WASHINGTON FOREST PROTECTION ASSOCIATION
724 Columbia St NW, Suite 250
Olympia, WA 98501
360-352-1500 Fax: 360-352-4621

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Submitted online via Ecology online comment web portal

Washington State Department of Ecology
Watershed Management Unit
PO Box 47696
Olympia, WA 98504-7696

Subject: Comment Letter on Ecology's Draft Tier II Antidegradation Analysis for Proposed Western Washington Type Np Buffer Rule (July 2025)

Dear Department of Ecology:

On behalf of the Washington Forest Protection Association (WFPA), I submit the following comments on Ecology's July 2025 Draft Tier II Antidegradation Analysis prepared for the Forest Practices Board's (FPB) proposed Western Washington Type Np buffer rule. WFPA is a forestry trade association founded in 1908 representing large and small private forest landowners and managers of more than four million acres of working forests in Washington State. Our members are essential to the environmental, economic, and social fabric of Washington's rural and urban communities, providing sustainably grown forest products for domestic and international markets.

Throughout the Type Np rulemaking process, Ecology has misapplied the requirements of Tier II antidegradation review as applied to forest practices and, in doing so, misdirected the FPB and its Adaptive Management Program (AMP). On that foundation, through its Draft Tier II Analysis, it has suddenly imposed an unprecedented process never before required in nearly a quarter century since the Forest Practices Rules were permanently adopted pursuant to the 1999 Forest and Fish Report and corresponding legislative amendments to the Forest Practices Act.

This sharp departure from precedent subverts the Legislature's explicit direction that Forest Practices Rules be guided by the scientifically based AMP, not through ad hoc reinterpretation and application of water quality regulations. By unilaterally stepping outside that framework, Ecology has effectively supplanted the FPB's process, as intended by the Legislature, with its own.

As outlined below, the Tier II analysis is flawed legally, procedurally, technically and scientifically. It reflects a novel, selective interpretation of Washington's Tier II antidegradation regulation, inconsistent application of Tier II requirements, misuse of statutory and regulatory authority, biased analysis of costs and benefits, and a selective presentation of scientific findings. Collectively, these deficiencies render Ecology's analysis deficient under state law. We urge Ecology to reconsider its extraordinary break from long-standing precedent so that the FPB may return this issue to the AMP for the evaluation of Type Np buffer effectiveness and alternatives with fidelity to the law, to science, and to the rulemaking process.

I. Ecology Misapplies Tier II by Treating the Proposal as a "New or Expanded Action"

Ecology asserts the FPB's proposed rule constitutes a "new or expanded action" requiring Tier II antidegradation review under WAC 173-201A-320. This interpretation is inconsistent with the plain language of WACs 173-201A-

020 and 320, ignores two decades of FPB and Ecology practice, and conflicts with the original adoption of Forest Practices Rules as a Water Pollution Control Program (WPCP).

For two decades, the Forest Practices Rules have been considered a Tier II-compliant WPCP pursuant to WAC 173-201A-320(6), subject to the AMP. Compliance with Tier II has been programmatic.[1] At no time has Ecology treated AMP-driven amendments to Forest Practices Rules affecting water quality as "new or expanded actions." The current proposed rule, misguided as it is due to Ecology's legally flawed reinterpretation of Tier II as prohibiting measurable temperature change, is an AMP-generated modification of the existing WPCP, not an entirely new regulatory regime. Ecology's new position constitutes an unwarranted and unprecedented departure from established Tier II implementation.

Further, Ecology's 2011 Supplemental Guidance on Implementing Tier II Antidegrdation[2] defines a "new or expanded action" as individual permitting activity not previously authorized, expanded discharge duration, volume, location, or pollutant load. None of these apply here: the rule making proposal modifies existing buffers under the existing Forest Practices Rules. New or expanded action is not even mentioned in the flow chart on page 2 of the guidance which describes the Tier II process for WPCPs.[3] Ecology's unilateral decision to exercise Tier II jurisdiction outside the AMP framework now, and not in any of the Forest Practices Rule amendments since 2001, is arbitrary and capricious under RCW 34.05.570(4).

Finally, Ecology continues to evolve its rationale on treating the proposed Type Np buffer rule as a "a new or expanded action" by stating the proposed rule is equivalent to a "reissued" general permit.[4] This latest justification for triggering Tier II as a new or expanded action is also inconsistent with the plain language of WAC 173-201A-320(6), Schedule M-2 of the Forests and Fish Report, Ecology practice for prior FPB rule makings affecting water quality, and Ecology's 2011 Antidegradation Tier II Guidance. Pursuant to WAC 173-201A-320(6), Tier II requirements are considered met for Forest Practices Rules, including Type Np buffers, via its AMP. There is therefore no basis for Ecology to treat the proposed rule as "new or expanded action"[5] Moreover, if, as Ecology's Tier II Analysis suggests, proposed amendments to Forest Practices Rules are akin to reissued general permits, Ecology has no basis to conduct a standalone assessment of whether Type Np buffers (i.e., nonpoint source best management practices) as applied to forest practices are "necessary and in the overriding public interest. Like general permits, Ecology's Supplemental Guidance indicates that the programmatic framework of the Forest Practices Rules, including its Type Np buffers, is in the overriding public interest and that the Tier II antidegradation regulation establishes a presumption that forest practices covered under WPCP are indeed necessary and in the overriding public interest.[6] As such, Ecology's

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[1] Ecology, WAC 170-201A Surface Water Quality Standards for the State of Washington, Responsiveness Summary, (July 1, 2003) (hereafter "Ecology 2003 Responsiveness Summary).

[2] Ecology, Supplemental Guidance on Implementing Tier II Antidegradation (Sep. 2011) (hereafter "Tier II Supplemental Guidance").

[3] *Id*. p. 2.

[4] Draft Western WA Type Np Tier II Antidegradation Analysis, p. 28 (July 2025) (hereafter "Tier II Analysis").

[5] By way of analogy, Ecology's Tier II approach for its 2025 industrial stormwater general permit, cites WAC 173-201A-320(6), stating "the antidegradation requirements of this section can be considered met for general permits and programs that have a formal process to select, develop, adopt, and refine control practices for protecting water quality and meeting the intent of this section." Ecology, Industrial Stormwater General Permit- Fact Sheet, p. 16 (May 15, 2024). Ecology goes on to state "Since Ecology has chosen to address Tier II anti-degradation in accordance with WAC 173-201A-320(6), Ecology will not perform site-specific analyses of each "new or expanded action" proposed for coverage under the permit." *Id.* at 18. The Forest Practices Rules, as an WPCP, is no different. Tier II compliance for the Forest Practices Rules, including its Type Np buffers, is addressed by law in accordance with WAC 173-201A-320(6), which acknowledges Tier II antidegradation requirements are met through the AMP. Under this framework, individual "new or expanded actions" seeking coverage an authorization under the WPCP, will not require site-specific Tier II analysis. It's clear then that the "new or expanded actions" phrase is meant for individual activities seeking coverage under the Forest Practices Rules, not to the programmatic framework of the Forest Practices Rules, including its Type Np buffer restrictions, which is a WPCP that complies with Tier II requirements via the AMP.

[6] Tier II Supplemental Guidance, p. 17 and 20.

unprecedented necessity and overriding public interest analysis for the proposed rule is inconsistent with its own policy in addition to multiple decades of implementing the Forest Practices Rules.

Attachment A to this letter presents a list of questions to Ecology regarding its past practice vis a vis Tier II and Forest Practices Rules.

