

1.3 Types of Literature Reviews

Literature reviews may differ based on their objectives and the rigor of approach used to search for documents, to screen found documents for relevance to review objectives, and to summarize content in the relevant documents. The search approach is foundational to any review, and so it is highlighted here.

Searches may aim to be comprehensive, attempting to identify every document relevant to the review objectives, but more often strive to balance sensitivity and precision. Precise or focused searches may retrieve fewer irrelevant results but have a higher risk of missing relevant documents and so can be less comprehensive. Sensitive or broad searches typically retrieve more documents but may require greater effort in evaluating which are relevant to the review objectives. When searching electronic databases, the greater the number of search terms linked with “AND,” the more precise and fewer results. Conversely, the more terms or synonyms linked with “OR,” the greater the sensitivity and number of results returned.

Searches are rarely comprehensive, and so searchers will introduce some level of bias when locating documents for review. To help reduce the potential for bias, a “predetermined” search approach identifies beforehand the sources (e.g., electronic databases, agency archives, or program repositories) to be searched as well as the search terms and how these are linked when searching those sources. A predetermined search approach aims to be transparent and reproducible. In contrast, a “traditional” search approach is iterative - the document sources and search terms may evolve during the search. For example, citations in an initial set of potentially relevant documents can be considered to reveal other potentially relevant documents, those documents are located, their citations considered, and the process of “citation

[1] Note: The Oregon Department of Forestry maintains a regulatory Geographic Information Systems layer of the Forest Practices Act delineation between eastern and western Oregon.

mining" is repeated until the reviewer decides to stop searching. Traditional searches may proceed until no or few new relevant documents are found.

Characteristics of the review types most pertinent to preparing this scoping proposal or providing useful context are briefly described here. Unless otherwise noted, much of the text below is summarized from the National Library of Medicine (2017).

Scoping reviews, such as the one conducted for this scoping proposal (Section 2), provide an initial assessment of the existing literature to answer a question or set of questions on an emergent topic. These are intended to broadly characterize the amount and types of studies available to help determine the value of undertaking a more comprehensive literature review and/or identify research gaps (Paré et al. 2015). Scoping reviews may use both predetermined and traditional search approaches and often consider peer-reviewed publications along with non-peer reviewed "gray" literature, such as working papers, technical reports, and conference proceedings. Consistent with their main objective, scoping reviews usually conclude by presenting an agenda or options for future work.

Narrative reviews are mainly descriptive, focusing on a subset of studies in an area chosen based on availability or author selection rather than predetermined searching and screening criteria as with the other types of review. A narrative review summarizes or synthesizes what has been written on a particular topic but does not seek generalization or cumulative knowledge from what is reviewed. Such reviews are common in the introduction section of peer-reviewed journal articles.

Descriptive Reviews determine the extent to which a body of knowledge on a particular topic reveals any interpretable patterns or trends. Descriptive reviews typically provide only a qualitative, narrative summary of the relevant literature, as illustrated in "Literature Review: Effects of Salvage Logging on Riparian Zones in Coniferous Forests of Eastern Washington and Adjacent Regions" (Barrett and Reilly 2017). Although descriptive reviews may apply predetermined strategies for searching and screening documents, these exclude a critical appraisal of study methods for quality.

Systematic reviews are designed to answer a clearly formulated and often narrow question on a well-researched topic and seek to identify causation or the effectiveness of a specific intervention. These reviews aggregate and synthesize all results from similar studies in the primary literature. Two of the better-known systematic literature review protocols developed for the field of environmental management are the Collaboration for Environmental Evidence (CEE 2022) and the RepOrting standards for Systematic Evidence Syntheses (ROSES, Haddaway et al. 2018). These build on methods developed to enhance objectivity and rigor when searching and synthesizing results in clinical medicine (e.g., Page et al. 2021; Higgins et al. 2024). The critical appraisal of study methods is a hallmark of systematic reviews. This is essential for any systematic review that includes a meta-analysis, whereby data from the reviewed studies are statistically summarized into a single quantitative estimate of effect size (CCE 2022).

Systematic maps retain many of the methodological requirements and benefits of systematic reviews but offer greater flexibility (Haddaway et al. 2016). For example, systematic maps are useful for addressing a wider array of questions, can include more types of studies (e.g., primary, secondary, quantitative, or qualitative), and are intended to identify knowledge gaps. These reviews are appropriate for synthesizing broad areas of science that have not been extensively studied and are prompted by open-framed questions, such as the primary and secondary focus questions in Section 1.2.

Rapid reviews accelerate "the process of conducting a traditional systematic review through streamlining or omitting a variety of methods to produce evidence in a resource-efficient manner (Smela et al 2023)." Similar time-saving modifications can be applied to systematic maps. Although it may increase bias, one of the more common modifications is to use only one reviewer, rather than multiple independent reviewers. Limiting the number of sources searched can also help accelerate the process but may return fewer publications, posing concerns about the reliability and validity of the results. Less or no effort can be expended in the critical appraisal of study validity, however lower quality studies with less reliable findings may be included that influence conclusions drawn from evidence synthesis. The Oregon Department of Forestry recently conducted a rapid review. Its purpose was "to determine whether the post-catastrophic event alternative vegetation retention prescriptions described in Oregon Administrative Rules (OAR) 629-643-0300(3) are effective in avoiding, minimizing, or mitigating effects on riparian areas and aquatic habitat" (Thompson et al. 2024). Their review, with a few departures, generally followed CEE protocol.

2. Scoping Literature Review

2.1 Introduction

This scoping literature review, as the first step in developing the eastern Oregon steep slopes proposal, was undertaken to help determine the value of conducting a more in-depth review. It is intended to serve, not as a comprehensive literature review, but rather to understand if literature might be available to support the development of a research proposal package and help the AMPC determine the next steps in investing resources. Unless future research questions from the AMPC specifically request answers through a review of the literature, a narrative review, in lieu of a scoping review, will likely be sufficient to support the associated scoping proposal for those questions and meet rule requirements (OAR 629-603-0200).

This scoping review does not directly address the broad, overarching question in Section 1.2. Instead, for the primary focus question, the scoping review provides a preliminary indication of the existing scientific research available that could potentially determine if shallow rapid slides are prevalent enough to be an important driver of riparian and stream habitats in eastern Oregon and if forest harvest is likely to influence characteristics (e.g., initiation rate, size, runout distance) of these slides. The scoping review uses a similar approach for the secondary focus question but considers other potentially important mass wasting processes and the influence of forest harvesting on those processes. Consistent with Appendix A, Section 3.3.8 from the Private Forest Accord Report (2022), the only hillslope processes considered for the secondary focus question are related to mass wasting.

2.3 Methods

This scoping review used a three-step process. Step one was finding the potentially relevant literature, step two was screening the found literature to determine relevance, and step three was a simple data extraction and summarization of articles that were deemed potentially relevant to the research questions.

Approaches to finding potentially relevant literature

Two search approaches (traditional and predetermined) were used to find potentially relevant literature for the scoping review.

Traditional search approach

Documents were obtained by soliciting the IRST, examining repositories of two related programs (Washington State's Cooperative Monitoring, Evaluation, and Research Committee (CMER) and California's Effectiveness Monitoring Committee (EMC)), and using the Google search engine. Consistent with the iterative process described in Section 1.3 for traditional searches, citations in potentially relevant documents were also considered (citation mining) to identify additional material not found in initial searches.

For the Google search, the search terms "debris flows", "landslides", "mass wasting", "semi-arid", "steep slopes", "hillslopes," "forest practices", "forest management", "lumbering", and "timber harvest" were input in combination with: a) individual names of four mountain ranges in eastern Oregon (specifically, Ochocos, Blue, Wallowa, and Strawberry); b) individual western state names of Idaho, Montana, Washington, Oregon, Utah, Colorado, and Wyoming; and, c) individual eastern Oregon national forests (specifically, Wallowa-Whitman, Deschutes, Malheur, Ochoco, and Umatilla). Not all eastern Oregon mountain ranges, federal lands, or national forests were included in this search effort.

Predetermined search approach

With input and revisions from the IRST, INR developed the predetermined search approach. This included specifying document sources, search terms, how search terms were linked, and how many articles to screen from each search. Searching took place from September to December 2024. Sources of potentially relevant documents were three electronic literature databases: Web of Science, Google Scholar, and the OSU Scholars Archive. The core topic areas and search terms in Table 1 were derived from the two research questions (Section 1.2).

Table 1. Core topic areas and terms used in the predetermined searches to find documents with potential relevance to the research questions.

Core Topic Area	Search Terms
Hillslope processes-mass wasting	mass wasting, "debris flow", landslid*, landslide, "debris slide", "hillslope process"
Environmental similarity to eastern Oregon	semi-arid, east, eastern, eastside, "eastern Oregon", Oregon, "eastern Washington", Washington, Idaho, Montana, Wyoming, Colorado, Utah, Nevada, Oregon, California, "British Columbia", OR "Sierra Nevada" OR Alberta
Forest harvest-related activities	forest
HCP covered species and their habitats	*(No specific terms were searched for, rather this topic was used in the review)*

* *The asterisk is a search operator available in some databases, it finds any words that begin with the preceding characters, e.g. landslid* finds landslide, landsliding, etc.*

Because few documents that directly addressed eastern Oregon were found in preliminary searches, search terms were broadened to include other western states with environments similar to eastern Oregon (Table 1). Search terms were linked in searches using Boolean operators. Examples include: forest AND hillslope AND (arid OR semi-arid OR dry), hillslope AND (trout OR salmon OR salamander) AND (eastern AND (Oregon OR Washington)). Given guidance in the PFA Report (Appendix A), search terms related to "roads" as a forest harvest-related activity were not considered.

For the predetermined searches, the first 20 results from each search were selected to be screened. If there were fewer than 20 search results, all were selected for screening.

Screening of the traditional and predetermined search results to assess potential relevance

Consistent with the *Standards for Best Available Science: A Guidance Document* produced by the IRST, documents were screened to assess potential relevance between the study subject matter and the primary and secondary focus questions. Potential relevance of the documents selected for screening was assessed by reading the abstracts or introductions and searching within each document for keywords that we identified for each topic area (Table 2).

Table 2. Core topic areas considered as inclusion criteria and related keywords for determining potential relevance to a research question as part of the screening process.

Core Topic Area (Inclusion Criteria)	Related Keywords
Hillslope processes-mass wasting	shallow rapid slides/landslides, landslides, debris flows, mass wasting, hillslope failure, slope stability, soil bulking, geologic mapping, geologic-mapped landslides, landslides with geologic map
Environmental similarity to eastern Oregon	semi-arid systems, arid systems, dry-side, arid environments, snow-dominated systems
Forest harvest-related activities	timber harvesting, harvest, clear cutting, thinning, fuel treatment
HCP covered species and their habitats	aquatic & riparian biota, cutthroat trout, bull trout, rainbow trout, salmonids, salmon, Torrent salamander, Giant salamander

The first three core topic areas in Table 2 were essential inclusion criteria when determining whether a document had potential relevance overall to a focus question. The fourth core topic area ("HCP covered species and their habitats") was not considered essential because studies meeting the other criteria could be connected to species impacts via the processes described in the draft HCP biological goals and objectives (Appendix A, Section B.2). The screening determined whether a document was potentially relevant but not the degree of relevance to a focus question.

Data extraction

For documents determined to be potentially relevant, the reference was entered into an Excel spreadsheet, along with a Yes/No indication for each of the screening criteria and whether content was relevant to the primary focus question (includes shallow rapid slides) or secondary focus question (includes other hillslope mass wasting processes). The general geographic location and text clips of the potentially relevant content were also recorded. These data were used to generate document counts by various categories.

2.4 Findings

General characterization of the potentially relevant literature

This scoping review provided an indication of the size, nature, and relevance of the existing literature with potential application to the primary focus and the secondary focus research questions from AMPC (Table 3). Seven predetermined searches were performed across the three electronic literature database sources. Regarding the traditional searches, 45 documents from the two document repositories, two documents contributed from IRST members, several documents returned from searching Google, and citations within these were screened.

Table 3. Results from traditional and predetermined searches performed to address the research questions

Source	Search Terms Strings	Total Articles	Articles Screened	Q1 Relevant Articles	Q2 Relevant Articles	Process Relevant[2]
Google Scholar	mass wasting OR "debris flow" forest semi-arid	7,170	20	1	0	1
	landslide forest Idaho OR Montana OR Wyoming OR Colorado OR Utah OR Nevada	41,200	20	3	1	3
	landslide forest "eastern Oregon" OR "eastern Washington"	4,280	20	2	0	0
Web of Science	(landslid* OR "debris flow") AND (Oregon OR Washington OR California OR "British Columbia") AND (east OR eastern OR eastside) AND forest*	10	10	0	0	0
	(landslid* OR "debris flow") AND (Idaho OR Montana OR Wyoming OR Colorado OR Utah OR Nevada OR "Sierra Nevada" OR Alberta) AND forest*	31	20	1	0	4
OSU ScholarsArchive	forest AND (landslide OR "mass wasting" OR "debris flow" OR "debris slide" OR "hillslope process")	1	1	0	0	0
	landslide OR "mass wasting" OR "debris flow" OR "debris slide" OR "hillslope process"	5	5	0	0	0
CA BoF EMC	[reviewed projects list on website]	18	18	0	0	0
WA CMER	[reviewed publications list on website]	27	27	1	0	0
Google Search + Citation Mining	[various – see section 2.3 Methods]	NA†	NA†	10	3	11
IRST Contributions		2	2	2	0	0
Totals			141	20	4	19

** The asterisk is a search operator available in some databases, it finds any words that begin with the preceding characters, e.g. landslid* finds landslide, landsliding, etc.*
† NA means that the information is not available.

Types of documents found and reviewed included peer-reviewed journal articles, dissertations and theses, government office or agency reports, technical reports, conference proceedings, and book chapters. Some of the potentially relevant documents were produced outside of traditional commercial, academic, or publishing channels, and may not be peer-reviewed. Examples include working papers, technical reports, conference proceedings, or oral presentations.

Although searches returned thousands of documents, few were screened - either by design in the predetermined searches or because most in the traditional searches had little relevance to the review questions. Of the 141 documents screened from the predetermined searches, the two repositories, and IRST contributions along with an uncounted number identified from the Google search and citation mining, 39 documents passed the screening and had potential relevance to the research questions (Table 3). Twenty documents were potentially relevant to the primary focus research question, four of which were

[2] "Process relevant" articles are not referenced in the body of the report; however, they are in the references (Section 4) indicated by the authors' names being in red italic font. Abstracts or summaries of these articles appear in Appendix D.

also potentially relevant to the secondary focus question, and 19 other documents were potentially relevant to mass wasting processes on forested lands but did not address forest harvest-related activities. Forest harvest-related topics included skid trails, logging with ground-based equipment and cable yarding, fuel treatments, stand density management, regeneration, preventing damage from disturbance, clearcutting, and harvest methods.

Of the 39 potentially relevant documents, 74% were published between 2001 and 2024 (Figure 2), indicating an increasing interest over time in the effects of forest harvest-related activities on mass wasting processes in semi-arid environments.

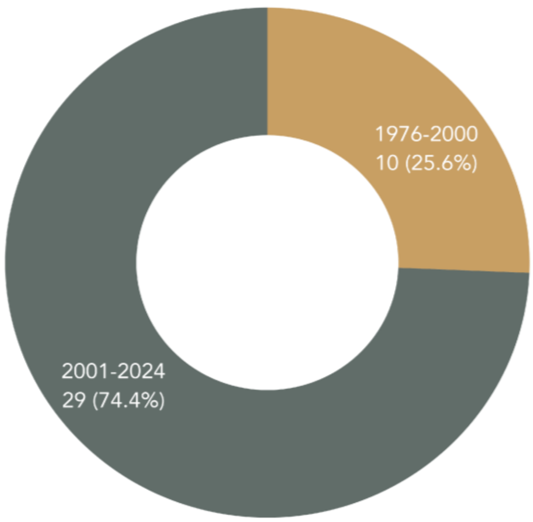

Figure 2. Number and percent of potentially relevant documents by publication year.

Whereas the traditional and predetermined searches focused on western states, the majority of potentially relevant documents were obtained from studies in Idaho (Figure 3). Only three documents were found from studies in eastern Oregon (Figure 3 and Table 4).

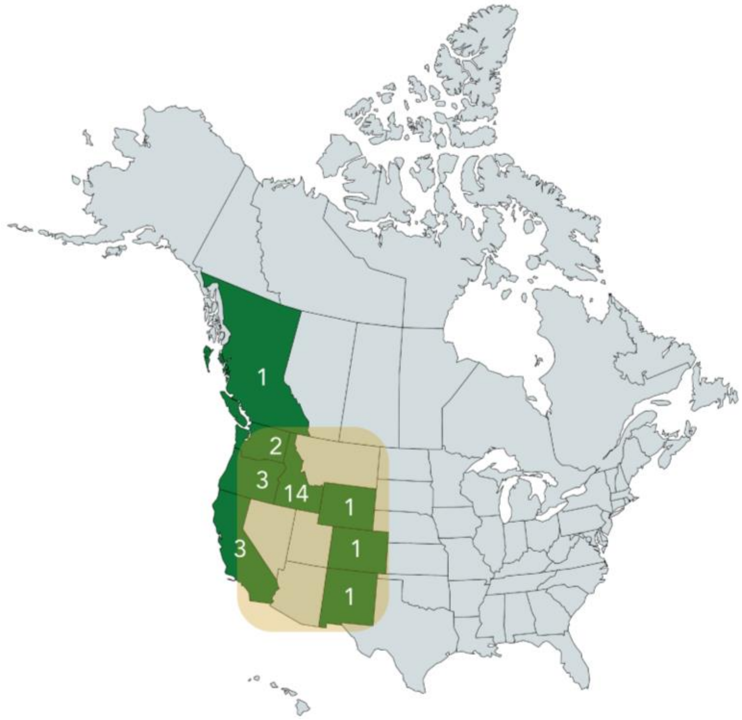

Figure 3. Locations of 39 potentially relevant studies identified in the scoping review. The 9 states and provinces yielding potentially relevant documents are shown in green. In addition, 12 documents were described simply as representing studies in the western United States (depicted by tan box), and one study included numerous locations not specific to any state, province, or region.

Table 4. The three potentially relevant documents that met the first three inclusion criteria (Table 2) and were located in eastern Oregon.

Fitzgerald, J., and C. Clifton 1997. Flooding, land use, and watershed response in the Blue Mountains of northeastern Oregon and southeastern Washington. In: Inland Northwest Water Resources Conference, Program and abstracts. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5208929.pdf
Halofsky, J.E., and D.L. Peterson. 2017. Climate change vulnerability and adaptation in the Blue Mountains region. Pacific Northwest Research Station General Technical Report, PNW-GTR-939. 331 p. https://doi.org/10.2737/PNW-GTR-939
Wondzell, S.M. 2001. The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of eastern Oregon and Washington. *Northwest Science* 75:128-140. https://rex.libraries.wsu.edu/esploro/outputs/journalArticle/The-influence-of-forest-health-and/99900501658801842

In assessing potential relevance to core topic areas, all 39 documents contained the core topic of mass-wasting related hillslope processes. Aquatic species were least well represented in the potentially relevant documents (Figure 4).

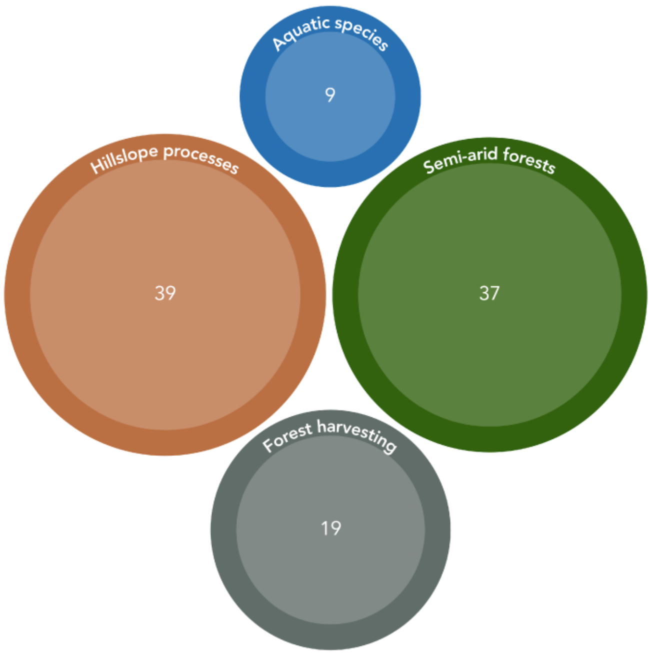

Figure 4. Distribution of the 39 potentially relevant studies in the scoping review by core topic area in Table 2.

Characterizing the publications in relation to the AMPC questions

Primary focus: What literature exists relating to upslope initiated shallow rapid slides and how timber harvesting may impact these in eastern Oregon environments?

Of the 39 potentially relevant documents, the 20 presented in Table 5 were deemed potentially relevant to the primary focus question and included content on hillslope processes, specifically shallow rapid slides. Three of these documents were studies focused in eastern Oregon, and two additional documents were from studies in eastern Washington. As previously noted, screening determined whether a document was potentially relevant but not the degree of relevance. Regarding the primary focus question for example, McGreer et al. (1998) and McClelland et al. (1997) associated timber harvest with mass wasting events using data from empirical studies, whereas Wondzell (2001) inferred the association based on westside literature.

Abstracts of the potentially relevant literature are provided in Appendix B.

Table 5. Documents potentially relevant to the primary focus research question.

Publication		Location	Forest harvest-related activities	Hillslope processes-mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Fitzgerald and Clifton (1997)		Eastern Oregon				
Halofsky and Peterson (2017)*						
Wondzell (2001)						
Harp et al. (1996)		Eastern Washington				
Klock and Helvey (1976)*						
Gorsveski et al. (2006)		Idaho				
Istanbulluoglu et al. (2004)*						
Ketcheson et al. (1999)						
Lineback Gritzner et al. (2001)						
McClelland et al. (1999)*						
Megahan et al. (1978)						
Platts et al. (1989)						
Goode et al. (2012)*		Western U.S.				
Herrera Environmental Consultants (2004)						
Luce et al. (2012)*						
McGreer et al. (1998)						
Peterson et al. (2009)*						
Wondzell and King (2003)*						
Jordan et al. (2010)		British Columbia				
Sidle (2005)		Various				

** Denotes a document that includes wildfire effects.*

Eight documents included content on wildfire and are highlighted in Table 5 because these provide insights into hillslope processes and mass wasting, with potential consequences for aquatic habitats and/or species.

The six documents that included content on aquatic species are briefly described here:

- Halofsky and Peterson (2017), in a climate change vulnerability assessment for three national forests in the Blue Mountain region, suggested that landslides and debris flows following wildfires are an issue in this area of eastern Oregon. They do not specifically link forest harvesting to mass wasting processes, but they do mention the potential for climate change to affect mass wasting impacts on aquatic species and recommend the need for debris flow / landslide hazard mapping as part of post-fire response approaches.
- Luce et al. (2012) described the nexus among physical processes, biological interactions, and management decisions as well as potential interactions of fish populations with wildfire.
- McClelland et al. (1997) investigated the extent of mass wasting in the Blue Mountains of eastern Washington after a severe rainfall event in 1996. They described the relative abundance and volume of sediment delivered by landslides and debris flows associated with natural areas (no management), roads, and timber harvest, and described "aquatic habitat parameters" that either degraded, were unchanged, or improved because of flooding or flooding with landslide sediment.

- McGreer et al. (1998) summarized results of mass wasting analyses for 23 watersheds in forested areas of eastern Washington, Idaho, and western Montana. In the original studies, landslide inventories were used to associate geology, geography, and forest management activities (both road- and non-road-related) with mass wasting events and their potential effects on aquatic resources, per the State of Washington's Watershed Analysis process.
- Peterson et al. (2009) assessed the effects of post-fire logging based on the biophysical setting of the forest, pattern of burn severity, operational aspects of tree removal, and other management activities (e.g., removal of snags, road construction, logging with ground-based equipment, cable yarding) in dry forests of the western United States. They describe potential effects on aquatic systems and species in relation to the intensity and extent of post-fire logging.
- Platts et al. (1989) documents sediment delivery to spawning and rearing areas for Chinook salmon (*Oncorhynchus tshawytscha*) and Steelhead (*Oncorhynchus mykiss*), noting logging and road construction, in combination with large storm events in a two-year period, resulted in increased amounts of fine sediment delivery to an Idaho river.

Secondary focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Four documents (Table 6) were deemed potentially relevant to the secondary focus question and included content on mass wasting processes apart from shallow rapid landslides, such as deep-seated earthflows, slumping, and soil bulking debris flows. One document included mention of aquatic species and fire. All four were also identified as potentially relevant to the primary focus question. Abstracts or summaries of the potentially relevant literature are provided in Appendix C.

Table 6. Documents potentially relevant to the secondary focus research question.

Publication	Location	Forest harvest-related activities	Hillslope processes-mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Lineback Gritzner et al. (2001)	Idaho				
Megahan et al. (1978)					
Luce et al. (2012)*	Western U.S.				
Jordan et al. (2010)	British Columbia				

** denotes publication that includes wildfire effects.*

Other process relevant studies

Nineteen documents were classified as "process relevant," (Table 3) that is, these considered mass wasting on forestlands but without any direct connection to forest management. These documents are summarized here as demonstrating the role that mass wasting can play after wildfire. Although not specifically addressed, forest harvest-related activities may affect the processes driving post-fire mass wasting. The largest number of documents came from studies in Idaho (7), followed by studies spanning multiple western states (6); three were located in California and one each in Colorado, Wyoming, and New Mexico. None were located in eastern Oregon or Washington. By definition, none of these addressed forest harvest-related activities but all addressed hillslope processes and all overlapped with semi-arid environments. Most of these studies (14) investigated post-wildfire surficial erosion and mass wasting. Abstracts or summaries of the potentially relevant literature are provided in Appendix D.

Studies with potentially useful literature review methods

Two literature reviews were found (Barrett and Reilly 2017; Herrera Environmental Consultants Inc. 2004) that described methods that could be useful in conducting a comprehensive literature review. Herrera (2004) included both project initiation and mid-project workshops in which information and feedback was solicited from broader user groups, whereas Barrett and Reilly (2017) gave a final presentation to the sponsoring group. Both reviews were focused on eastern Washington, but because of the lack of literature directly addressing this area, they broadened their searches to similar environments in other western states and Canada. Both reviews researched literature databases and solicited documents from subject matter experts. These two reviews are also useful for estimating the time and cost of this type of work. Further details on the review steps used in each of these literature reviews can be found in Appendix D.

2.5 Insights

The scoping review yielded insights that could be valuable for the AMPC when considering future work and for those designing and conducting that work. Insights were gleaned on the process of conducting the review and from the content of the reviewed documents.

Review process insights

Although the gray literature was particularly helpful in addressing the research questions, no gray literature was identified from predetermined searches of the three electronic literature databases. Approximately half the documents that were potentially relevant to the primary focus question (9 of 20) and the secondary focus question (2 of 4) were classified as gray literature. All of the gray literature was found via the traditional search approach (i.e., personal contacts (IRST members), agency websites, Google searches, and subsequent reviews of citations). Only one of the 19 documents describing the process-relevant literature was classified as gray literature. This may be due to different search emphases – process-relevant literature was not requested from IRST members and not included in the review of agency websites. Rather the process-relevant category was created after examining search results. More than half of the process-relevant literature came from searching Google and mining citations; the latter led to formally published sources.

Although the predetermined search approach returned thousands of documents, the majority of these are unlikely to be relevant for a more comprehensive review. This was particularly true of the Google Scholar search, where results included less relevant conference abstracts and multiple entries for a single document. If a comprehensive review related to the research questions is pursued, the reviewer will need to determine a reasonable top number of search results to review.

The search for literature conducted for this scoping review was not exhaustive and was not intended to be a full synthesis of existing information relative to the research questions. Thus, a more comprehensive search that includes other search terms may return documents not considered here. However, the IRST does not expect expanded searches to discover substantially more studies specific to the research questions and conducted in eastern Oregon. A subsequent literature review would synthesize across the best available science and has the potential to develop different conclusions than the content insights that follow.

Content insights

Based on the limited amount of literature identified and characterized in the scoping review, we provide the following insights:

1) The approach used to search and review the literature identified few documents that directly addressed the research questions, and only Fitzgerald and Clifton (1997) explicitly examined mass wasting in eastern Oregon.
2) Many of the potentially relevant documents reported mass wasting in northeastern Oregon, southeastern Washington, and Idaho following an intense storm event in February 1996.
3) Landslide inventories generally indicated that fewer landslides and debris flows occur in arid and semi-arid environments east of the Cascade Mountain Crest compared to west of the Crest.
4) Although not well characterized in the literature for eastern Oregon, the factors associated with the initiation and runout of shallow rapid slides and other mass wasting processes appear similar to those in western Oregon. These factors include slope steepness and heavy precipitation.
5) The effects of changing climate and weather patterns on precipitation events and thus mass wasting in eastern Oregon are unclear but may be important for evaluating landslide susceptibility and risk to covered species. Halofsky and Peterson (2017) report that climate change impacts to precipitation, plant communities, and wildfires in eastern Oregon may contribute to increasing mass movement susceptibility.
6) Shallow rapid landslides were associated with timber harvest in environments similar to eastern Oregon. However, the influence of timber harvesting on landslide and debris flow characteristics (e.g., number, size, runout distance) in semi-arid environments is less well studied and understood than in westside forests.
7) Watershed analyses in eastern Washington, Idaho, and western Montana included landslide inventories and explicitly examined the role of forest management on landslides. These landslide inventories may be a source of information to address the research questions.
8) The impacts of debris flows and other hillslope processes on habitat characteristics or their influence on demographics and persistence of covered amphibian and fish species in eastern Oregon has not been researched extensively. Limited studies identified in the scoping review examined changes to in-stream habitat conditions following mass wasting events. Other studies from semi-arid regions broadly infer habitat responses to changes in sediment levels related to climate change, forest management practices, and in particular the frequency, extent and severity of wildfires (e.g., Goode et al. 2012, Halofsky et al. 2017, Luce et al. 2012). The eastside watershed analyses may contain information on fish habitat as related to mass wasting, but this has not yet been explored.