II. Ecology's Position on Temperature Thresholds Is Inconsistent and Appears Outcome-Driven
Ecology has inconsistently applied its own temperature rules to justify Tier II review and the specific buffer prescriptions in the proposed rule. During the AMP's evaluation of Type Np buffers and alternative buffer options for proposed rulemaking, Ecology staff repeatedly—and inaccurately—asserted that Tier II prohibited forest practices from causing any measurable temperature increase (≥0.3°C) on Type Np waters and therefore studies showing measurable temperature change from application of existing Type Np buffers constitute a "violation" of Tier II requirements.[7]

This radical interpretation, however, is a drastic departure from the plain language of Tier II and Ecology's own long-standing interpretation of Tier II. Tier II, which has been around for more than 20 years, has never before been used to prohibit all measurable temperature change as dictated by Ecology in developing the proposed rule. As Ecology explained in 2003 when it developed the current iteration of its Tier II regulation, temperature increase that does not violate water quality criteria is not a violation of Tier II nor state water quality law:

> Allowing degradation that doesn't violate the water quality criteria established to protect uses is consistent with state and federal laws and regulations on antidegradation. Tier II just ensures that such degradation is necessary and that it provides compensating public benefits.[8]

And regarding the "measurable change" concept, Ecology explained in 2003 that it was simply a screening tool to determine which discharges subject to the Tier II law warrant Tier II *review*:

> The measurability factors are just a screen for sorting out which discharges are significant enough to warrant a Tier II review. It is not intended to capture every one, and the water quality criteria are in place to guard against tipping the balance for the health of a waterway.[9]

To summarize: Tier II expressly allows actions that have measurable temperature change where underlying criteria are met and such actions are necessary and have compensating public benefits; measurable change does not exceed or violate Tier II requirements; measurable change is simply one of the Tier II screening tools to determine whether Tier

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[7] See e.g., Technical Type Np Prescription Workgroup, Review of current and proposed riparian management zone prescriptions in meeting westside Washington State anti-degradation temperature criterion, Final Report, p. 3 (May 20, 2021) ("The state water quality measurable change standards permit no temperature increase of 0.3°C or greater," citing WAC 173-201A-320); Triangle Associates, Final Report for Type Np Buffer Dispute, p. 4-5 (September 12, 2022) ("[t]he central disagreement among the parties was regarding the amount of change in buffer prescriptions that would be needed from current rules to meet the anti-degradation water quality temperature standard" and "increased buffer widths and lengths needed to result in less than .3-degree Celsius increase [, i.e., "measurable change,"] in stream temperatures (to meet anti-degradation standards)."); Type Np Majority Recommendations to the Forest Practices Board, p.7, 8, (October 2022) ("studies found that all of the riparian buffer treatment options resulted in a stream temperature increase greater than 0.3°C, exceeding the WQS."; "Tier II applies to waters that are not impaired where lowering of water quality is allowed to a limited extent, defined for temperature as not greater than 'measurable change' defined as 0.3° C."; "the majority caucuses understand warming of Type Np streams should be limited to 0.3°C in accordance with the state's Tier II antidegradation standards."); Ecology Director Letter to FPB re CWA Assurances, p. 3 (November 30, 2022) ("studies demonstrated that all riparian buffer treatment options resulted in temperature increases that greatly exceeded the allowable increase of 0.3 degrees Celsius."; The 0.3 degree Celsius limit is based on Washington's antidegradation water quality standard. WAC 173-201A-320(3)(a)").
[8] Ecology 2003 Responsiveness Summary, p. 108.
[9] *Id*. at 103.

II analysis applies at all. After years of misleading the FPB and its AMP, Ecology's Draft Tier II analysis now concedes measurable temperature increases *greater than* 0.3°C are permissible within the context of Ecology's preferred buffer alternative.[10] This shift reveals the ≥0.3°C temperature change threshold was never a lawful limit, but a policy preference deployed early to improperly constrain the AMP and FPB consideration of alternatives. Ecology's assertion that non-preferred alternatives would fail to meet state water quality standards lacks evidentiary support, conflicts with Hard Rock and Soft Rock study findings, and relies on "beliefs" over data, undermining transparency, the scientifically based AMP, and public confidence.

III. Ecology Exceeds Its Statutory Authority in the FPB Rulemaking Process

Ecology's authority under RCW 76.09.040(1)(b) is more limited than has been portrayed. While FPB and Ecology must reach "agreement" before the FPB may *adopt* a forest practices rule pertaining to water quality, Ecology has no statutory authority to unilaterally impose its preferred policy through control of forest practice rule *development*. If this were the case, there would be no need for the FPB and all Forest Practices Rules pertaining to water quality would be under the sole review authority of Ecology. This is clearly not the intent of Legislative authority providing the FPB ultimate authority to adopt rules and to Ecology a limited role to reach agreement with the FPB prior to rule adoption. Nor does Tier II imbue Ecology with veto power over the science-based AMP process directed by the FPB under RCW 76.09.370. Ecology's independent preparation of a Tier II analysis outside AMP usurps the FPB's authority and contravenes the Legislature's direction that adaptive management is the vehicle to produce rule changes per RCW 76.09.370(6) and (7).

IV. Ecology's Necessary and Overriding Public Interest Analysis is Superficial and Technically Deficient

As explained above, Ecology has no basis to perform a unilateral necessity and overriding public interest analysis for the proposed rule. Setting that aside, Ecology's necessity and overriding public interest analysis is technically deficient. Ecology claims the proposed rule is necessary and cost-feasible by referencing the FPB's cost benefit analysis (CBA) and comparing the proposed Np buffer rule to a strawman 100' continuous Np buffer. The 100' continuous buffer was notably rejected during the AMP process, even under an improper interpretation and application of Tier II's measurable change concept as directed by Ecology. Its only purpose in the Tier II analysis appears to be designed to support selection of the proposed rule. Ecology itself refers to 100' continuous buffer as being only for "illustrative purposes."[11] Presenting an alternative solely for show, without genuine analysis, falls well short of what Tier II and the Administrative Procedures Act (APA) demand and instead reflects the predetermined nature of this process.

Ecology's analysis should have included and objectively evaluated a range of alternatives, including the existing buffer rules and the AMP Minority proposal, either of which might very well satisfy Tier II as necessary and in the overriding public interest relative to the proposed rule. However, Ecology improperly eliminated alternatives without basis early in the AMP process, predicated on its Tier II misinterpretation and misapplication. Having done so, Ecology's Tier II analysis on the proposed rule is superficial and perfunctory. Its actions prevent the FPB from selecting the least burdensome alternative as required under the APA.[12]

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[10] *See e.g.,* Tier II Analysis at 87 ("Based on our review, following potential implementation of the proposed buffer prescriptions, we anticipate some Type Np streams will exhibit warming beyond 0.3°C following timber harvest activities due to regional and site-specific factors, likely to last no longer than two years. . . . Ecology finds it necessary and in the overriding public interest to allow the Forest Practices Board to adopt the proposed rule, thereby continuing to incur a level of risk, and likely exceeding Tier II measurable change temperature thresholds in some areas."). While Ecology now concedes that Tier II does not prohibit measurable temperature change, it is worth noting that the Tier II Analysis repeatedly and inaccurately refers to measurable change as exceeding a threshold or exceeding Tier II requirements. This is false. The Measurable change "standard" is simply a screening tool or eligibility criteria for whether Tier II analysis applies at all. In fact, a project proponent can assume measurable change rather than providing supporting data so that it can move straight to Tier II review. Tier II Supplemental Guidance, p. 7.

[11] Tier II Analysis, p. 9, 84.

[12] RCW 34.05.328.

The projected economic losses, up to $1 billion or more in timberland asset value and $5-$8 billion in broader economic losses in the first rotation,[13] make clear the proposed rule is *not feasible* nor cost-justified. Small forest landowners are disproportionately harmed. Ecology relies on the CBA by Industrial Economics (IEc) which:

- reiterates the vague purpose for the rule making, "*…ensure the buffers protect water quality… from potential temperature increases"* and ignores the FPB's resource objective for stream temperature;[14]
- produces cost estimates which range 2.5-4.5× from low to high, reflecting high uncertainty;
- ignores costs associated with increased road and landing construction to access timber and "stranded timber" which is too expensive and/or risky to access;
- relies heavily on stated preference surveys which measure attitude rather than actual behavior and are known to suffer from hypothetical bias;
- treats carbon credit revenue opportunity (a cost) incorrectly as a benefit; and,
- lacks transparency and provides no rationale comparative analysis of costs/benefits.