3. Scoping Proposals

3.1 Introduction

Although few studies that related forest harvest to mass wasting hillslope processes in eastern Oregon and similar environments were found in the scoping review, it is expected that additional relevant literature would be found with more intensive searching, particularly in gray literature and state-sponsored technical reports. Based on the scoping review, the literature for the primary and secondary focus questions seems sufficiently intertwined that separate reviews are unlikely to be fruitful if future work is undertaken. Therefore, the four options presented here could address both of the AMPC research questions together. The options are: 1) a full systematic mapping review following the Collaboration for Environmental Evidence (CEE) process, 2) a more rapid systematic mapping review following the corresponding CEE advice, 3) a standard but less rigorous descriptive review, and 4) no further literature review. If subsequent review is pursued, the IRST would provide advice and oversight throughout, including reviewing the search and screening protocols, initial search results, data coding plan, and draft of final results. The following information describes the four options in more detail.

3.2 Scoping proposal: Systematic map

Scope of work

A systematic mapping approach, following the CEE process, could be used to more fully describe the amount and nature of the literature on forest harvest practices related to hillslope processes in eastern Oregon. The search terms could be broadened beyond those used in the scoping review to include non-empirical studies that use modeling. These types of studies are often framed as susceptibility or risk assessments. Databases from empirical studies or developed in modeling work could be compiled as part of the systematic map to be made available for use in future research, particularly in developing and calibrating new models for application in eastern Oregon if deemed appropriate.

Given that the Private Forest Accord (PFA) identified the differences in climate and geology between eastern and western Oregon, part of the systematic mapping process could describe these differences and inventory data sources available to assess these differences. Similarly, a section related to the aquatic/riparian species of most concern and their habitat needs in relation to mass wasting processes could be included. To best access gray literature, a list of organizational and individual experts could be developed and contacted. This option could include workshops for input and broad participation, beyond iterative interaction with the IRST. Consistent with its previously listed roles, the IRST would advise on the contact list of experts for workshop participation and document solicitation.

Screening and coding/analysis of publications would be done by multiple independent reviewers with checks for consistency. A full database of the publications found, including those accepted and rejected, and other coding fields would be delivered, as well as a list of accepted publications in Zotero or a common bibliographic interchange format (RIS, Bibtex). Critical appraisal of study validity and data would be described (e.g., model v. empirical datasets; experimental design v. opportunistic assessment; statistical analysis and sample size). Empirical databases that can be used for later model calibration and/or mapping purposes would be compiled and made available (possibly using GitHUB).

The core elements, milestones, and timelines of the scope of work are documented in Figure 5, showing a maximum estimated duration of 18 months, not including administrative startup and closeout.

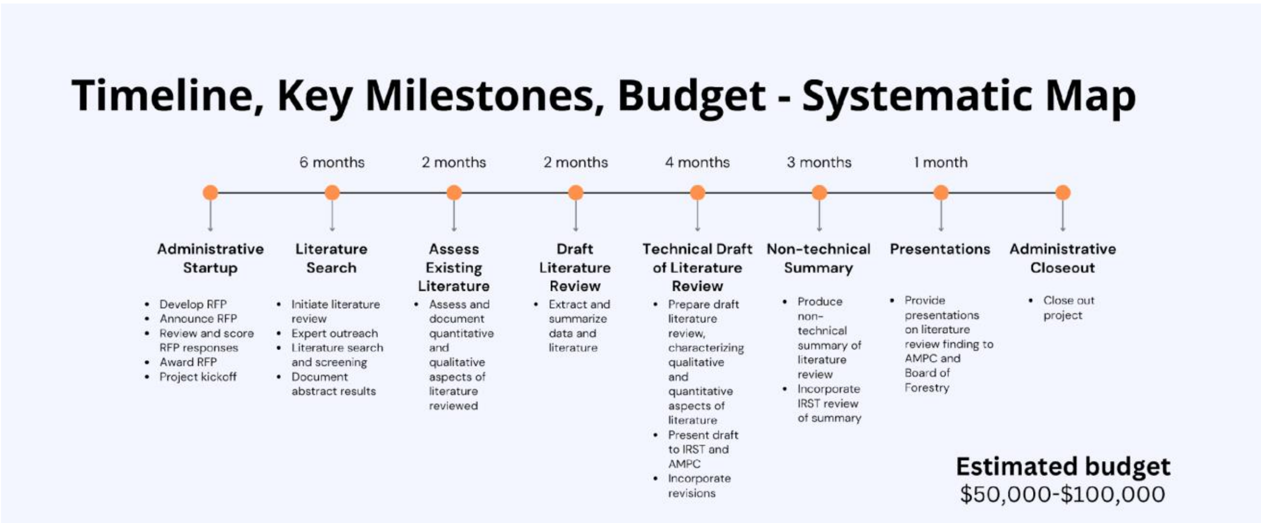

Figure 5. Timeline, key milestones, and budget for a systematic map.

Knowledge contribution

A systematic map is intended to inform the AMPC on the extent of knowledge about whether forest practices on private lands in eastern Oregon are affecting hillslope processes that in turn may affect HCP-covered species. A full mapping would be expected to uncover all the literature available on the topic, particularly the more difficult to find gray literature. It would identify important gaps and compile relevant empirical data that could be used in later analysis/research efforts (as in model calibration for landslide susceptibility/risk assessment). This option may also further describe the differences in the drivers of mass wasting processes eastside vs. westside, and what is known about related species habitat vulnerabilities on the eastside. This information on knowledge gaps and environmental condition differences could support AMPC policy decisions or inform the need for future research.

Budget

The estimated budget for the full systematic mapping review ranges from an estimated $50,000 to $100,000. This budget is primarily personnel costs (e.g., salary and benefits). It excludes indirect costs, which vary among institutions.

3.3 Scoping proposal: Rapid systematic map

Scope of work

Conduct a more rapid systematic mapping review following the corresponding CEE advice. The process would be simplified from the full option by:

1) Reducing review and inputs beyond the IRST (e.g., no external workshops);
2) Reducing the number of databases searched and experts consulted;
3) Relying on only one reviewer, rather than two or more independent reviewers, when screening and extracting information from each publication;

4) Limiting the critical appraisal of study validity;
5) Limiting the literature database to only relevant documents, rather than also including those that were rejected, and;
6) No compilation of available empirical datasets.

The core elements, milestones, and timelines of the scope of work are documented in Figure 6, showing a maximum estimated duration of 4–8 months, not including administrative startup and closeout.

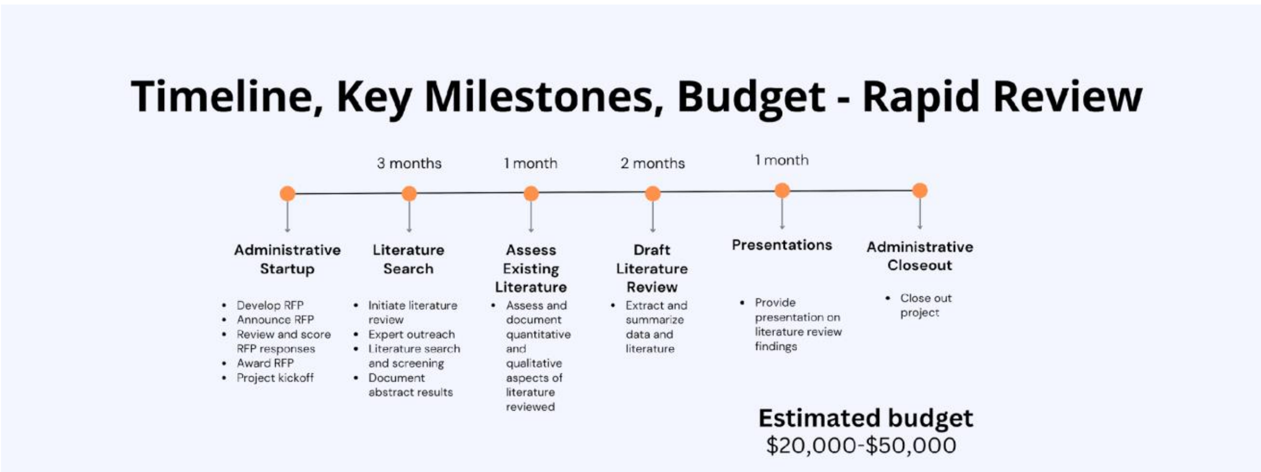

Figure 6. Timeline, key milestones, and budget for a rapid review.

Knowledge contribution

A rapid systematic mapping review would collate the relevant literature on this topic. As with the full systematic map, this review would be expected to extract data from the documents and, based on this, summarize the state of knowledge and identify research gaps, but would not capture some of the gray literature that could be identified in workshops of subject experts. This option could begin to describe the differences in the drivers of mass wasting processes eastside vs. westside, and what is known about related species habitat vulnerabilities on the eastside. The search and review process would be well documented for transparency and replicability, however, relying only on one or two reviewers without consistency checking would increase the potential influence of individual biases. Because relevant empirical databases would not be compiled, later use in model calibration for risk or susceptibility assessment would not be possible.

Budget

The estimated budget for the rapid review ranges from an estimated $20,000 to $50,000. This budget is primarily personnel costs (e.g., salary and benefits). It excludes indirect costs, which vary among institutions.

3.4 Scoping proposal: Descriptive review

Scope of work

A descriptive review would spend less effort on documenting a systematic and transparent procedure but would still include a knowledge synthesis with some information on searching, screening and classifying methods. Multiple literature sources would be searched, but expert contacts would be limited. Characteristics of the review literature would be summarized, such as publication year, research methods, data collection techniques, and general research outcomes. Relevance to AMPC questions would be described, but no empirical data would be compiled, and no critical appraisal of study methods would occur.

The core elements, milestones, and timelines of the scope of work are documented in Figure 7, showing an estimated duration of 3–6 months, not including administrative startup and closeout.

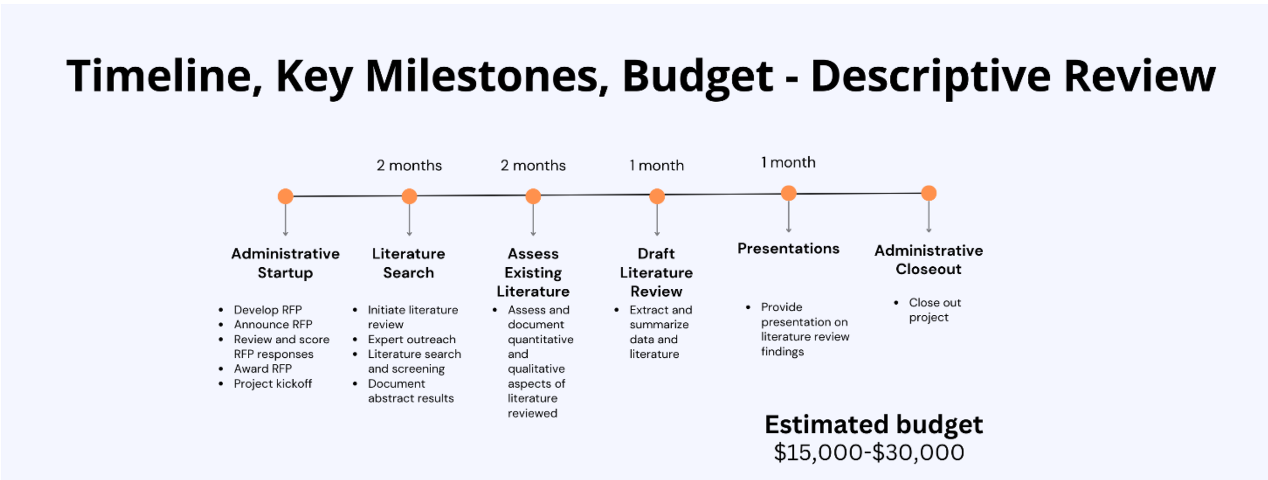

Figure 7. Timeline, key milestones, and budget for a descriptive review.

Knowledge contribution

As with the rapid systematic mapping, this option would collate the literature on this topic but may not capture some of the gray literature because the focus would be on peer-reviewed and journal published sources. The searching, screening and review methods would not be as thoroughly documented as in the full systematic map or the rapid review, yielding a less transparent and replicable product. Only a narrative synthesis of findings would be presented without a quantitative summary of the literature. Related datasets would not be compiled.

Budget

The estimated budget for the narrative review ranges from an estimated $15,000 to $30,000. This budget is primarily personnel costs (e.g., salary and benefits). It excludes indirect costs, which vary among institutions.

3.5 Scoping proposal: No further searching or review

The results of the scoping review suggest that mass wasting can be an issue in eastern Oregon and can be influenced by forest removal by both management activities and natural disturbance. Although only five percent of the area on private lands in eastern Oregon has slopes exceeding 65 percent, a full characterization of other drivers that might render locations susceptible to mass wasting, how forest harvest-related activities may affect susceptibility, and where covered species might be most at risk were not well represented in the cursory scoping review. However, a more thorough search and review process may or may not yield further insights. Should an additional search be completed, the search would include search terms such as landslide susceptibility, landslide inventory, and topics including geologic maps, climate models, and arid steep slope processes. In which case, knowledge gaps with relevance to timber management practices on steep slopes in eastern Oregon could be identified and research proposals prepared.

Knowledge contribution

Unless further work is directed by the AMPC to characterize knowledge gaps and develop associated scoping proposals, the knowledge gained from this option is summarized in Section 2.5 Content Insights.

3.6 Summary

The four options for addressing the research questions differ in the time required, cost, and knowledge contribution (Table 7). The costs exclude indirect costs, which vary among institutions; and the timeframes exclude administrative start up and close out. Knowledge contributions from the first three of the four options in Table 7 should sufficiently characterize the state of science and gaps in understanding to help inform policy discussions regarding steep slopes in eastern Oregon. However, the knowledge contribution from those three options do vary regarding several factors, including the inclusion of gray literature, potential for bias in the results, exploration of issues beyond forest harvest-related activities that may influence mass wasting, and acquisition of empirical data for future use.

Table 7. Summary of scoping proposal options relative to timeframes, costs (excluding indirect costs and administrative startup and closeout time), and knowledge contributions.

Option	Timeframe	Cost	Knowledge Contribution
Full systematic map	12–18 mo.	$50,000-$100,000	Extracts data from reviewed documents to support quantitative and narrative synthesis about the state of and important gaps in knowledge regarding eastern Oregon steep slopes. Compiles any existing empirical databases for future use. Further describe differences between eastern and western Oregon in the drivers of mass wasting processes and what is known about covered species habitat vulnerabilities in eastern Oregon.
Rapid systematic map	4–8 mo.	$20,000-$50,000	Extracts data from reviewed documents to support quantitative and narrative synthesis about the state of and important gaps in knowledge regarding eastern Oregon steep slopes. This may exclude some of the gray literature, especially older studies or those from other states. The search and review process would still be well documented for transparency and replicability but relying only on one or two reviewers without consistency checking could increase bias.
Descriptive review	3–6 mo.	$15,000-$30,000	Provides a reasonable collation of the literature on steep slopes in eastern Oregon based primarily on peer-reviewed literature. It is unlikely to capture much of the gray literature, especially older studies or those from other states. The searching, screening and review methods would not be as thoroughly documented, so would be less transparent and replicable. A narrative synthesis of findings would result but would be more limited than for the rapid systematic mapping option.
No further searching or review	0 mo.	N/A	Provides only the characterization and summary of the literature garnered from this scoping effort (Section 2.5 Content Insights, Appendices B, C, and D) and does not identify knowledge gaps. The search for literature conducted for this scoping review was not exhaustive and was not intended to be a full synthesis of existing information relative to the research questions.