Ecology improperly relied on the flawed CBA as a surrogate for its overriding public interest analysis and provides insufficient basis to determine the proposed rule is "necessary" (i.e., implementable and feasible, including cost feasibility) and in the overriding public interest given the staggering costs, negligible to minor benefits to aquatic habitat, and when other, less costly alternatives that protect water quality were eliminated from analysis without basis. Further, Ecology's suggestion that the proposed rule *avoids future regulatory costs* is speculative, coercive, and without evidence.

V. Scientific Record Does Not Support the Proposed Rule

Ecology's Tier II Analysis suffers from myriad technical and scientific inaccuracies and interpretations.

First, the analysis misrepresents and omits critical findings from the Cooperative Monitoring, Evaluation and Research (CMER) Hard Rock and Soft Rock studies. While the Tier II analysis emphasizes better thermal performance from 100% buffer treatment, it fails to mention that other buffer treatments, such as the 0% buffer treatment, sometimes performed similarly with regard to 7-day average daily maximum temperature (7DAM). In both studies, some of the coolest post-harvest sites had partial buffers and performed similarly to the reference sites, and more than 90% of temperature observations across all treatments in both studies were below the designated use numeric temperature criteria of 16 °C.

Second**,** the method of counting all temperature increases >0.5°C as equal is highly misleading, failing to reflect ecological relevance. Additionally, first year post-harvest temperature responses in the Hard Rock and Soft Rock studies did not have any relationship with canopy closure (%), percent of channel with buffer, or total buffer length. This suggests stream temperature response in Np streams is more complex than buffer length/width alone, and the analysis does not reflect that complexity.

Third, the Tier II analysis draws inappropriate conclusions about the influence of site-specific variables that were not directly manipulated in the studies. The studies allow inference about average treatment effects across specific criteria and conditions, not causation from untested variables.

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[13] See Attachment B, Mason, Bruce & Girard Type Np Cost Benefits Analysis, prepared for WFPA, August 7, 2025; also see U of W NRSIG, Quantifying Washington's Forest Practices Buffers; although not factored into the costs of the proposed rule, Industrial Economics (IEc) CBA estimates $167M-$771M/year in regional economic impact.

[14] WAC 222-12-045(2)(a)(ii)(C) "…forest practices, either singularly or cumulatively, will not significantly impair the capacity of aquatic habitat to meet or exceed water quality standards (protection of beneficial uses, narrative and numeric criteria, and antidegradation)." Schedule L-1 provides the performance target for this resource objective, which is the designated use numeric criteria for temperature (e.g., 16 °C).

Fourth, the analysis overreaches by applying study results to broader areas of the landscape without scientific justification. The Hard Rock and Soft Rock studies were limited in geographic and ecological scope, and findings cannot be generalized to all the managed forest landscape in Western Washington. Two independent assessments, one by WFPA and one by DNR, found that less than 2% of routine timber harvests in Western Washington match the treatments in the Hard Rock study.[15] Even under the extreme harvest scenarios not reflective of the vast majority of real word timber harvests, scientific findings showed that temperature effects of harvest under existing Type Np buffers were spatially and temporally limited, did not persist downstream, and that relevant biological and ecological responses were not correlated with the targeted standard. Ecology's Tier II analysis and its approach throughout this rulemaking process ignores these issues and the Legislature's express directive in RCW 90.48.420(1) to consider the "uses of the receiving waters, diffusion, down-stream cooling, and reasonable transient and short-term effects resulting from forest practices."

Fifth, the analysis attempts to predict future responses using narrative matching of physical features rather than established predictive tools. For example, there was no consistent relationship between canopy cover and temperature change above 70% shade, and yet the report ignores this context and relies heavily on canopy closure as a basis for the proposed rule. In addition, Ecology asserts that declining to adopt larger Np buffers risks additional 303(d) temperature listings. Yet, there is no empirical demonstration that increasing shade in small, headwater Np streams produce *meaningful downstream temperature improvements* in large receiving systems (e.g., South Fork Nooksack) with wide active channels but shallow and narrow flow paths during the dry season. These systems are unlikely to benefit from expanded buffering on Np streams, which are already well below the applicable numeric temperature criteria, as there are likely other non-management factors contributing to the temperature regime. However, the analysis ignores the potential role of non-forestry management factors and fails to consider how changing precipitation patterns and reduced discharge could increase river temperatures even with high levels of shading. Thus, Ecology's claim that the rule protects Tier I uses is unsupported.

Missing entirely from the analysis is any coherent standard from which the public and regulated community can assess and understand Ecology's anomalous version of Tier II "compliance" as applied only to forest practices. As noted above, Tier II should be considered met for existing Forest Practices Rules because of its AMP. Setting that aside, Ecology's analysis doesn't explain the basis or threshold for what it considers Tier II compliance versus noncompliance. This omission prompts a series of questions, including:

- If temperature change ≥0.3 °C is not a limit, as originally dictated to the AMP, what is the so-called "limit" or "threshold"?
- Is it the numeric criteria? If not, why not?
- Is it a qualitative or quantitative assessment of getting close to 0.3 °C?
- If so, what is the basis for this threshold?
- How close is close enough in Ecology's view?
- How is it measured or assessed? Where is it measured or assessed?
- What frequency and duration of temperature effects are required for compliance or noncompliance in the future? How far downstream? Are diffusion, down-stream cooling, and reasonable transient and short-term effects considered? How? If not, why not?
- Under what specific circumstances will the proposed rule result in measurable temperature change? Are those the only acceptable circumstances? On what basis?
- Ecology says forest practices under existing rules are likely to result in measurable change in greater frequency and magnitude than the proposed Np buffer rule, but as noted earlier, CMER studies did not

[15] Type Np Minority Recommendations to the Forest Practices Board, p.16, (October 2022); IEc CBA, p. 20-21.

evaluate routine harvest scenarios adjacent to Np streams. What is the basis for extending data from rare harvest scenarios to routine harvest scenarios? When was it analyzed and presented to the public?

Attachment C to this letter contains a more detailed review and critique of technical components in Ecology's Tier II analysis.

In summary, the technical components of the Tier II analysis draw conclusions not supported by the science it cites, omits relevant data, misinterprets scope of inference, relies on weak prediction methods, and provides no rationale science basis to understand Tier II "compliance." Absent these details and analysis, Ecology's Draft Tier II analysis is specious at best.

VI. Conclusion

Ecology's Draft Tier II Antidegradation Analysis:

- Relies upon newly invented interpretations of "new or expanded" actions contrary to WAC 173-201A-020 and 320;
- Misapplies temperature thresholds in WAC 173-201A-320 to eliminate viable alternatives from consideration and drive a preferred outcome contrary to RCW 34.05.328, RCW 43.21C.030, RCW 76.09.370 and the principles of the AMP;
- Exceeds Ecology's statutory authority under RCW 76.09.040 and RCW 90.48.420;
- Utilizes a deeply flawed necessity and overriding public interest analysis that ignores alternative options, disproportionate impacts and concludes speculative, qualitative benefits exceed billions of dollars in regional economic impact;
- Selectively presents scientific findings while ignoring context and scientific uncertainty;
- Offers no workable Tier II compliance framework; and
- Undermines the integrity of both the AMP and public trust in FPB rulemaking.

Evidence produced by the AMP demonstrates the current Forest Practices Rules already satisfy or are better than designated use numeric temperature standards, with rare, transient exceptions better suited for site-specific corrective actions, not wholesale rule expansion. The proposed rule imposes severe, unjustified burdens on Washington's working forests with speculative environmental benefit contrary to the Legislature's declaration in the Forest Practices Act for balancing the viability of the forest product industry with natural resource protection. Accordingly, WFPA urges Ecology to:

1. Reconsider whether new, independent Tier II analysis is legally triggered by this rulemaking under WAC 173-201A-320;
2. Acknowledge continued Tier II programmatic compliance of the Forest Practices Rules as a WPCP with its Legislatively mandated AMP;
3. Support rigorous and objective evaluation of all AMP-developed alternatives, including the Minority proposal and existing rules;
4. Ensure compliance with RCW 34.05.328, RCW 76.09.370, and RCW 90.48.420; and
5. Support a science-based, legally grounded process that protects both working forests and water quality through adaptive, site-specific strategies.

Thank you for considering these comments. WFPA welcomes continued engagement with Ecology and the FPB to support lawful, effective policies grounded in science, and the long-term stewardship of Washington's working forests and viability of Washington's forest products industry.

Sincerely,

Darin D Cramer

Darin D. Cramer
Forest Policy Director
Washington Forest Protection Association

Attachment A - Additional WFPA Questions for Ecology on Tier II Analysis for Forest Practices

Prior Practice and Antidegradation Analyses

1. Identify and explain all previous FPB rulemakings since the adoption of the 2001 Forest Practices Rules that have undergone a Tier II Antidegradation analysis or similar antidegradation review process under WAC 173-201A-320.

2. For each such prior rulemaking:
   - Provide references to the specific antidegradation analyses conducted.
   - Explain how those processes were conducted.
   - Explain how the current process is consistent with or different from those prior undertakings.

3. If FPB rulemakings since 2001 have not undergone a Tier II Antidegradation analysis explain why and explain the basis for treating the Type Np rulemaking process differently.

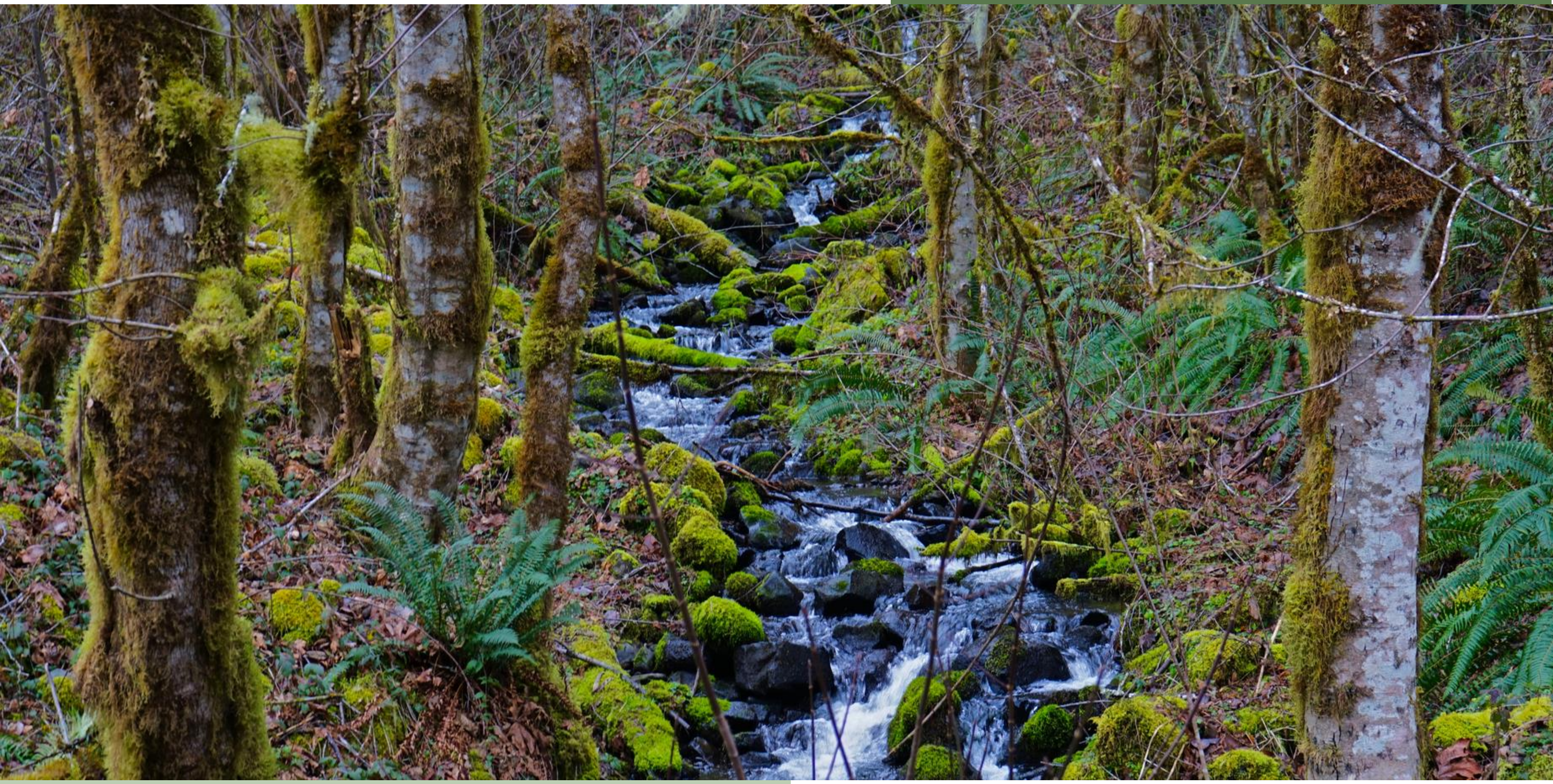
4. Ecology's July 2025 draft Tier II analysis for the proposed rule states that: (1) the Forest Practices Rules are an "other water pollution control program authorized, implemented, or administered by Ecology" under Tier II; and (2) the Board's proposal of new or revised Forest Practices Rule is a "new or expanded action" under Tier II.
   - What is the basis for these conclusions?
   - Has Ecology made similar determinations for prior FPB rulemaking? Is so, please provide examples. If not, explain why these determinations are being made for the Type Np buffers rule rather than following prior practice?
   - If the proposed rule is a trigger for Tier II analysis, explain Ecology's determination and direction to adaptive management prior to publication of the proposed rule that existing Type Np buffer rules violate Tier II requirements. In your explanation, explain the triggering event for Ecology's prior determination and direction that existing Type Np buffer rules violate Tier II when no purported "new or expanded action" had yet occurred.
   - Explain Ecology's direction and determinations made during adaptive management regarding Tier II compliance when no proposed rules were before the Board.
   - Explain whether Ecology considers Forest Practices Rules to be an "other water pollution control program" governed by WAC 173-201A-320(6), which states Tier II requirements can be considered met through adaptive management.

5. Ecology's July 2025 Draft Tier II Analysis states that potential for measurable change requires an overriding public interest analysis under Tier II. Ecology states that the CBA required by the APA for the proposed rule is key to informing this analysis. Are the OPI factors in WAC 173-201A-320(4) for the same purpose as the CBA analysis required by the APA? If not, what are the differences? What is the statutory/regulatory basis for using the CBA to support the OPI analysis? Has Ecology taken this position for prior FPB rulemakings affecting water quality? Has Ecology completed an OPI analysis under Tier II for prior FPB rulemakings. If not, why not?