4. References

NOTE: *Articles with authors' names in red italic are "process relevant" articles that are not referenced in the body of the report; however, "process relevant" articles are a column in Table 3 (Search results). Abstracts or summaries of these articles appear in Appendix D.*

Barrett, S.W., and M. Reilly. 2017. Literature Review: Effects of Salvage Logging on Riparian Zones in Coniferous Forests of Eastern Washington and Adjacent Regions. Cooperative Monitoring Evaluation and Research Report CMER 17-100. Olympia, WA: Washington State Forest Practices Adaptive Management Program. Washington Department of Natural Resources. https://www.dnr.wa.gov/publications/fp_cmer_17_100.pdf

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5. Appendices

Appendix A. AMPC Research Questions Package

Appendix B. Abstracts or Summary of Publications Potentially Relevant to the Primary Focus

Appendix C. Abstracts or Summary of Publications Potentially Relevant to the Secondary Focus

Appendix D. Abstracts or Summary of "Process Relevant" Publications

Appendix E. Literature Review Examples

Appendix A. Key Aspects of the AMPC Research Questions Package

A. Final research questions

These preliminary research questions were approved by the AMPC as a substantial decision at their July 2, 2024 meeting. These questions apply east of the crest of the Cascades[3] in Oregon and are to be answered via literature reviews. In addition to an overview of literature, the review should provide an assessment of how robust the conclusions from the literature are and where there may be need for additional research.

Overarching Question:

What impacts do hillslope processes have on the covered species in the draft HCP and their habitats in eastern Oregon?

Primary Focus: What does the literature say about upslope initiated shallow rapid slides and how timber harvesting may impact these in eastern Oregon environments?

Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft HCP and are these processes changed by forest practices?

B. Contextual information

The remainder of this document provides contextual information that details the context for the preliminary research questions, as required by rule[4]. The following are organized per the elements in this rule.

B.2 The rule, biological goals and objectives (BGOs), or other issue being studied[5]

AMPC response: The BGOs[6] are listed below with those applicable to these questions [in red font]:

"Overarching Goal: Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats.

Goal 1: Provide clean water and substrate for the covered species.

- *Objective 1.1 - Forest practices near streams minimize sediment delivery.*
- *Objective 1.2 – Slope Retention Areas reduce episodic sediment delivery to fish-bearing streams.*
- *Objective 1.3 – Road runoff directly to streams is minimized.*
- *Objective 1.4 – Roads are not a significant source of episodic sediment delivery to streams.*

Goal 2: Shade and watershed processes controlling stream temperature provide cool water compatible with the needs of the covered species.

- *Objective 2.1 – Forest practices maintain stream shade sufficient to support desired cool water temperatures on fish-bearing streams.*

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[3] Note: ODF maintains a regulatory GIS layer of the FPA delineation between eastern and western Oregon.

[4] OAR 629-603-0200 (3)(a)

[5] OAR 629-603-0200(3)(a)(B)

[6] The most recent version of the BGOs is in the Dec. 2022 draft HCP. The BGOs will be finalized within the HCP due Dec. 31, 2027.

- *Objective 2.2 – No-harvest RMAs maintain stream shade sufficient to support desired cool water temperatures for covered amphibians.*
- *Objective 2.3 – Forest practices near non-fish-bearing perennial streams do not notably increase water temperatures in fish-bearing streams.*

Goal 3: Stream network connectivity satisfies freshwater habitat needs for covered species.

- *Objective 3.1 – Road crossings on fish-bearing streams are passable by the covered fish species.*
- *Objective 3.2 – Forest practices maintain the hydrologic continuity of stream-associated wetlands and stream-adjacent seeps and springs to stream habitats.*
- *Objective 3.3 – Timber harvest maintains stream-associated connectivity in riparian areas along non-fish streams sufficient to support covered amphibians.*

Goal 4: Riparian areas function to support complex habitats for the covered species.

- *Objective 4.1 – Mature, complex riparian forests are fostered in no-harvest zones of RMAs.*
- *Objective 4.2 – Forest practices within tree retention areas of RMAs promote delivery of large wood.*
- *Objective 4.3 – Designated Debris Flow Traversal Areas function to deliver large wood to fish-bearing streams.*
- *Objective 4.4 – Forest practices maintain stream-associated wetlands and stream-adjacent seep and spring habitat for amphibians."*

B.3 The objective of the research[7]

The objective of this research is to inform deliberations about whether rules or other policies are needed regarding timber harvest and other forest practices on steep slopes in eastern Oregon to protect HCP-covered species.

B.4 A brief description of the context of the research question[8]

The following direction was provided in the PFA Report and provides the foundation for these research questions:

"CHAPTER 3. TIMBER HARVEST ON STEEP SLOPES

3.2 Goals

The goals of the PFA commitments regarding timber harvest on steep slopes is to provide large wood and sediment consistent with maintaining or improving aquatic habitat within large basins over long timeframes. (For the purposes of this Chapter, large basins are those of a size equivalent to those supporting independent populations of Oregon coastal coho salmon. In modeling to support the PFA, these are USGS HUC 4th Field [8-digit] basins). To accomplish this, sediment sources and debris flow runout paths will be identified and a subset of these will be managed during timber harvest activities to retain trees and other vegetation. These actions, together with other HCP commitments, are intended to provide high-quality

[7] OAR 629-603-0200(3)(a)(C)

[8] OAR 629-603-0200(3)(a)(D)

habitat to support recovery and long-term conservation of the species covered by this HCP on private forestlands.

3.2.1 Objectives

- *Aligned with the overall goals for timber harvest on steep slopes to provide high-quality habitat that supports the recovery, protection, and long-term conservation of covered species on private forestlands, the Authors establish the following objectives under the PFA:*
- *Leave trees in Designated Debris Flow Traversal Areas to help create and maintain high-quality habitat in:*
  - *Type F or Type SSBT streams by delivering large wood and regulating sediment storage and transport.*
  - *Type N streams by creating shade and cover for amphibians covered under the HCP.*
- *Leave trees in Slope Retention Areas to:*
  - *Reduce timber-harvest-related increases in the frequency and volume of sediment delivered to Type F or Type SSBT streams from mass wasting events.*
  - *Contribute large wood to Type F or Type SSBT streams.*
  - *Leave trees on a subset of steep (>70%) slopes immediately adjacent to Type F or Type SSBT streams to:*
  - *Stabilize these areas.*
  - *Contribute large wood to Type F or Type SSBT streams.*

3.3.8 Timber Harvest on Steep Slopes in Eastern Oregon

The Private Forest Accord does not prescribe new management measures for landslide initiation zones or debris flow traversal channels in Eastern Oregon. The Authors agree that Eastern Oregon's unique geologies and climates likely mean that these processes are different in magnitude, frequency, and impact on the covered species, when compared to Western Oregon. Similarly, the impact of timber harvesting on these processes is potentially different in Eastern Oregon. In light of this uncertainty, the Authors agree that the Adaptive Management Program shall, beginning no later than January 1, 2024, examine the scientific literature on the impacts that hillslope processes have on the covered species in Eastern Oregon. The primary focus will be on upslope initiated shallow rapid slides and how timber harvesting may impact these in Eastern Oregon environments. A secondary and more limited focus is whether other hillslope processes that likely affect covered species are changed by forest practices. Findings of the Adaptive Management Program on these topics will be presented to the Board of Forestry. These findings should focus primarily on the importance of shallow rapid landslides in Eastern Oregon to habitat for the covered species and the potential modification of these processes by forest practices or lack thereof. The report on this primary topic may or may not include recommendations as to desirability and relative importance of potential management measures. In addition, the report should convey whether the secondary review of literature on the effect of forest practices on other hillslope processes merits more thorough consideration by the Adaptive Management Program in light of scientific literature on the connection of these processes to covered species. Nothing in this Report should be read to suggest that any additional Eastern Oregon steep slope or other hillslope prescriptions are, or are not, necessary. The timber harvest prescriptions for steep *slopes established under Section 3.3.3 of this Chapter for Designated Debris Flow Traversal Areas and under Section 3.3.4 of this Chapter for Designated Sediment Source Areas and Slope Retention Areas do not apply to any private forest ownership class east of the summit of the Cascade Mountains. The timber harvest prescriptions for steep slopes established under Section 3.3.7 Stream Adjacent Failures apply to all private forest ownership classes both west and east of the summit of the Cascade Mountains."*

Appendix B. Abstracts of Publications Potentially Relevant to the Primary Focus

Primary Focus: What literature exists relating to upslope initiated shallow rapid slides and how timber harvesting may impact these in eastern Oregon environments?

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Fitzgerald and Clifton 1997	eastern Oregon	Q1		x	x	x	

Reference

Fitzgerald, J., and C. Clifton. 1997. Flooding, land use, and watershed response in the Blue Mountains of northeastern Oregon and southeastern Washington. In: Inland Northwest Water Resources Conference, Program and Abstracts. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5208929.pdf

Abstract

The northern Blue Mountains sustained heavy rain and rapid snowmelt in November 1995 and rapid snowmelt over frozen soil in February 1996. The result was multiple record flood events, with February peak flows being more wide-spread and of higher magnitude. In addition to flooding, the storms triggered debris flows and slides on the Umatilla National Forest. These features commonly occurred in the rain-snow transition zone, in saturated loam-clay-ash soil, and on steep slopes (30-80 percent). Debris flows or torrents were the dominate feature, starting as an earthslide and then transporting debris sometimes over a mile. Roading and logging were associated with 37 percent of the observed mass wasting features. High flows and mass wasting combined to produce a variety of channel responses including: scouring of substrate and banks; aggradation of sediment; accumulation of large woody debris; and, lateral channel migration. Fluvial responses appear to differ with elevation and land use intensity. Flood discharge of National Forest streams was estimated using the indirect, slope-area method based on post-flood field evidence. Flood frequencies were then estimated using U. S. Geological Survey regional flood equations. Flood magnitude and frequency varied by watershed with some areas experiencing one or more "100 year" events (Umatilla and Walla Walla) and others experiencing less than a "25 year" event (Tucannon and Wenaha). Flood effects on National Forest investments (instream fish habitat structures and road-stream crossings) were also assessed. Results from field inventories indicate a high rate (73 percent) of instream fish habitat structure survival. Anchored rock weirs had the highest success rate. In roaded watersheds, a sample of culverts at stream-road crossings indicated about 50 percent of the culverts failure. The failure rate varies by watershed, however, from 23 to 95 percent. Culverts failed because of plugging with sediment often causing additional flood damage to roads and streams. Preliminary results indicate variability in watershed response to flooding which is partly attributed to different watershed characteristics and land use intensities. The post-flood assessments will be used to improve understanding of watershed response to extreme hydrologic events and to improve management practices to reduce damage from future high flows.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Goode et al. 2012	western US	Q1		x	x	x	

Reference

Goode, J.R., C.H. Luce, and J.M. Buffington. 2012. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: implications for water resource management and aquatic habitat in the northern Rocky Mountains. Geomorphology 139: 1–15. https://doi.org/10.1016/j.geomorph.2011.06.021

Abstract

Sediment yields tend to be larger in semi-arid climates than in arid and humid environments due to the regulating effect of vegetation on hillslope stability and soil generation. Sediment yields in semi-arid mountain basins will increase in response to projected warming and increased climate variability. Potential approaches for reducing sediment through land management include post-fire stabilization, suppression of fire and fire severity, and attention to other anthropogenic sources of sediment (e.g., roads, logging, grazing, mining). Determining the most effective method depends on the relative contribution of each source, management resources and objectives, and feasibility of actions. Increased sediment yields following logging result from vegetation disturbance; exposure of bare soils accelerates surface erosion, loss of forest interception and transpiration increases soil pore pressure, and loss of root strength destabilizes shallow hillslope soils, increasing the potential for shallow land sliding in both humid and semi-arid landscapes. Logging roads exacerbate this erosion and commonly produce greater erosion per unit area, but their overall extent is small compared to the area of timber harvest (Megahan,1986). Although logging has declined in the western US over the last few decades, legacy sediment stored within the fluvial system may continue to affect channel morphology and aquatic habitat. The ecological consequences of sediment chronically supplied from roads may be more detrimental than from sediment periodically supplied from post-fire debris flows. Despite the dramatic nature of debris-flow disturbances and their potential impacts to river corridor infrastructure, salmonids and other aquatic organisms have evolved with, and are adapted to, these disturbances.

Aquatic Species: The authors generally reference aquatic species, fish, and salmonids.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Gorsevski et al. 2006	Idaho	Q1		x	x	x	

Reference

Gorsevski, P.V., P.E. Gessler, J. Boll, W.J. Elliot, and R.B. Foltz. 2006. Spatially and temporally distributed modeling of landslide susceptibility. Geomorphology 80(3): 178–198. https://doi.org/10.1016/j.geomorph.2006.02.011

Abstract

Mapping of landslide susceptibility in forested watersheds is important for management decisions. In forested watersheds, especially in mountainous areas, the spatial distribution of relevant parameters for landslide prediction is often unavailable. This paper presents a GIS-based modeling approach that includes representation of the uncertainty and variability inherent in parameters. In this approach, grid-based tools are used to integrate the Soil Moisture Routing (SMR) model and infinite slope model with probabilistic analysis. The SMR model is a daily water balance model that simulates the hydrology of forested watersheds by combining climate data, a digital elevation model, soil, and land use data. The infinite slope model is used for slope stability analysis and determining the factor of safety for a slope. Monte Carlo simulation is used to incorporate the variability of input parameters and account for uncertainties associated with the evaluation of landslide susceptibility. This integrated approach of dynamic slope stability analysis was applied to the 72-km2 Pete King watershed located in the Clearwater National Forest in north-central Idaho, USA, where landslides have occurred. A 30-year simulation was performed beginning with the existing vegetation covers that represented the watershed during the landslide year. Comparison of the GIS-based approach with existing models (FSmet and SHALSTAB) showed better precision of landslides based on the ratio of correctly identified landslides to susceptible areas. Analysis of landslide susceptibility showed that (1) the proportion of susceptible and non-susceptible cells changes spatially and temporally, (2) changed cells were a function of effective precipitation and soil storage amount, and (3) cell stability increased over time especially for clear-cut areas as root strength increased and vegetation transitioned to regenerated forest. Our modeling results showed that landslide susceptibility is strongly influenced by natural processes and human activities in space and time; while results from simulated outputs show the potential for decision-making in effective forest planning by using various management scenarios and controlling factors that influence landslide susceptibility. Such a process-based tool could be used to deal with real-dynamic systems to help decision-makers to answer complex landslide susceptibility questions.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Halofsky and Peterson 2017	eastern Oregon	Q1		x	x	x	x

Reference

Halofsky, J.E., and D.L. Peterson. 2017. Climate change vulnerability and adaptation in the Blue Mountains region. Pacific Northwest Research Station General Technical Report, PNW-GTR-939. 331 p. https://doi.org/10.2737/PNW-GTR-939

Abstract

The Blue Mountains Adaptation Partnership was developed to identify climate change issues relevant to resource management in the Blue Mountains region, to find solutions that can minimize negative effects of climate change, and to facilitate transition of diverse ecosystems to a warmer climate. Partnering organizations included three national forests (Malheur, Umatilla, Wallowa-Whitman National Forests), the Pacific Northwest Research Station and Pacific Northwest Region of the U.S. Department of Agriculture, Forest Service, the University of Washington, and the Climate Impacts Research Consortium at Oregon

State University. These organizations worked together over a 2-year period to conduct a state-of-the-science climate change vulnerability assessment and develop adaptation options for national forests in the Blue Mountains region. The vulnerability assessment emphasized four resource areas—water, fish, upland vegetation, and special habitats—regarded as the most important resources for local ecosystems and communities.