Attachment B

Type Np Cost Benefits Analysis: Preliminary Results

Prepared for
WFPA



MASON BRUCE & GIRARD
Natural Resource Consultants

Mike Buffo
Mason, Bruce & Girard, Inc.
707 SW Washington Street, Suite 1300
Portland, OR 97205

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Background

The Washington Forest Practices Board is considering changes to Forest Practices rules concerning Western Washington Type Np buffers. Options for the proposed rules would result in one of the following buffer configurations:

Scenario 1A >3ft bank full width (BFW): 75-foot[1] no-harvest buffer for the first 600 feet upstream of a confluence with a Type F or S water. Beyond 600 feet upstream, a 50-foot no-harvest buffer for the remaining Np stream length plus a 25-foot partial harvest buffer where up to 50% of the trees can be removed following diameter and species distribution requirements.

Scenario 1A <3ft BFW: 75-foot no-harvest buffer for the first 600 feet upstream of a confluence with a Type F or S water. Beyond 600 feet upstream, a 50-foot no-harvest buffer for the remaining Np stream length.

Scenario 1B >3ft BFW: 75-foot no-harvest buffer for the first 600 feet upstream of a confluence with a Type F or S water. Beyond 600 feet upstream, a 65-foot no-harvest buffer for the remaining Np stream length.

Scenario 1B <3ft BFW: 75-foot no-harvest buffer for the first 600 feet upstream of a confluence with a Type F or S water. Beyond 600 feet upstream, a 50-foot no-harvest buffer for the remaining Np stream length. (Same as Scenario 1A <3ft BFW).

Scenario 2: 75-foot no-harvest buffer for the entire length of a Type Np water. This scenario is applicable if the Np basin is ≥30 acres and ≥85% of the basin will be harvested within a five-year period.

The report provides a cost/benefit analysis of these proposed rule changes. Undiscounted annual values or total values are provided.[2]

Methods and preliminary results

Change in Type Np buffer area

The first step in a cost benefit analysis is to understand the potential changes due to the proposed rules, compared to the existing rules. In this case, the changes are the length of Type Np streams within a buffer and the area of Type Np buffers. Neither of these values are accurately known. No single dataset provides a full accounting of the length of Type Np streams in Washington and no single dataset shows where Type Np stream buffers would be required. Complicating this, buffering of Type Np streams is affected by multiple aspects of current Forest Practices rules, including for Type S and F buffers, potentially unstable landform protections, perennial initiation point buffers, and sensitive site protections.

Previous efforts to determine Np stream length have utilized the DNR's WC hydro layer, or remote-sensing (e.g., the Spatial Analysis of the Water Typing System Rule Synthetic Stream Development, Comparison of Alternatives, and Buffer Analysis by Four Peaks). In a review of the *Preliminary Findings of the Economic Analyses of the Proposed Type Np Water Buffer Rule* dated November 22, 2024, Ecology expressed concerns about perennial stream assumptions. The letter suggests utilizing field verified stream data available in FPAs to assess stream typing (letter included in Appendix 6). Use of FPA data to assess stream typing and buffering was further discussed during a call with WFPA, Ecology, DNR, and MB&G staff on January 13, 2025.[3]

[1] All buffer widths are reported as one-side horizontal distances.

[2] Reviewers of this report are listed in Appendix 7.

[3] Due to the need to meet timelines set by DNR for input, this project was developed as a proof-of-concept for the use of data from FPAs to inform the discussion of Np stream length and buffer percent. FPAs in each ecoregion were sampled independently. We selected a sample size of 20 per ecoregion because this size was both possible to be sampled in the time available and would likely provide an estimate of Np stream length and buffer area with narrow enough confidence intervals to be informative.

In an effort to assess the extent of existing buffering of Np streams, Mason, Bruce & Girard (MB&G) and Rocinante Consulting collected data from Forest Practices Applications (FPAs) from a 5-year period sample of the area of current Np buffers.

We randomly selected 20 Forest Practice Applications (FPAs) in each of four ecoregions (North Cascades, Northwest Coast, Puget Trough, West Cascade), resulting in a stratified sampling method.[4] We selected only FPAs that met the following criteria:

1. Received by DNR between 1/1/2020 and 12/31/2024,
2. The FPA was not withdrawn or disapproved,
3. The timber harvest type was "Even/Salvage," "Even-age," or "Even R/W,"[5]
4. The FPA was a class III or IV-S,
5. The FPA was for private lands not covered by a Habitat Conservation Plan with a riparian conservation strategy,
6. The FPA applied to lands that do not meet the 20-acre exemption criteria, and
7. All harvest units included in an FPA were in a single ecoregion.[6]

From the selected FPAs, we collected data from question 26 of the FPA in which applicants were asked to report the following: "If harvesting within 50 feet of Type Np Water, complete the table(s) below. Show RMZs and stream segment identified on the Activity Map" (Figure 1). In this review we found that some applicants delineate the harvest area 50 feet or more away from all Np streams and are therefore not required to report in question 26. In these cases, the effective buffer is at least 50 feet wide along the entire stream adjacent to the harvest area.[7] If data were not provided in question 26, we did not include these FPAs in our sample of 20 FPAs per ecoregion. In total we eliminated 14 FPAs, 13% of the total we reviewed, due to lack of data. As a result, our average totals likely underestimate the amount of Np buffer associated with harvest activities since data from Np streams with full length buffers is not included.

26. If harvesting within 50 feet of Type Np Water, complete the table(s) below. Show RMZs and stream segment identifiers on the Activity Map.

Stream Segment Identifier *(letter)*	**Total Stream Length in Harvest Unit** *(feet)*	**Length of No-Harvest, 50-foot Buffers in Harvest Unit** *(feet)*

Stream Segment Identifier *(letter)*	**Total Stream Length in Harvest Unit** *(feet)*	**Length of No-Harvest, 50-foot Buffers in Harvest Unit** *(feet)*

Figure 1. Question 26 in the January 2020 version of the western Washington FPA form.

We found that FPA applicants fill out the table in question 26 differently. Some aggregate all Np streams above a fish/no-fish break (F/N break) into a single stream system, the length of the stream system, and the length of buffers along the system. Others report each stream branch separately. When determining the length of buffer required on Type Np

[4] The inconsistent sampling intensity across ecoregions is accounted for in the statistical analysis.

[5] R/W indicates harvest in a right-of-way.

[6] FPAs were screened for selection criteria 1 through 4 and 7 in GIS. The number of FPAs that meet these criteria by ecoregion is: North Cascades – 527, Northwest Coast – 2,428, Puget Trough – 1,956, West Cascades – 1,517, Total – 6,428. The number that additionally meet selection criteria 5 and 6 is not known and would require screening all 6,428 FPAs manually.

[7] We note that there are two possible situations that result in an FPA not reporting Np streams: 1) There are no streams adjacent to the activity, and 2) Np streams are entirely buffered by at least 50 feet.

streams, we used the former method to aggregate the length of all Np streams above an F/N break. MB&G recompiled responses to question 26 for total stream length and buffer length, when needed to aggregate Np streams above F/N breaks, based on review of maps provided in the FPA.

Based on data from question 26, we calculated the average length of Np streams and the average length of buffer by ecoregion (Table 1). Among the FPAs reviewed, average stream lengths ranged from about 107 feet (the lowest) in the Puget Trough to 3,350 feet (the highest) in the North Cascades. The average proportion buffered ranged from 60% to 81%. The number of FPAs reporting Np-adjacent management activity in question 26 ranged from 2 of 20 in the Puget Trough to 15 of 20 in the North Cascades.

Table 1. Average length of Type Np streams and buffers by ecoregion.

Ecoregion	Number of FPAs sampled	Number of FPAs with Type Np stream buffers†	Average length of Type Np streams (feet)††	Average length of buffer on Type Np streams (feet)	Percent of Type Np stream length buffered
North Cascades	20	15	3,353.7	1,841.2	60%
Northwest Coast	20	10	1,287.1	761.8	60%
Puget Trough	20	2	106.8	73.5	81%
West Cascades	20	11	1,480.7	1,061.1	71%

† This number is lower than the number of FPAs sampled because some FPAs in each region do not report Np stream buffers either because there is no stream adjacent to the harvest area or because the Np stream has a full-length buffer of at least 50 feet and so reporting the Np stream is not required based on the wording in Question 26 of the FPA.
†† Does not include Np streams with full length buffers.