The vulnerability assessment indicated that effects of climate change on hydrology in the Blue Mountains will be especially significant. Decreased snowpack and earlier snowmelt will shift the timing and magnitude of streamflow; peak flows will be higher, and summer low flows will be lower. Projected changes in climate and hydrology will have far-reaching effects on aquatic and terrestrial ecosystems, especially as frequency of extreme climate events (drought) and associated effects on ecological disturbance (wildfire, insect outbreaks) increase. Abundance and distribution of spring Chinook salmon (Oncorhynchus tshawytscha Walbaum), redband trout/steelhead (O. mykiss gibsii Walbaum)/(O.m. Walbaum), and especially bull trout (Salvelinus confluentus Suckley) will be greatly reduced, although effects will differ by location as a function of both stream temperature and competition from nonnative fish species. Increasing air temperature, through its influence on soil moisture, is expected to cause gradual changes in the abundance and distribution of tree, shrub, and grass species throughout the Blue Mountains, with drought tolerant species becoming more competitive. Ecological disturbance, including wildfire and insect outbreaks, will be the primary facilitator of vegetation change. High-elevation forest types will be especially vulnerable to disturbance.

Resource managers developed a detailed list of ways to address these climate change vulnerabilities through management actions. The large number of adaptation strategies and tactics, many of which are a component of current management practice, provide a pathway for slowing the rate of deleterious change in resource conditions.

<u>Aquatic Species</u>: The authors reference chinook salmon (*Oncorhynchus tshawytscha*), redband trout/steelhead (*O. Mykiss*), bull trout (*Salvelinus confluentus*), and other aquatic species that are not on the HCP list.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Harp et al. 1996	eastern WA	Q1		x	x	x	

Reference

Harp, E.L., A.F. Chleborad, R.L. Schuster, S.H. Cannon, M.E. Reid, and R.C. Wilson. 1996. Landslides and landslide hazards in Washington State due to February 5-9,1996 storm. U.S. Geological Survey Administrative Report. 33 p. https://faculty.washington.edu/kramer/522/USGS1996StormSlides.pdf

Abstract

The authors did not provide an abstract.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Herrera Environmental Consultants, Inc. 2004		Q1		x	x	x	

Reference

Herrera Environmental Consultants Inc. 2004. Review of the Available Literature Related to Wood Loading Dynamics in and around Streams in Eastern Washington Forests. https://www.dnr.wa.gov/publications/fp_cmer_03_308.pdf

Abstract

The authors did not provide an abstract.

Specific location: eastern WA and similar ecoregions

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Istanbulluoglu et al. 2004	Idaho	Q1		x	x	x	

Reference

Istanbulluoglu, E., D. Tarboton, R. Pack, and C. Luce. 2004. Modeling of the interactions between forest vegetation, disturbances, and sediment yields. Journal of Geophysical Research-Earth Surface 109(F1) https://doi.org/10.1029/2003JF000041

Abstract

The controls of forest vegetation, wildfires, and harvest vegetation disturbances on the frequency and magnitude of sediment delivery from a small watershed (similar to3.9 km(2)) in the Idaho batholith are investigated through numerical modeling. The model simulates soil development based on continuous bedrock weathering and the divergence of diffusive sediment transport on hillslopes. Soil removal is due to episodic gully erosion, shallow landsliding, and debris flow generation. In the model, forest vegetation provides root cohesion and surface resistance to channel initiation. Forest fires and harvests reduce the vegetation. Vegetation loss leaves the land susceptible to erosion and landsliding until the vegetation cover reestablishes in time. Simulation results compare well with field observations of event sediment yields and long-term averages over similar to 10,000 years. When vegetation is not disturbed by wildfires over thousands of years, sediment delivery is modeled to be less frequent but with larger event magnitudes. Increased values of root cohesion (representing denser forests) lead to higher event magnitudes. Wildfires appear to control the timing of sediment delivery. Compared to undisturbed forests, erosion is concentrated during the periods with low erosion thresholds, often called accelerated erosion periods, following wildfires. Our modeling suggests that drainage density is inversely proportional to root cohesion

and that reduced forest cover due to wildfires increases the drainage density. We compare the sediment yields under anthropogenic (harvest) and natural (wildfire) disturbances. Disturbances due to forest harvesting appear to increase the frequency of sediment delivery; however, the sediment delivery following wildfires seems to be more severe. These modeling-based findings have implications for engineering design and environmental management, where sediment inputs to streams and the fluctuations and episodicity of these inputs are of concern.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Jordan et al. 2010	British Columbia	Q1, Q2		x	x	x	

Reference

Jordan, P., T.H. Millard, D. Campbell, J. W. Schwab, D.J. Wilford, D. Nicol, and D. Collins. 2010. Forest Management Effects on Hillslope Processes (Chapter 9, page 275-330). In: Compendium of Forest Hydrology and Geomorphology in British Columbia Volume 1 of 2. (Eds) R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler, and K. D. Bladon. Ministry of Forests and Range Forest Science Program. British Columbia https://fews.forestry.oregonstate.edu/publications/AA_LMH66_volume1of2.pdf

Abstract

The authors did not provide an abstract.

Specific location: Interior British Columbia

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Ketcheson et al. 1999	Idaho	Q1		x	x	x	

Reference

Ketcheson, G.L., W.F. Megahan, and J.G. King. 1999. “R1–R4” and “BOISED” sediment prediction model tests using forest roads in granitics. Journal of the American Water Resources Association 35, 83–98. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.1999.tb05454.x

Abstract

Erosion and sedimentation data from research watersheds in the Silver Creek Study Area in central Idaho were used to test the prediction of logging road erosion using the R1-R4 sediment yield model, and sediment delivery using the "BOISED" sediment yield prediction model. Three small watersheds were instrumented and monitored such that erosion from newly constructed roads and sediment delivery to the mouths of the watersheds could be measured for four years following road construction. The errors for annual surface erosion predictions for the two standard road tests ranged from +3 1.2 t/ha/yr (+15

percent) to -30.3 t/ha/yr (-63 percent) with an average of zero t/ha/yr and a standard deviation of the differences of 18.7 t/ha/yr. The annual prediction errors for the three watershed scale tests had a greater range from -40.8 t/ha/yr (-70 percent) to +65.3 t/ha/yr (+38 percent) with a mean of -1.9 t/ha/yr and a standard deviation of the differences of 25.2 t/ha/yr. Sediment yields predicted by BOISED (watershed scale tests) were consistently greater (average of 2.5 times) than measured sediment yields. Hillslope sediment delivery coefficients in BOISED appear to be overly conservative to account for average site conditions and road locations, and thus over-predict sediment delivery. Mass erosion predictions from BOISED appear to predict volume well (465 tonnes actual versus 710 tonnes predicted, or a 35 percent difference) over 15 to 20 years, however mass wasting is more episodic than the model predicts.

Specific location: Silver Creek, central Idaho

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Klock and Helvey 1976	eastern WA	Q1		x	x	x	

Reference

Klock, G.O., and J.D. Helvey. 1976. Debris flows following wildfire in north central Washington. Proceedings of the Third Inter-agency Sedimentation Conference. US Water Resources Council, Sedimentation Committee, Washington DC. x1-91–1-98.
https://babel.hathitrust.org/cgi/pt?id=umn.31951000143903p&seq=109

Abstract

A combination of rapid snowmelt, high intensity rainstorms, and fire-denuded watersheds resulted in massive debris torrents from numerous tributary streams of the Entiat River in north-central Washington during the spring and summer of 1972. Debris torrents are summarized by location, soil type, topography, and land use history for five adjacent watersheds. Alternative forest management recommendations are suggested for minimizing the impact of possible future debris torrents within the study area.

Specific location: north-central Washington (Entiat River Valley 20 miles north of Wenatchee, WA)

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Lineback-Gritzner et al. 2001	Idaho	Q1, Q2		x	p		

Reference

Lineback Gritzner, M., W.A. Marcus, R. Aspinall, and S.G. Custer. 2001. Assessing landslide potential using GIS, soil wetness modeling and topographic attributes, Payette River, Idaho. Geomorphology 37(1): 149–165. https://doi.org/10.1016/S0169-555X(00)00068-4

Abstract

This study utilizes GIS modeling to determine if the location of 559 landslides in the 875 km2 catchment of the Middle Fork of the Payette River, Idaho can be predicted based on topographic attributes and a wetness index generated by the DYNWET model. Slope and elevation were significantly related to landslide occurrence at this landscape scale. Aspect was also retained as a variable for further analysis because, despite a non-significant chi-square relation to landslide occurrence, graphical analysis suggested a relation between aspect and mass wasting. Chi-square analysis indicated that plan and profile curvature, flow path length, upslope contributing area, and the DYNWET-based moisture index were not significantly related to landsliding. A Bayesian probability model based on combinations of elevation, slope, aspect, and wetness indicates that elevation exhibits the closest relation to landsliding, followed by slope; but that neither aspect nor wetness index values help in prediction. The Bayesian probability model using elevation and slope generates a map of relative landslide risk that can be used to direct activities away from mass wasting prone areas. The association between elevation and landslides is perplexing but is perhaps due to the location of logging road at specific elevations (roads could not be included in the input data for analysis because they have not been adequately mapped). The lack of explanation provided by the DYNWET wetness index was also surprising and may be due to the 30-m digital elevation model (DEM) and the soils data having resolutions too coarse to adequately portray local variations key to mass wasting. We believe the inadequacy of data to drive the models is typical of the majority of catchment scale setting. For now, the ability of researchers to effectively model landscape scale landsliding is more limited by the type, resolution, and quality of available data than by the quality of the landslide models.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Luce et al. 2012	western US	Q1, Q2		x	x	x	x

Reference

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. Gen. Tech. Rep. RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 207 pp https://research.fs.usda.gov/treesearch/41932#

Abstract

Fire will play an important role in shaping forest and stream ecosystems as the climate changes. Historic observations show increased dryness accompanying more widespread fire and forest die-off. These events punctuate gradual changes to ecosystems and sometimes generate stepwise changes in ecosystems. Climate vulnerability assessments need to account for fire in their calculus. The biophysical template of forest and stream ecosystems determines much of their response to fire. This report describes the framework of how fire and climate change work together to affect forest and fish communities. Learning how to adapt will come from testing, probing, and pushing that framework and then proposing new ideas. The western U.S. defies generalizations, and much learning must necessarily be local in implication. This report serves as a scaffold for that learning. It comprises three primary chapters on physical processes,

biological interactions, and management decisions, accompanied by a special section with separately authored papers addressing interactions of fish populations with wildfire. Any one of these documents could stand on its own. Taken together, they serve as a useful reference with varying levels of detail for land managers and resource specialists. Readers looking for an executive summary are directed to the sections titled “Introduction” and “Next Steps.”

Aquatic species: fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
McClelland et al. 1999	Idaho	Q1		x	x	x	x

Reference

McClelland, D.E., R.B. Foltz, C.M. Falter, W.D. Wilson, T. Cundy, R.L. Schuster, J. Saurbier, C. Rabe, and R. Heinemann. 1999. Relative Effects on a Low-Volume Road System of Landslides Resulting from Episodic Storms in Northern Idaho. Transportation Research Record. 1652(1): 235–243. https://doi.org/10.3141/1652-63

Abstract

In late November to early December 1995 and February 1996, northern Idaho was hit by heavy rains on a deep snowpack, resulting in two flood and landslide events of historic magnitude. Each of these storms was larger than the previous significant storm, which occurred in January 1974. A study was initiated by the U.S. Department of Agriculture Forest Service to survey and study the effects of the resultant landslides on the Clearwater National Forest, including the effects on the aquatic ecosystem. The results of this study were compared with the estimated average natural sediment resulting from landslides to evaluate the incremental impacts of these recent episodic landslides. They were also compared with the results of a study conducted on the landslides resulting from the January 1974 storm to determine if the landscape was responding more severely to large storms as a result of Forest Service management activities over the past 21 years. The general results of this study indicate that, of the Forest Service management activities, roads are the major contributor; however, they contribute less sediment than natural landslides. The total resultant sediment appears to be within the transport capacity of the aquatic system, and the landslide response in 1974 was similar to the 1995–1996 response. The results of the aquatic ecosystem study were generally mixed, with some habitat parameters indicating degradation, some unchanged, and some improved as a result of the flooding or flooding with landslide sediment.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
McGreer et al. 1998	eastern WA & western MT	Q1		x	x	x	x

Reference

McGreer, D.J., B.D. Sugden, and D.T. Schult. 1998. Surface Erosion and Mass Wasting Assessment and Management Strategies for Plum Creek's Native Fish Habitat Conservation Plan. Native Fish Habitat Conservation Plan Technical Report #3. Columbia Falls, Montana: Plum Creek Timber Company.

Abstract

The authors did not provide an abstract.

Aquatic Species: Salmonids and fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Megahan et al. 1978	Idaho	Q1, Q2		x	x		

Reference

Megahan, W.F., N.F. Day, and Bliss, 1978. Landslide occurrence in the western and central northern Rocky Mountain physiographic province in Idaho. In: Youngberg, C.T. (Ed.), Forest Soils and Land Use, Proceedings of the Fifth North American Forest Soils Conference. Colorado State University, Department of Forest and Wood Sciences, Fort Collins, CO, pp. 116–139.
https://geodata.geology.utah.gov/pages/view.php?ref=4784&search=&offset=15100&order_by=resourcetype&sort=DESC&archive=0&k=&

Abstract

The authors did not provide an abstract.