Next, we estimated the total number of streams in each ecoregion. To do this, we estimated area in each ecoregion subject to Forest Practices Rules. We did this by selecting all property parcels identified as "forestry department" indicating large private ownership, and land identified as "non-industrial private forestland" (NIPF) with at least 10 acres of forest in a forest land ownership database for 2019 by Rogers et al. (2021). We limited the acres in this analysis to these two ownership types for a total of 4.411 million acres (Table 2, Figure 2)[8,9,10]. We calculated the average stream length per acre of activities in the FPAs. We then multiplied this average by the acres in each ecoregion. This step assumes all lands in each ecoregion on large private and NIPF lands are available for harvest, which is likely an overestimate as some lands do not support commercial timber or are unavailable for regulatory or operational reasons. Based on this calculation, we found a total of over 26,000 miles of Np streams in the four ecoregions (Table 3). By dividing the total length of Np steams in each ecoregion by the average length of streams in each ecoregion we calculated the average number of Np streams in each ecoregion.

[8] The total area identified as NIPF by Rogers et al. (2021) was 2,427,647 acres. Using this area, there is a total of 5,853,488 acres of large private and NIPF acres. By not including NIPF parcels with fewer than 10 acres of forest we may be underestimating total impacts.
[9] The Forest Practices Habitat Conservation Plan reports estimated 6.1 million covered acres in Western Washington https://www.dnr.wa.gov/publications/fp_hcp_06exsum.pdf page iii.
[10] Reducing the minimum area of forest per parcel to 5 acres increases the area to 4,701,784 acres.

Table 2. Acres by ownership group by ecoregion. Data and ownership groups from Rogers et al. (2021).

Ecoregion	Large private (acres)	NIPF (acres)	Subtotal large private and NIPF (acres)	Conservation (acres)	Other, real estate, and utility (acres)	Total (acres)
North Cascades	375,724	81,808	457,532	6,818	6,215	470,564
Northwest Coast	1,626,887	228,723	1,855,610	34,279	20,632	1,910,521
Puget Trough	524,314	522,178	1,046,492	16,425	49,681	1,112,597
West Cascades	898,916	152,972	1,051,888	7,651	23,218	1,082,757
Total	**3,425,841**	**985,681**	**4,411,522**	**65,173**	**99,745**	**4,576,439**

Table 3. Estimated total miles of Np streams by ecoregion.

Ecoregion	Number of Type Np streams	Type Np stream length (miles)	95% confidence interval of Type Np stream length (lower, miles)	95% confidence interval of Type Np stream length (upper, miles)	Half width of 95% CI as % of miles of Type Np stream
North Cascades	7,926	5,035	4,656	5,413	15%
Northwest Coast	35,062	8,547	7,759	9,335	18%
Puget Trough	15,489	313	221	406	59%
West Cascades	29,752	8,343	7,412	9,275	22%
Total	**89,163**	**26,294**	**24,795**	**27,792**	**11%**

For each of the proposed buffer scenarios, we calculated the area of buffer per foot of stream. In this calculation we assumed that the first 100 feet of each Np stream is encompassed by a Type S or F buffer. We did not adjust for the following:

1. The possibility a long stretch of Np stream (>100') might be within a Type S or F buffer,
2. That parallel streams may have overlapping buffers,
3. That buffers may create otherwise harvestable areas inaccessible due to being surrounded by stream buffers.

The first two points would contribute to an overestimate of impacts, while the latter will contribute to an underestimate.

We then multiplied the area of buffer per foot of stream by the total length of stream reported in each of the sample FPAs. For the scenario with partial harvest buffers, we calculated the area of the 25-foot (per side) partial harvest buffer, but divided the area by 2 since "up to 50% of the trees may be harvested" and the "leave trees shall be representative of the diameters found within the managed zone…" according to the proposed language for WAC 22-30-0211 (3)(b)(i)(A)(II).

To estimate the current buffer area, we multiplied the reported length of buffered stream from the sample FPAs by 100 ft, assuming 50-foot buffers on each side of stream.

Appendix 1 provides average and 95% confidence intervals for Np stream length and buffer area. Table 4 provides a list of key assumptions and likely direction of possible error from each assumption. Our analysis resulted in an estimate of Type Np stream miles about 7,000 miles more than IEc's low end and 18,000 miles less than IEc's high end estimate reported on Table 4 in the April 23, 2025, CBA. Our confidence that the estimates are approximately correct is increased, given that multiple analyses using different assumptions yielded broadly similar results. Nonetheless, the extent of Type Np streams is the single most important factor for assessing the costs and benefits of the proposed rule change. The full costs and benefits of the proposed rule change are necessarily uncertain without validation of the Type Np stream extent. Field assessment of a sample of Type Np streams would likely be the best validation method.

Table 4. Key analysis assumptions.

Assumption	Impact on estimate
Data reported in FPAs represent the extent of Np waters.	FPAs typically provide information regarding stream length only when activities occur within 50 feet of Np waters. In addition, FPAs may only report stream length for the portion an Np stream adjacent to a harvest activity, not the total stream length. This results in an **underestimate** of total Np stream length.
FPAs reported stream length incudes the length of Type Np streams located within Type F or S buffers.	We deducted 100 feet from reported stream lengths to account for the length of Type Np streams in Type F and S buffers. If the reported length on Np streams includes this portion of the Np stream, our estimate of the total area of buffer may be an **overestimate** as more than 100 ft of Np streams may be in Type F or S buffers. If FPA do not report the length of Type Np streams in Type F and S buffers, our estimate is likely an **underestimate**.
Data reported in FPAs represents the extent of Np buffering.	FPAs typically provide information regarding buffering only when activities occur within 50 feet of Np waters. If the activity is more than 50 feet from an Np water, no buffering information is typically provided. Activities may be more than 50 feet from Type Np waters for multiple reasons including operational or regulatory reasons (e.g. unstable slopes). By excluding buffers on streams not reported on FPAs, we underestimate the current extent of buffers. However, since these streams are excluded from our analysis, this assumption has **no effect** on the proportional relationship between current and proposed buffers on streams reported on FPAs.
20 FPAs per ecoregion provide an adequate sample of activities	After accounting for FPAs with no Type Np streams, the number of FPAs with reported Np buffers ranged from a high of 15 to a low of 2 across ecoregions. Additional samples will increase the accuracy of our estimate. Given our small sample size for one region, more sampling could yield an estimate that is higher or lower than our estimate.
The average stream length in each ecoregion is representative of actual stream lengths.	All Scenario 1 variants have a wider no-harvest buffer for the first 600 feet of an Np stream than the remainder of the stream. As a result, the total buffer area depends on both the number and length. Many short Np streams would have more buffer area collectively than fewer longer Np streams with the same total length due to higher percentage of the length of the streams being in the first 600 feet of the Np stream where the buffer is widest. In our calculations, we use the average stream length (based on FPA data) in each ecoregion to calculate buffer area. This represents only one of many possible configurations of streams. Again, increasing the sample size could yield an estimate that is higher or lower than our estimate.

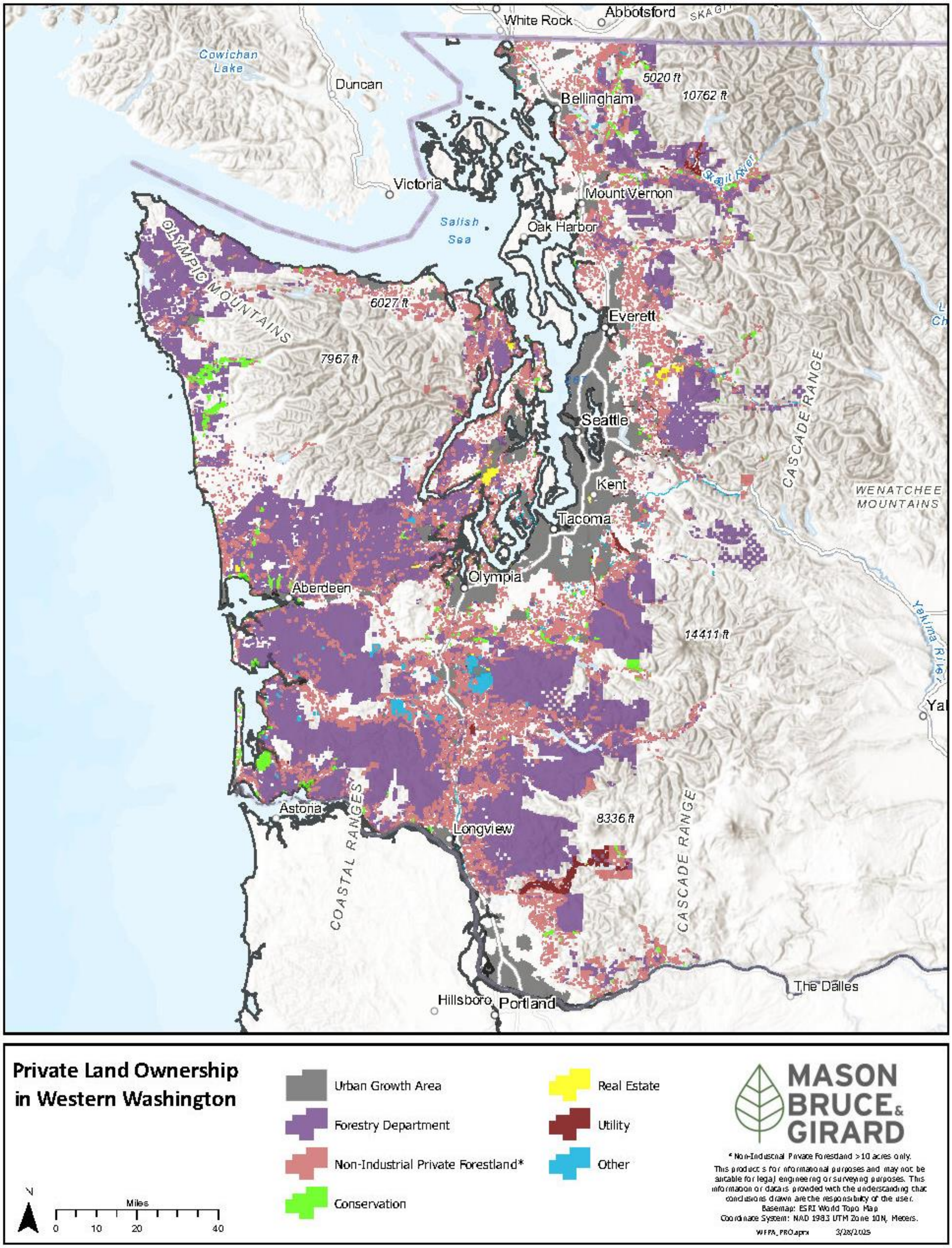

Figure 2. Private lands in the four analysis ecoregions. Non-industrial lands include only parcel with more than 10 acres of forest. "Forestry Department" is the designation for industrial ownerships in Rogers et al. (2021).

Change in buffer area

We estimated that total Np buffer area under current forest practices rules is 197,250 acres. The proposed rule changes increased the area of buffer by 85% to 119% under the different versions of Scenario 1. Under Scenario 2 the buffers would increase by 142% (Table 5)[11]. However, since Scenario 2 would be implemented only under specific conditions in the proposed rule change, it would not be applied to all streams. [12]

Table 5. Estimated total Type Np buffer acres and change from current buffer acres by scenario.

Scenario	Total buffer area (acres)	Change in buffer area (acres)	Change in buffer area (% current buffer area)
Current	197,250		
Scenario 1A >3 ft BFW	421,162	223,912	114%
Scenario 1A<3ft BFW	364,226	166,976	85%
Scenario 1B>3ft BFW	432,550	235,300	119%
Scenario 1B<3ft BFW	364,226	166,976	85%
Scenario 2	478,209	280,959	142%

Costs and benefits

Potential costs or benefits of the proposed Type Np rule that will be assessed in this CBA are:

1. Change in forestland value.
2. Regional economic impacts.
3. Cultural impacts.
4. Changes to water quality and quantity.
5. Changes in carbon storage.
6. Changes in forest operations.
7. Changes in regulatory risk.

Change in forest land value

MB&G developed a forest valuation model based on a discounted cashflow calculation. This calculation uses an age-class distribution and site class from the US Forest Service Forest Inventory and Analysis (FIA) plots from private lands in western Washington and growth rates from Chambers (1989). In the model, MB&G assumes stands are managed under financially optimal rotations, based on discount rate and site index. This results in a 45-year rotation at a 4.5% discount rate for site classes I and II, a 50-year rotation for site class III, a 55-year rotation for site class IV, and a 60-year rotation for site class V. The assumed stumpage value is $450 per Mbf. Under a 4.5% discount rate the average acre would have a present value

[11] Darin Cramer of WFPA reports this is similar to the percent increase in buffers estimated, assuming 75-foot buffers were applied to Np streams in four recent harvest units near Shelton (pers. Comm 4/22/2025).

[12] MB&G is aware of an analysis by the University of Washington that produces an estimate of buffer area estimate of about 214,000, which is within the range we estimate for Scenario 1 buffers.

of $3,933 per acre.[13] Under a 2.0% discount rate the value would be $8,489 per acre.[14] These values account for costs from administration[15], stand establishment[16], and harvest taxes.[17]

Based on these per acre values, we estimate the loss in timberland value under the Scenario 1 options to range from $656 million to $925 million at a 4.5% discount rate, and a loss of $1.4 billion to $2.0 billion under a 2% discount rate (Table 6). If implemented everywhere, costs for Scenario 2 would range from $1.1 billion to $2.4 billion.

Table 6. Estimated loss of timberland value due to proposed Type Np buffers, by scenario.

Scenario	4.5% discount rate	2.0% discount rate
1A >3 ft BFW	$881 million	$1.901 billion
1A <3ft BFW	$657 million	$1.417 billion
1B >3ft BFW	$925 million	$1.997 billion
1B <3ft BFW	$657 million	$1.417 billion
2	$1.105 billion	$2.385 billion

Regional economic impacts

Evidence from past regulatory changes indicated that harvest reductions in one geographic region generally result in a high percentage of harvest being replaced by harvest from outside the region (a concept generally referred to as leakage). The Northwest Forest Plan implementation, while far larger in scale, offers some local parallels. Wear and Murray (2004) found that the change in US timber consumption was near zero following the implementation of the Northwest Forest Plan despite a significant reduction in the federal timber harvest. They report, "In essence, substitution of supply from nonrestricted sources makes up for most of the loss in supply in restricted sources, thereby leaving total US consumption changed very little." Overall, Wear and Murray found that leakage of timber harvest outside the western US was 84 percent. We assume a low-end leakage of 84% in this analysis. However, unlike in 1994, when harvest could shift to private lands within the Pacific Northwest, driven by substantially higher log prices[18], the proposed rules affect private lands. Unless substantial amounts of private land are available for harvest that is currently underutilized for timber, leakage could be up to 100%. This analysis provides a range of estimates of volume-based leakage rates ranging from 84% to 100%

[13] Based on a proprietary survey conducted annually by MB&G, large land managers use approximately a 4.5% discount rate when considering land transactions. Based on the survey, the discount rate used when considering acquisitions has decreased in recent years.