Specific location: Idaho batholith - Clearwater National Forest in northern Idaho and Boise National Forest in west-central Idaho

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Peterson et al. 2009	Western US	Q1		x		x	x

Reference

Peterson, D.L., J.K. Agee, G.H. Aplet, D.P. Dyskstra, R.T. Graham, J.F. Lehmkuhl, D.S. Pilliod, D.F. Potts, R.F. Powers, and J.D. Stuart. 2009. Effects of timber harvest following wildfire in western North America. General Technical Report PNW-GTR-776. Portland, OR: USDA Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p. https://doi.org/10.2737/PNW-GTR-77

Abstract

Timber harvest following wildfire leads to different outcomes depending on the biophysical setting of the forest, pattern of burn severity, operational aspects of tree removal, and other management activities. Fire effects range from relatively minor, in which fire burns through the understory and may kill a few trees, to severe, in which fire kills most trees and removes much of the organic soil layer. Postfire logging adds to these effects by removing standing dead trees (snags) and disturbing the soil. The influence of postfire logging depends on the intensity of the fire, intensity of the logging operation, and management activities such as fuel treatments. In severely burned forest, timing of logging following fire (same season as fire vs. subsequent years) can influence the magnitude of effects on naturally regenerating trees, soils, and commercial wood value. Removal of snags reduces long-term fuel loads but generally results in increased amounts of fine fuels for the first few years after logging unless surface fuels are effectively treated. By reducing evapotranspiration, disturbing the soil organic horizon, and creating hydrophobic soils in some cases, fire can cause large increases in surface-water runoff, streamflow, and erosion. Through soil disturbance, especially the construction of roads, logging with ground-based equipment and cable yarding can exacerbate this effect, increasing erosion and altering hydrological function at the local scale. Effects on aquatic systems of removing trees are mostly negative, and logging and transportation systems that disturb the soil surface or accelerate road-related erosion can be particularly harmful unless disturbances are mitigated. Cavity-nesting birds, small mammals, and amphibians may be affected by harvest of standing dead and live trees, with negative effects on most species but positive or neutral effects on other species, depending on the intensity and extent of logging. Data gaps on postfire logging include the effects of various intensities of logging, patch size of harvest relative to fire size, and long-term (10+ years) biophysical changes. Uncertainty about the effects of postfire logging can be reduced by implementing management experiments to document long-term changes in natural resources at different spatial scales.

Specific location: western U.S., from the coastal ranges, Cascade Range, and Sierra Nevada east to the Rocky Mountains and associated ranges, and from SW Canada to the SW United States, including dry forests dominated by ponderosa pine, cold forests dominated by Engelmann spruce, fir species and lodgepole pine, and woodlands in the American Southwest

Aquatic species: fish, amphibian, benthic invertebrates

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Platts et al. 1989	Idaho	Q1		x	x	x	x

Reference

Platts, et al. 1989. Changes in spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Transactions of the American Fisheries Society 118:274-283. https://doi.org/10.1577/1548-8659(1989)118%3C0274:CISSAR%3E2.3.CO;2

Abstract

Levels of surface and subsurface fine sediment (<4.75 mm in diameter) were measured annually from 1965 to 1985 in spawning and rearing areas for chinook salmon *Oncorhynchus tschawytscha* and steelhead *O. mykiss* (formerly *Salmo gairdneri*) in the South Fork Salmon River, Idaho. Between 1950 and 1965, logging and road construction, in combination with large storm events of 1964 and 1965, resulted in the delivery of increased amounts of fine sediments to the South Fork Salmon River. Surface and subsurface fine sediment levels peaked at 46% of the surface area in 1966 and 48% of the volume in 1969, respectively. A logging moratorium initiated in 1965, coupled with natural recovery and watershed rehabilitation, led to significant decreases in the amounts of fine sediments delivered to and stored in the South Fork Salmon River; this reduction led to a limited resumption of logging operations within the watershed in 1978. By 1985, surface and subsurface sediment levels in chinook salmon spawning areas averaged 19.7% of the surface area and 25.4% of the volume, respectively. However, additional recovery to pre-logging fine sediment levels is probably contingent on both further watershed recovery and the occurrence of flood flows capable of transporting material downstream. An equilibrium between incoming sediment from the watershed and outgoing sediment from the river appears to have been reached under flow regimes that have occurred since 1975.

Specific location: South Fork Salmon River, Idaho

Aquatic species: salmonids

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Sidle 2005	various			x	x	p	

Reference

Sidle, R.C. 2005. Influence of forest harvesting activities on debris avalanches and flows. In: Hungr, O., Jacob, M. (Eds.), Debris Flow Hazards and Related Phenomena. Praxis, Springer-Verlag, Berlin, pp. 387-403 https://link.springer.com/content/pdf/10.1007/3-540-27129-5_15.pdf

Abstract

The author did not provide an abstract.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Wondzell and King 2003	Western US	Q1		x	x	x	

Reference

Wondzell, S.M., and J.G. King. 2003. Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions. Forest Ecology and management 178(1–2): 75–87. https://doi.org/10.1016/S0378-1127(03)00054-9

Abstract

The objective of this paper is to provide a general overview of the influence of wildland fires on the erosional processes common to the forested landscapes of the western United States. Wildfire can accelerate erosion rates because vegetation is an important factor controlling erosion. There can be great local and regional differences, however, in the relative importance of different erosional processes because of differences in prevailing climate, geology and topography; because of differences in the degree to which vegetation regulates erosional processes; and because of differences in the types of fire regimes that disrupt vegetative cover. Surface erosion, caused by overland flow, is a dominant response to wildfire in the Interior Northwest and Northern Rocky Mountains (Interior Region). A comparison of measured postfire infiltration rates and long-term records of precipitation intensity suggest that surface runoff from infiltration-excess overland flow should also occur in the Coastal and Cascade Mountains of the Pacific Northwest after fires, but this has not been documented in the literature. Debris slides and debris flows occur more frequently after wildfire in the Interior Region and in the Coastal and Cascade Mountains of the Pacific Northwest (Pacific Northwest Region). Debris flows can be initiated from either surface runoff or from soil-saturation-caused debris slides. In the Pacific Northwest Region, debris flows are typically initiated as debris slides, caused by soil saturation and loss of soil cohesion as roots decay following fire. In the Interior Region, both overland-flow-caused and debris-slide-caused debris flows occur after wildfire. Surface erosion, debris slides, and debris flows all occur during intense storms. Thus, their probability of occurrence depends upon the probability of intense storms occurring during a window of increased susceptibility to surface erosion and mass wasting following intense wildfire.

Specific location: Pacific Northwest and Rocky Mountains

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Wondzell, S.M. 2001	eastern Oregon	Q1		x	x	x	x

Reference

Wondzell, S.M. 2001. The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of eastern Oregon and Washington. Northwest Science 75:128-140.

https://rex.libraries.wsu.edu/esploro/outputs/journalArticle/The-influence-of-forest-health-and/99900501658801842

Abstract

A variety of Forest Health and Protection treatments have been proposed to reduce long-term risks to forests from wildfire, insects, and disease. This review examines the potential effects of these treatments on sediment production in watersheds of eastern Oregon and Washington, USA, channel forming processes, riparian vegetation, and risks posed to riparian zones. Wildfires can affect upland erosion; however, erosion from prescribed fires burning the same area should be much smaller. Dense riparian vegetation might help regulate the amount of sediment that reaches streams, but this effect would be strongly dependent on the geomorphic setting. Forest pathogens are not expected to cause accelerated erosion and stream sedimentation directly, but indirect effects might be substantial if they lead to increased wildfire. The largest risk of accelerated erosion is expected from ground-disturbing activities during fuels reduction treatments, such as construction of roads and firebreaks or salvage logging or thinning. Intense grazing has changed composition and cover of riparian vegetation, leading to bank erosion, and in many places, widening or incision of stream channels. Improved grazing prescriptions can result in major changes to riparian vegetation, but response of channel morphology will most likely be slow. Most of the studies reviewed were conducted at the site or small-watershed scale. Consequently, conclusions at these scales are generally well supported by the available literature. The cumulative effects of forest health and protection treatments imposed across a large region are difficult to assess, however. Given the current state of knowledge, dramatically changing forest land use practices across eastern Oregon and Washington-including the widespread use of prescribed fires, salvage logging, and mechanical fuel treatments-is a long-term, landscape-scale experiment, the cumulative effects of which are unknown.

Aquatic Species: The author mentions salmonids and the negative effects of sedimentation.

Appendix C. Abstracts of Publications Potentially Relevant to the Secondary Focus

Secondary Focus: Are there hillslope processes other than upslope initiated shallow rapid slides that may affect covered species within the draft Habitat Conservation Plan (HCP) and are these processes changed by forest practices?

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Jordan et al. 2010	British Columbia	Q1, Q2		x	x	x	

Reference

Jordan, P., T.H. Millard, D. Campbell, J. W. Schwab, D.J. Wilford, D. Nicol, and D. Collins. 2010. Forest Management Effects on Hillslope Processes (Chapter 9, page 275-330). In: Compendium of Forest Hydrology and Geomorphology in British Columbia Volume 1 of 2. (Eds) R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler, and K. D. Bladon. Ministry of Forests and Range Forest Science Program. British Columbia https://fews.forestry.oregonstate.edu/publications/AA_LMH66_volume1of2.pdf

Abstract

The authors did not provide an abstract.

<u>Specific location</u>: Interior British Columbia

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Lineback-Gritzner et al. 2001	Idaho	Q1, Q2		x	p		

Reference

Lineback Gritzner, M., W.A. Marcus, R. Aspinall, and S.G. Custer. 2001. Assessing landslide potential using GIS, soil wetness modeling and topographic attributes, Payette River, Idaho. Geomorphology 37(1): 149–165. https://doi.org/10.1016/S0169-555X(00)00068-4

Abstract

This study utilizes GIS modeling to determine if the location of 559 landslides in the 875 km2 catchment of the Middle Fork of the Payette River, Idaho can be predicted based on topographic attributes and a wetness index generated by the DYNWET model. Slope and elevation were significantly related to landslide occurrence at this landscape scale. Aspect was also retained as a variable for further analysis because, despite a non-significant chi-square relation to landslide occurrence, graphical analysis suggested a relation between aspect and mass wasting. Chi-square analysis indicated that plan and profile curvature, flow path length, upslope contributing area, and the DYNWET-based moisture index were not significantly related to landsliding. A Bayesian probability model based on combinations of elevation, slope, aspect, and wetness indicates that elevation exhibits the closest relation to landsliding, followed by slope; but that neither aspect nor wetness index values help in prediction. The Bayesian probability model using elevation and slope generates a map of relative landslide risk that can be used to direct activities away from mass wasting prone areas. The association between elevation and landslides is perplexing but is perhaps due to the location of logging road at specific elevations (roads could not be included in the input data for analysis because they have not been adequately mapped). The lack of explanation provided by the DYNWET wetness index was also surprising and may be due to the 30-m digital elevation model (DEM) and the soils data having resolutions too coarse to adequately portray local variations key to mass wasting. We believe the inadequacy of data to drive the models is typical of the majority of catchment scale setting. For now, the ability of researchers to effectively model landscape scale landsliding is more limited by the type, resolution, and quality of available data than by the quality of the landslide models.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Luce et al. 2012	western US	Q1, Q2		x	x	x	x

Reference

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. Gen. Tech. Rep. RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 207 pp https://research.fs.usda.gov/treesearch/41932#

Abstract

Fire will play an important role in shaping forest and stream ecosystems as the climate changes. Historic observations show increased dryness accompanying more widespread fire and forest die-off. These events punctuate gradual changes to ecosystems and sometimes generate stepwise changes in ecosystems. Climate vulnerability assessments need to account for fire in their calculus. The biophysical template of forest and stream ecosystems determines much of their response to fire. This report describes the framework of how fire and climate change work together to affect forest and fish communities. Learning how to adapt will come from testing, probing, and pushing that framework and then proposing new ideas. The western U.S. defies generalizations, and much learning must necessarily be local in implication. This report serves as a scaffold for that learning. It comprises three primary chapters on physical processes, biological interactions, and management decisions, accompanied by a special section with separately authored papers addressing interactions of fish populations with wildfire. Any one of these documents could stand on its own. Taken together, they serve as a useful reference with varying levels of detail for land managers and resource specialists. Readers looking for an executive summary are directed to the sections titled “Introduction” and “Next Steps.”

<u>Aquatic species</u>: fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Megahan et al. 1978	Idaho	Q1, Q2		x	x		

Reference

Megahan, W.F., N.F. Day, and Bliss, 1978. Landslide occurrence in the western and central northern Rocky Mountain physiographic province in Idaho. In: Youngberg, C.T. (Ed.), Forest Soils and Land Use, Proceedings of the Fifth North American Forest Soils Conference. Colorado State University, Department of Forest and Wood Sciences, Fort Collins, CO, pp. 116–139. https://geodata.geology.utah.gov/pages/view.php?ref=4784&search=&offset=15100&order_by=resourcetype&sort=DESC&archive=0&k=&

Abstract

The authors did not provide an abstract.

Specific location: Idaho batholith - Clearwater National Forest in northern Idaho and Boise National Forest in west-central Idaho

Appendix D. Abstracts of "Process Relevant" Publications

These documents found were classified as "process relevant," that is they were focused on mass wasting on forestlands but without any direct connection to forest management activities. As these were seen as containing potentially useful context information, they are summarized here. The largest number came from Idaho (7), followed by studies spanning multiple western states (6); three were located in California and one each in Colorado, Wyoming, and New Mexico. None were located in eastern Oregon or Washington. By definition none of these addressed forest practices but all addressed hillslope processes and all overlapped with semi-arid environments. Most of these studies (14) involved investigations of post-wildfire surficial erosion and mass wasting.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Cannon and DeGraff 2008	California		x		x	x	

Reference

Cannon, S.H., and J. DeGraff. 2008. The increasing wildfire and post-fire debris-flow threat in western USA, and implications for consequences of climate change. In: Sassa, K., Canuti, P. (Eds.), Landslides — Disaster Risk Reduction: Proceedings of 1st World Landslide Forum. Springer-Verlag, Berlin, pp. 177–190. https://link.springer.com/chapter/10.1007/978-3-540-69970-5_9

Abstract

The authors did not provide an abstract.

<u>Specific location</u>: southern California and the intermountain West

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Cannon and Gartner 2005	western US		x		x	x	

Reference

Cannon, S.H., and J.E. Gartner. 2005. Wildfire-related debris flow from a hazards perspective. In: Hungr, O., Jacob, M. (Eds.), Debris Flow Hazards and Related Phenomena. Praxis, Springer-Verlag, Berlin, pp. 363–385 https://link.springer.com/content/pdf/10.1007/3-540-27129-5_15.pdf

Abstract

The authors did not provide an abstract.

<u>Specific location</u>: various - data from 95 basins throughout the western United States

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Cannon et al. 2003	western US		x			x	

Reference

Cannon, S.H., J.E. Gartner, C. Parrett, and M. Parise. 2003. Wildfire-related debris-flow generation through episodic progressive sediment-bulking processes, western USA. In: Rickenmann, D., Chen, C. (Eds.), Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment. Millpress, Rotterdam, pp. 71–82.

Abstract

Debris-flow initiation processes on hillslopes recently burned by wildfire differ from those generally recognized on unburned, vegetated hillslopes. These differences result from fire-induced changes in the hydrologic response to rainfall events. In this study, detailed field and aerial photographic mapping, observations, and measurements of debris-flow events from three sites in the western U.S. were used to describe and evaluate the process of episodic progressive sediment bulking of storm runoff that leads to the generation of post-wildfire debris flows. Our data demonstrate the effects of material erodibility, sediment availability on hillslopes and in channels, the degree of channel confinement, the formation of continuous channel incision, and the upslope contributing area and its gradient on the generation of flows and the magnitude of the response are demonstrated.

Specific location: three sites in the western United States - Hamilton, Montana, Glenwood Springs, Colorado, and Los Alamos, New Mexico

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Cannon et al. 2010	western US		x	x	x	x	

Reference

Cannon, S.H., J.E. Gartner, M.G. Rupert, J.A. Michael, A.H. Rea, and C. Parrett. 2010.Predicting the probability and volume of post-wildfire debris flows in the intermountain western United States. Geological Society of America Bulletin 122, 127–144. https://www.researchgate.net/publication/249527492_Predicting_the_probability_and_volume_of_postwildfire_debris_flows_in_the_intermountain_western_United_States

Abstract

Empirical models to estimate the probability of occurrence and volume of post wildfire debris flows can be quickly implemented in a geographic information system (GIS) to generate debris-flow hazard maps either before or immediately following wildfires. Models that can be used to calculate the probability of debris-flow production from individual drainage basins in response to a given storm were developed using logistic regression analyses of a database from 388 basins located in 15 burned areas located throughout the U.S.

Intermountain West. The models describe debris-flow probability as a function of readily obtained measures of areal burned extent, soil properties, basin morphology, and rainfall from short-duration and low recurrence-interval convective rainstorms. A model for estimating the volume of material that may issue from a basin mouth in response to a given storm was developed using multiple linear regression analysis of a database from 56 basins burned by eight fi res. This model describes debris-flow volume as a function of the basin gradient, aerial burned extent, and storm rainfall. Applications of a probability model and the volume model for hazard assessments are illustrated using information from the 2003 Hot Creek fire in central Idaho. The predictive strength of the approach in this setting is evaluated using information on the response of this fi re to a localized thunderstorm in August 2003. The mapping approach presented here identifies those basins that are most prone to the largest debris-flow events and thus provides information necessary to prioritize areas for postfire erosion mitigation, warnings, and pre-fire management efforts throughout the Intermountain West.

Specific location: U.S. Intermountain West - Idaho, Montana, Utah, Colorado, and southern California

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Cannon et al. 2008	western US		x		x	x	

Reference

Cannon, S.H., J.E. Gartner, R.C. Wilson, J.C. Bowers, and J.L. Laber. 2008. Storm rainfall conditions for floods and debris flows from recently burned areas in southwestern Colorado and southern California. Geomorphology 96, 250–269.

Abstract

Debris flows generated during rain storms on recently burned areas have destroyed lives and property throughout the Western U.S. Field evidence indicate that unlike landslide-triggered debris flows, these events have no identifiable initiation source and can occur with little or no antecedent moisture. Using rain gage and response data from five fires in Colorado and southern California, we document the rainfall conditions that have triggered post-fire debris flows and develop empirical rainfall intensity–duration thresholds for the occurrence of debris flows and floods following wildfires in these settings. This information can provide guidance for warning systems and planning for emergency response in similar settings.

Debris flows were produced from 25 recently burned basins in Colorado in response to 13 short-duration, high-intensity convective storms. Debris flows were triggered after as little as six to 10 min of storm rainfall. About 80% of the storms that generated debris flows lasted less than 3 h, with most of the rain falling in less than 1 h. The storms triggering debris flows ranged in average intensity between 1.0 and 32.0 mm/h, and had recurrence intervals of two years or less. Threshold rainfall conditions for floods and debris flows sufficiently large to pose threats to life and property from recently burned areas in south-central, and southwestern, Colorado are defined by: $I=6.5D^{-0.7}$ and $I=9.5D^{-0.7}$, respectively, where I=rainfall intensity (in mm/h) and D=duration (in hours).

Debris flows were generated from 68 recently burned areas in southern California in response to long-duration frontal storms. The flows occurred after as little as two hours, and up to 16 h, of low-intensity (2–10 mm/h) rainfall. The storms lasted between 5.5 and 33 h, with average intensities between 1.3 and 20.4 mm/h, and had recurrence intervals of two years or less. Threshold rainfall conditions for life- and property-threatening floods and debris flows during the first winter season following fires in Ventura County, and in the San Bernardino, San Gabriel and San Jacinto Mountains of southern California are defined by $I= 12.5D^{-0.4}$, and $I=7.2D^{-0.4}$, respectively. A threshold defined for flood and debris flow conditions following a year of vegetative recovery and sediment removal for the San Bernardino, San Gabriel and San Jacinto Mountains of $I=14.0D^{-0.5}$ is approximately 25 mm/h higher than that developed for the first year following fires.

Specific location: Colorado and southern California

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
DeGraff 1994	California		x	x	x	x	

Reference

DeGraff, J.V. 1994. The geomorphology of some debris flows in the southern Sierra Nevada, California. Geomorphology and Natural Hazards. Elsevier, 1994. 231-252. https://doi.org/10.1016/0169-555X(94)90019-1

Abstract

Debris flows are one of the natural hazards present in the southern Sierra Nevada of California. Historic debris flow activity is documented at a USDA Forest Service research facility in the Kings River drainage related to a 1937 storm event. No subsequent study of this phenomenon was undertaken until 1982. Observations of debris flows over the succeeding 10 years offer an initial assessment of the physical geomorphology of debris flows in this area. This information provides a starting point for future efforts to avoid or limit the effect of this natural hazard.

Observations were made in the Tuolumne, Merced, San Joaquin, and Kings River drainages. Of the twenty-six debris flows observed, six were examined in detail to provide specific data on this phenomenon. Triggering events for debris flows in the southern Sierra Nevada include intense rainfall, rain-on-snow storms, and seasonal melting of heavy snowpacks. Movement typically occurs at depths between 0.3 and 5 m below ground surface. This is representative of depths for the three interfaces associated with initiation of movement: (1) at the base of the root zone, (2) at the contact of well-weathered and less-weathered soil, and (3) at the contact between soil and unweathered bedrock. Measurement of debris flow velocity based on indirect methods found values ranging from 2.6 m/s to 7.2 m/s (9 km/h to 26 km/h). Recurrence intervals based on radiocarbon dates are between 425 and 500 years BP.

Roads and other land use investments have suffered damage from debris flow activity during the 1982 to 1993 period. Stump Springs road in the San Joaquin river drainage required US$1.4 million to repair damage primarily from 1982 debris flows. The threat to life arising from debris flows is illustrated by the consequences of vegetation losses from wildfire near El Portal, California. The projected population growth

with associated increased infrastructure raises concern for greater impacts from future debris flow occurrence in the southern Sierra Nevada.

Specific location: southern Sierra Nevada of California, Tuolomne, Merced, San Joaquin, and Kings River drainages

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Dunham et al. 2007	Idaho		x		x	x	x

Reference

Dunham, J.B., A.E. Rosenberger, C.H. Luce, and B.E. Rieman. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems 10:335–346. https://doi.org/10.1007/s10021-007-9029-8

Abstract

Wildfire can influence a variety of stream ecosystem properties. We studied stream temperatures in relation to wildfire in small streams in the Boise River Basin, located in central Idaho, USA. To examine the spatiotemporal aspects of temperature in relation to wildfire, we employed three approaches: a pre–post fire comparison of temperatures between two sites (one from a burned stream and one unburned) over 13 years, a short term (3 year) pre–post fire comparison of a burned and unburned stream with spatially extensive data, and a short-term (1 year) comparative study of spatial variability in temperatures using a ''space for time'' substitutive design across 90 sites in nine streams (retrospective comparative study). The latter design included streams with a history of stand-replacing wildfire and streams with severe post-fire reorganization of channels due to debris flows and flooding. Results from these three studies indicated that summer maximum water temperatures can remain significantly elevated for at least a decade following wildfire, particularly in streams with severe channel reorganization. In the retrospective comparative study we investigated occurrence of native rainbow trout (*Oncorhynchus mykiss*) and tailed frog larvae (*Ascaphus montanus*) in relation to maximum stream temperatures during summer. Both occurred in nearly every site sampled, but tailed frog larvae were found in much warmer water than previously reported in the field (26.6_C maximum summer temperature). Our results show that physical stream habitats can remain altered (for example, increased temperature) for many years following wildfire, but that native aquatic vertebrates can be resilient. In a management context, this suggests wildfire may be less of a threat to native species than human influences that alter the capacity of stream-living vertebrates to persist in the face of natural disturbance.

Specific location: Boise River basin in central Idaho

Aquatic species: Rainbow trout (*Oncorhynchus mykiss*), Rocky Mountain tailed frog (*Ascaphus montanus*) and bull trout (*Salvelinus confluentus*)

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Gorsevski 2023	Idaho		x				

Reference

Gorsevski, P.V. 2023. A free web-based approach for rainfall-induced landslide susceptibility modeling: Case study of Clearwater National Forest, Idaho, USA. Environmental Modelling & Software. 161: 105632. https://doi.org/10.1016/j.envsoft.2023.105632

Abstract

This study presents an interactive web-based approach for modeling rainfall-induced landslide susceptibility using Free Open Source Software (FOSS). The design is based on the R statistical framework and Shiny package coupled with the shallow slope stability model (SHALSTAB) from SAGA GIS. The easy-to-use real-time application extends the potential of current modeling efforts to non-expert R and GIS users and can also be used in an educational context for classroom teaching activity and enabling research-informed learning. The parsimonious approach (i.e. few parameter inputs) is accomplished in two sequential steps including modeling and validation by the use of site-specific datasets. The approach was tested in a case study on the Clearwater National Forest and the results from the validation showed an overall accuracy of 0.894, kappa of 0.789 and AUC from ROC curve was 0.715. The modeled landslide potential may be used as a decision-support tool for local planning.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Istanbulluoglu et al. 2003	Idaho		x	x	x	x	

Reference

Istanbulluoglu, E., D.G. Tarboton, R.T. Pack, and C.H. Luce. 2003. A sediment transport model for incision of gullies on steep topography. Water Resources Research 39,1103. https://research.fs.usda.gov/treesearch/8362

Abstract

We have conducted surveys of gullies that developed in a small, steep watershed in the Idaho Batholith after a severe wildfire followed by intense precipitation. We measured gully length and cross sections to estimate the volumes of sediment loss due to gully formation. These volume estimates are assumed to provide an estimate of sediment transport capacity at each survey cross section from the single gully-forming thunderstorm. Sediment transport models commonly relate transport capacity to overland flow shear stress, which is related to runoff rate, slope, and drainage area. We have estimated the runoff rate and duration associated with the gully-forming event and used the sediment volume measurements to calibrate a general physically based sediment transport equation in this steep, high shear stress environment. We find that a shear stress exponent of 3, corresponding to drainage area and slope exponents of M = 2.1 and N = 2.25, match our data. This shear stress exponent of 3 is approximately 2 times higher than those for bed load transport in alluvial rivers but is in the range of shear stress exponents derived from flume experiments on steep slopes and with total load equations. The concavity index of the gully profiles obtained theoretically from the area and slope exponents of the sediment transport equation, $q_c = (M-1)/N$, agrees well with the observed profile concavity of the gullies. Our results, although preliminary because of the uncertainty associated with the sediment volume estimates, suggest that for steep hillslopes such as those in our study area, a greater nonlinearity in the sediment transport function exists than that assumed in some existing hillslope erosion models which calculate sediment transport capacity using the bed load equations developed for rivers.

Specific location: Idaho batholith region - Trapper Creek within the North Fork of the Boise River in SW Idaho

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Kirchner et al. 2001	Idaho		x		x	x	x

Reference

Kirchner, J.W., R.C. Finkel, C.S. Riebe, D.E. Granger, J.L. Clayton, J.G King, and W.F. Megahan. 2001. Mountain erosion over 10 yr., 10 k.y., and 10 m.y. time scales. Geology 29, 591–594. https://research.fs.usda.gov/treesearch/23971

Abstract

We used cosmogenic ^{10}Be to measure erosion rates over 10 k.y. time scales at 32vIdaho mountain catchments, ranging from small experimental watersheds (0.2 km2) to large river basins (35 000 km2). These long-term sediment yields are, on average, 17 times higher than stream sediment fluxes measured over 10–84 yr, but are consistent with 10vm.y. erosion rates measured by apatite fission tracks. Our results imply that conventional sediment-yield measurements—even those made over decades—can greatly underestimate long-term average rates of sediment delivery and thus overestimate the life spans of engineered reservoirs. Our observations also suggest that sediment delivery from mountainous terrain is extremely episodic, sporadically subjecting mountain stream ecosystems to extensive disturbance.

Specific location: central Idaho

Aquatic species: species that recolonize disturbed habitats

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
McGuire et al. 2016	Colorado		x	?	x	x	

Reference

McGuire, L., F. Rengers, J. Kean, J. Coe, B. Mirus, R. Baum, and J. Godt. 2016. Elucidating the role of vegetation in the initiation of rainfall-induced shallow landslides: Insights from an extreme rainfall event in the Colorado Front Range. GEOPHYSICAL RESEARCH LETTERS. 43(17): 9084–9092. https://doi.org/10.1002/2016GL070741

Abstract

More than 1100 debris flows were mobilized from shallow landslides during a rainstorm from 9 to 13 September 2013 in the Colorado Front Range, with the vast majority initiating on sparsely vegetated, south facing terrain. To investigate the physical processes responsible for the observed aspect control, we made measurements of soil properties on a densely forested north facing hillslope and a grassland-dominated south facing hillslope in the Colorado Front Range and performed numerical modeling of transient changes in soil pore water pressure throughout the rainstorm. Using the numerical model, we quantitatively assessed interactions among vegetation, rainfall interception, subsurface hydrology, and slope stability. Results suggest that apparent cohesion supplied by roots was responsible for the observed connection between debris flow initiation and slope aspect. Results suggest that future climate-driven modifications to forest structure could substantially influence landslide hazards throughout the Front Range and similar water-limited environments where vegetation communities may be more susceptible to small variations in climate.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Meyer et al. 2001	Idaho		x	?	x	x	

Reference

Meyer, G., J. Pierce, S. Wood, and A. Jull. 2001. Fire, storms, and erosional events in the Idaho batholith. Hydrological Processes 15(15): 3025–3038. https://doi.org/10.1002/hyp.389

Abstract

In late December 1996, the South Fork Payette River basin in west-central Idaho experienced a prolonged storm that culminated on January 1. 1997, with intense rain on melting snow that triggered slide failures, producing debris flows and sediment-charged floods. Failures occurred in saturated, cohesionless, grussy colluvium derived from Weathered Idaho batholith granitic rocks. Many failures along the South Fork Payette River originated in ponderosa pine forests burned in the 1989 stand-replacing Lowman fire. An example is the 0.49 km(2) 'Jughead' Creek basin. where a single large colluvial failure produced almost 40% of the total volume eroded from the basin and generated a massive and rapid debris flow. Failures also occurred in steep, unburned. and unforested drainages such as Hopkins Creek. In this south-facing 0.58 km(2) basin, 15 colluvial hollows failed. but no single failure produced more than 10% of the total eroded volume. Sediment transport in Hopkins Creek occurred by prolonged sediment-charged sheetflooding. Despite vegetation differences, sediment yields from the geomorphically similar Hopkins Creek (similar to 42 000 Mg km(-2)) and Jughead Creek (similar to 44 000 Mg km(-2)) basins were quite similar. These 1997 erosion events are equivalent to several thousand years of sediment yield at low rates (2.7-30 Mg km(2) year(-1)) measured by short-term sediment trapping and gauging in Idaho batholith watersheds. If similar large events were solely responsible for sediment export. recurrence intervals (Rls) of several hundred years would account for higher sediment yields averaged over similar to 10(4) year from Idaho batholith watersheds. Dating of small fire-induced sheetflooding events in an early Holocene tributary junction fan of Jughead Creek indicates that frequent small sedimentation events (RI approximate to 33-80 year) occurred between 7400 and 6600 cal year BP. with an average yield not greatly exceeding 16 Mg km(-2) year(-1). Compared with the Holocene average, erosion rates during that 800-year period were unusually low, suggesting that sediment yields have not been constant over time, and that climatic variations and related fire regime changes may exert a strong influence on the probability of major erosional events.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Meyer et al. 1992	western US		x		x	x	

Reference

Meyer, G.A., S.G. Wells, R.C. Balling Jr, and A.J.T. Jull. 1992. Response of alluvial systems to fire and climate change in Yellowstone National Park. NATURE. 357(6374): 147–150. https://doi.org/10.1038/357147a0

Abstract

Projections of the ecological effects of global climate change often include increased frequency and/or intensity of forest fires in regions of warmer and drier climate 1-3. In addition to disturbing biological systems, widespread intense fires may influence the evolution of the physical landscape through greatly enhanced sediment transport 4. Debris-flow to flood-streamflow sedimentation events following the 1988 fires in the Yellowstone National Park area (Wyoming and Montana, USA) have allowed us to examine the geomorphological response to fire in a mountain environment. Abundant analogous deposits in older alluvial fan sequences bear witness to past fire-related sedimentation events in northwestern Yellowstone, and radiocarbon dating of these events yields a detailed chronology of fire-related sedimentation for the past 3,500 years. We find that alluvial fans aggrade during periods of frequent fire-related sedimentation events, and we interpret these periods as subject to drought or high climatic variability. During wetter periods, sediment is removed from alluvial fan storage and transported down axial streams, resulting in floodplain aggradation. The dominant alluvial activity is strongly modulated by climate, with fire acting as a drought-actuated catalyst for sediment transport.

Specific location: Montana, Wyoming

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Moody and Martin 2009	western US		x		x	x	

Reference

Moody, J.A., and D.A. Martin. 2009. Synthesis of sediment yields after wildland fire in different rainfall regimes in the western United States. International Journal of Wildland Fire 18: 96–115. https://doi.org/10.1071/WF07162

Abstract

Measurements of post-fire sediment erosion, transport, and deposition collected within 2 years of a wildfire were compiled from the published literature (1927–2007) for sites across the western United States. Annual post-fire sediment yields were computed and grouped into four measurement methods (hillslope point and plot measurements, channel measurements of suspended-sediment and sediment erosion or deposition volumes). Post-fire sediment yields for each method were then grouped into eight different rainfall regimes. Mean sediment yield from channels (240 t ha^{-1}) was significantly greater than from hillslopes (82 t ha^{-1}). This indicated that on the time scale of wildfire (10–100 years) channels were the primary sources of available sediment. A lack of correlation of sediment yield with topographic slope and soil erodibility further suggested that sediment availability may be more important than slope or soil erodibility in predicting post-fire sediment yields. The maximum post-fire sediment yields were comparable to long-term sediment yields from major rivers of the world. Based on 80 years of data from the literature, wildfires have been an important geomorphic agent of landscape change when linked with sufficient rainfall. These effects are limited in spatial scale to the immediate burned area and to downstream channel corridors.

Specific location: western U.S., including the Sub-Pacific rainfall regime, which spans eastern Oregon and eastern Washington

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Pierce et al. 2004	Idaho		x		x	x	

Reference

Pierce, J., G. Meyer, and A. Jull. 2004. Fire-induced erosion and millennial scale climate change in northern ponderosa pine forests. Nature. 432(7013): 87–90. https://doi.org/10.1038/nature03058

Abstract

Western US ponderosa pine forests have recently suffered extensive stand-replacing fires followed by hillslope erosion and sedimentation(1-4). These fires are usually attributed to increased stand density as a result of fire suppression, grazing and other land use, and are often considered uncharacteristic or unprecedented(1-3). Tree-ring records from the past 500 years indicate that before Euro-American settlement, frequent, low-severity fires maintained open stands(1-3). However, the pre-settlement period between about AD 1500 and AD 1900 was also generally colder than present(5-10), raising the possibility that rapid twentieth-century warming promoted recent catastrophic fires. Here we date fire-related sediment deposits in alluvial fans in central Idaho to reconstruct Holocene fire history in xeric ponderosa pine forests and examine links to climate. We find that colder periods experienced frequent low-severity fires, probably fuelled by increased understory growth. Warmer periods experienced severe droughts, stand-replacing fires and large debris-flow events that comprise a large component of long-term erosion(11) and coincide with similar events in sub-alpine forests of Yellowstone National Park(12). Our results suggest that given the powerful influence of climate, restoration of processes typical of pre-settlement times may be difficult in a warmer future that promotes severe fires.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Rengers et al. 2023	New Mexico		x		x	x	

Reference

Rengers, F.K., L.A. McGuire, K.R. Barnhart, A.M. Youberg, D. Cadol, A.N. Gorr, O.J. Hoch, R. Beers, and J.W. Kean. 2023 The influence of large woody debris on post-wildfire debris flow sediment storage. Natural Hazards and Earth System Sciences 23(6): 2075–2088.

Abstract

Debris flows transport large quantities of water and granular material, such as sediment and wood, and this mixture can have devastating effects on life and infrastructure. The proportion of large woody debris (LWD) incorporated into debris flows can be enhanced in forested areas recently burned by wildfire because wood recruitment into channels accelerates in burned forests. In this study, using four small watersheds in the Gila National Forest, New Mexico, which burned in the 2020 Tadpole Fire, we explored new approaches to estimate debris flow velocity based on LWD characteristics and the role of LWD in debris flow volume retention. To understand debris flow volume model predictions, we examined two models for debris flow volume estimation: (1) the current volume prediction model used in US Geological Survey debris flow hazard assessments and (2) a regional model developed to predict the sediment yield associated with debris-laden flows. We found that the regional model better matched the magnitude of the observed sediment at the terminal fan, indicating the utility of regionally calibrated parameters for debris flow volume prediction. However, large wood created sediment storage upstream from the terminal fan, and this volume was of the same magnitude as the total debris flow volume stored at the terminal fans. Using field and lidar data we found that sediment retention by LWD is largely controlled by channel reach slope and a ratio of LWD length to channel width between 0.25 and 1. Finally, we demonstrated a method for

estimating debris flow velocity based on estimates of the critical velocity required to break wood, which can be used in future field studies to estimate minimum debris flow velocity values.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Rengers 2020	California		x		x	x	

Reference

Rengers, F.K., L.A. McGuire, N.S. Oakley, J.W. Kean, D.M. Staley, and H. Tang. 2020. Landslides after wildfire: initiation, magnitude, and mobility. Landslides 17(11): 2631–2641. https://doi.org/10.1007/s10346-020-01506-3

Abstract

In the semiarid Southwestern USA, wildfires are commonly followed by runoff-generated debris flows because wildfires remove vegetation and ground cover, which reduces soil infiltration capacity and increases soil erodibility. At a study site in Southern California, we initially observed runoff-generated debris flows in the first year following fire. However, at the same site three years after the fire, the mass-wasting response to a long-duration rainstorm with high rainfall intensity peaks was shallow landsliding rather than runoff-generated debris flows. Moreover, the same storm caused landslides on unburned hillslopes as well as on slopes burned 5 years prior to the storm and areas burned by successive wildfires, 10 years and 3 years before the rainstorm. The landslide density was the highest on the hillslopes that had burned 3 years beforehand, and the hillslopes burned 5 years prior to the storm had low landslide densities, similar to unburned areas. We also found that reburning (i.e., two wildfires within the past 10 years) had little influence on landslide density. Our results indicate that landscape susceptibility to shallow landslides might return to that of unburned conditions after as little as 5 years of vegetation recovery. Moreover, most of the landslide activity was on steep, equatorial-facing slopes that receive higher solar radiation and had slower rates of vegetation regrowth, which further implicates vegetation as a controlling factor on post-fire landslide susceptibility. Finally, the total volume of sediment mobilized by the year 3 landslides was much smaller than the year 1 runoff-generated debris flows, and the landslides were orders of magnitude less mobile than the runoff-generated debris flows.

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Welcker 2011	Idaho		x		x	x	x

Reference

Welcker, C. 2011. Bulking debris flow initiation and impacts. PhD Thesis, University of Idaho. 196pp. https://www.academia.edu/89622446/Bulking_Debris_Flow_Initiation_and_Impacts

Abstract

Bulking debris flows (BDFs) are generated by infiltration excess (Horton) overland flow, eroding sufficient sediment on steep, sparsely-vegetated hillslopes to achieve debris-flow rheology. BDFs erode sediment from hillslopes and previously unchanneled hollows, entering the perennial stream network and scouring alluvium along their path to junctions with larger streams, where they typically deposit. Although BDFs have been documented in arid or burned sites throughout the western United States for over 100 years, their initiation is poorly understood, as are their geomorphic and ecological effects.

I developed a numerical model of BDF initiation from overland flow to test the hypothesis that BDFs can be generated without mass failure or episodic addition of sediment. The model incorporated erosion of sediment as bedload, transfer of bedload to suspended load, and alteration of fluid properties based on increased suspended load, which in turn increased bedload and suspended sediment transport. The predicted transition to debris-flow sediment concentrations and the pattern of hillslope erosion showed good agreement with field observations.

Debris-flow generation in arid landscapes that experience progressive sediment bulking should lead to measurably different slope area trends of channel-head locations and topography than humid landscapes by shallow landslide debris flows (SLDFs). I hypothesized that the slope area trend of BDF channel heads would follow the underlying hillslope topography, rather than previously described theoretical relationships, and this expectation was confirmed by field surveys. I also hypothesized that the lack of bedrock erosion by BDFs would result in a different topographic signature than the profile previously attributed to SLDFs. Surprisingly, survey results revealed longitudinal profiles for BDFs similar to SLDFs, but they did not correspond with the observed extent of BDF erosion.

I hypothesized that BDF disturbance would reduce riparian vegetation and shading, leading to increased stream temperatures and adverse effects on aquatic biota. Field work demonstrated that BDF effects on stream temperature lasted for 7-40 years and were found to be greater than for wildfire disturbance alone. Stream temperature was well correlated with solar radiation, but reach heating was complicated by site-specific cooling, which appears to be related to the size of the local, alluvial aquifer.

Specific location: Idaho batholith

Aquatic species: fish

Reference	Location	Question (Q1 or Q2)	Process relevant	Forest harvest-related activities	Hillslope processes - mass wasting	Environmental similarity to eastern Oregon	HCP covered species and their habitats
Zung et al. 2009	Wyoming	Q2?			x	x	

Reference

Zung, A.B., C.J. Sorenson, and E. Winthers. 2009. Landslide Soils and Geomorphology in Bridger-Teton National Forest, Northwest Wyoming. Physical Geography. 30(6): 501–516. https://doi.org/10.2747/0272-3646.30.6.501

Abstract

Active landslides are evident throughout Bridger-Teton National Forest (BTNF), and northwestern Wyoming has one of the highest landslide densities in the country. Land use changes and increased demands for infrastructure challenge BTNF personnel to better understand landslide processes in order to make informed land management decisions. Despite recent population growth in the region, research on landslide phenomena is lacking. In this study, soil and geomorphic properties related to landslide occurrence were studied at 18 landslides in the BTNF. Landslides were categorized as active or inactive based on geomorphic features. Landslide soil characteristics including texture, shrink-swell potential, clay mineralogy, and horizonation were compared on active and inactive landslides. The results indicate that soil characteristics related to the degree of soil formation are different on active and inactive landslides. Soil characteristics such as plasticity, shrink-swell potential, and clay mineralogy influence slope stability and were distinctly different on active and inactive landslides, especially in C horizons. This study shows that soil characteristics and slope geomorphic properties may be useful for assessing landslide frequency. Our results support a hypothesis that landslide occurrence in the BTNF is related to weathering of soil and unconsolidated material, which affects clay mineralogy.

Appendix E. Literature Review Examples

The methods and structure of two literature reviews found as part of the search process were analyzed as examples (Barrett and Reilly 2017; Herrera Environmental Consultants Inc. 2004). Both reports were commissioned by Washington's adaptive management program. The following paragraphs summarize key aspects of these studies that may be relevant for the development of IRST's research proposal.

Research questions: Barrett and Reilly (2017) reviewed the potential effects of salvage logging on riparian areas for Washington eastside forests, whereas Herrera (2004) focused on wood loading dynamics in and around streams in eastern Washington forests. Herrera was given a list of 41 specific research questions grouped into nine topic areas. Barrett did not have a list of questions, but they identified five relevant research subthemes (Silviculture/Forest Practices, Fuels/Fire, Erosion/Soils, Riparian/Aquatic, and Biodiversity/Ecosystems).

Process context: The Herrera study was embedded in a broader process, which included a kick-off workshop with the sponsoring committee, followed by the literature search, a broader workshop to review the literature found, consolidation of results in a literature database, and a final report. Barrett did not report on broader process but presented their findings to the sponsoring committee at project conclusion.

Eligibility criteria (Study area): Both studies expanded their search to include similar environments outside of the target state. Barrett's search encompassed Oregon, Idaho, western Montana, northern California, northern Nevada, southeastern British Columbia, and southwestern Alberta and searched for specific forest types. Herrera (2004) described three location categories: eastern Washington, "analogous regions" (they did not further define this), and other studies relevant to the topic.

Search: Both studies searched literature databases and solicited documents from subject matter experts. Barrett mentions searching in Google Scholar and ResearchGate and provided a few keyword examples. Herrera provided an appendix explicitly listing all databases searched (but not keywords) and all individuals and institutions contacted.

Selection (Screening): Barrett includes a short section on screening but without much description of an explicit methodology or number of documents screened. They reviewed 75 documents. Herrera reports compiling more than 5,000 documents, however, no further information on screening is provided.

Data extraction: Barrett was given a number of elements to extract, including topics/keywords, location, forest types, forest practices, and analysis methods. In addition, they assigned studies to five relevant research subthemes (Silviculture/Forest Practices, Fuels/Fire, Erosion/Soils, Riparian/Aquatic, Biodiversity/Ecosystems). They used an Excel workbook to store and analyze the information.

Results: Herrera structured the main body of their report around the 41 specific research questions grouped into nine topic areas, addressing each one in a separate section. Each relevant literature source that contains quantitative data is briefly discussed, and an assessment is made of the extent to which data collected for the question covers eastern Washington stream channel sizes and forest types. Both reports started with a large number of specific questions (15 for Barrett and 41 for Herrera) and summarized the literature for each question. Barrett identified five relevant research subthemes (Silviculture/Forest Practices, Fuels/Fire, Erosion/Soils, Riparian/Aquatic, Biodiversity/Ecosystems) and summarized the literature for each. Barrett mapped the location of each study and noted certain clusters around large fires.

Additional products: Barrett produced a database of publications in Excel format; Herrera compiled the literature found in a Procite bibliographic database.