[14] This analysis assumes the same harvest schedule under the 4.5% and 2.0% discount rates. However, different discount rates result in different financially optimal rotations. Lower discount rates result in longer rotations than higher rates.

[15] Administration costs include management, property taxes, fixed costs such as road maintenance, patrol/protection, and insurance.

[16] Includes all costs of stand establishment: site prep, seedlings, planting, post-planting competition and stocking control

[17] Includes the forest tax and B&O tax.

[18] The extent to which higher log prices can be passed on to mills and consumers depends primarily on the lumber market, the main destination for timber in Pacific Northwest. In addition to Pacific Northwest timber supply and lumber production, lumber prices are affected by supply factors, including levels of imports - primarily from Canada (which itself is affected by Canadian forest policy and tariffs), production and shipping costs for lumber produced in the U.S. Southeast, and log export volumes, and demand factors that include rates of new home construction and rates of home repair and remodel.

We assumed that yields follow Chambers (1989)[19], equal areas of each age class[20] exist, and harvest occurs at the financially optimal rotation age for each site index class (Table 7)[21]. We prorate results for non-industrial lands by the ratio of even-age FPA acres on industrial, compared to non-industrial lands. Based on these assumptions and leakage rates of 84% and 100%, we found that timber harvest loss ranges from 67 to 112 million board feet (MMbf) per year under the Scenario 1 options,[22] and up to 134 MMbf under Scenario 2. The Scenario 1 harvest loss is between 4% and 7% of the total private land harvest in Washington 2023 (Table 8; DOR 2024, refer to Appendix 2 for detailed description of the methods)[23]. These results are higher than DNR's CBA produced by IEc, which reports 13 to 57 MMbf in lost harvest per year.

Potential loss of harvest due to the proposed buffers would exacerbate the long-term decline in harvest from private lands (Figure 3). The harvest volume from private lands in 2023, the most recent year full-year data are available, was the second lowest since 2000. The only lower year was 2009 during the Great Recession. Public harvests on average have increased since the early 2000s but by far less than the decline in private harvest volume (Figure 4). The decline in harvest has contributed to mill closures across the Pacific Northwest.

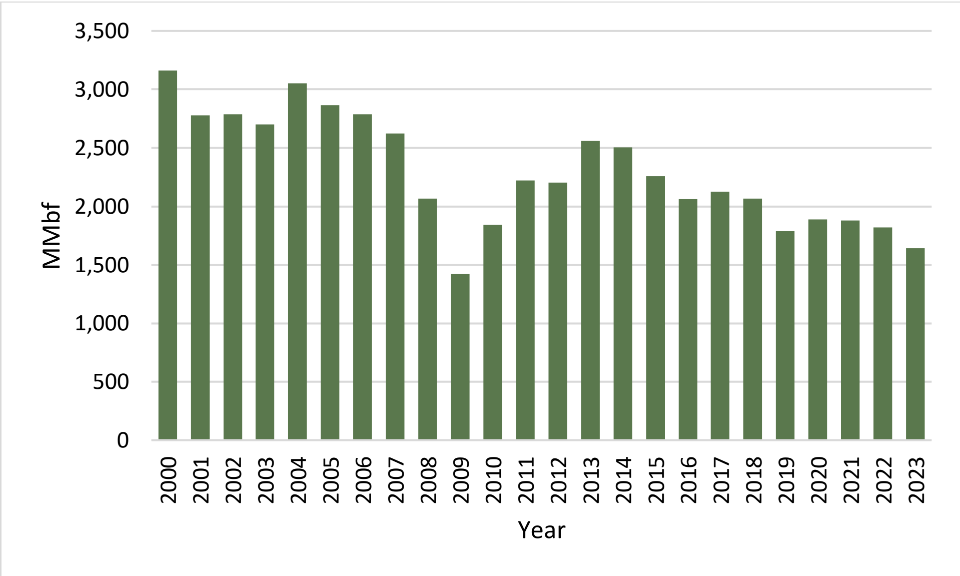

Figure 3. Annual harvest volume from private lands in Washington. Data from DOR.

[19] Yields are for fully-stocked sites. Site index values by site class are site index class (SIC) I:140 ft, SIC II: 130 ft, SIC III: 110 ft, SIC IV: 90 ft, and SIC V: 70 ft. Yields assume 32 ft logs.

[20] This condition is termed a regulated forest. In fact, about 13% of stands are over the minimum rotation age used in this analysis. Harvest of these stands would result in higher harvest volumes than projected here, if these areas are available for harvest.

[21] We note that this is a simplifying assumption. In practice, not every stand is harvested at the financially optimal rotation due to landowner management objectives or other financial considerations.

[22] This approximates the volume processed annually by a medium sized or "Class B" sawmill as defined in DNR's mill survey reports. https://www.dnr.wa.gov/about/fiscal-reports/washington-state-mill-surveys

[23] The Washington Department of Revenue found 1,640,970 Mbf (1.64 billion board feet) were harvested from private lands in Washington in 2023, the most recent year for which full-year data is available.

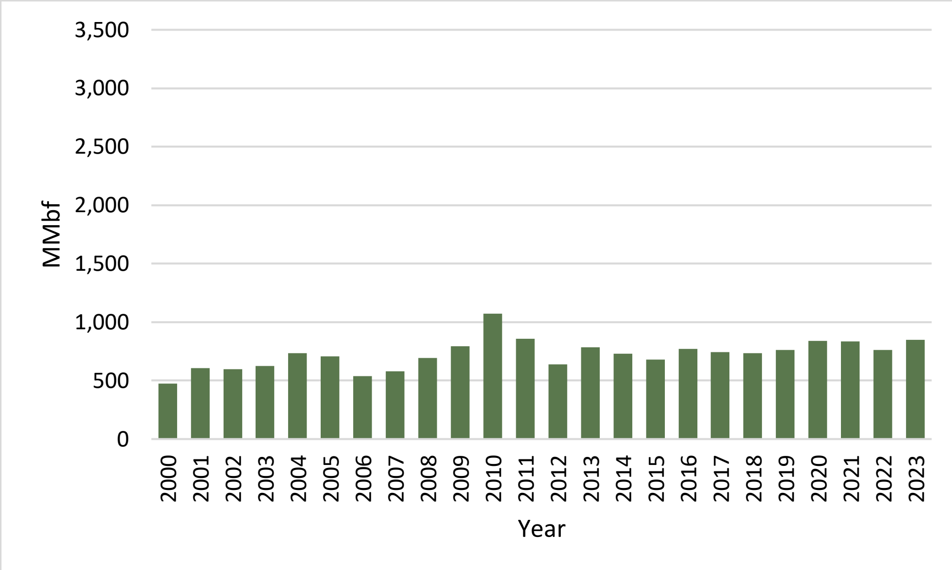

Figure 4. Annual harvest volume from public lands in Washington. Data from DOR.

Past analysis by MB&G (MB&G 2021) shows 15 direct jobs are supported per MMbf per year. Using different methods, analysis by DNR using the IMPLAN[24] model found 12 direct, indirect, and induced jobs per MMbf. Multiplying the average timber harvest change per year by these employment estimates, between 802 and 1,682 jobs would be lost due to the added buffers under Scenario 1. This increases to up to 2,008 jobs under Scenario 2.[25]

The economic loss of this reduction in timber harvest can be calculated, based on the product value after primary manufacturing. In a 2021 analysis by MB&G for western Oregon, we found this value was $1,930 per thousand board feet in 2020 dollars. For this analysis we adjusted the value to $2,350 in 2024 dollars based on the Consumer Price Index.[26] Since timber markets in western Washington are broadly similar in terms of species and products, this value provides a reasonable estimate of value for western Washington. Multiplying the average timber harvest change per year by the average value of primary wood products, we estimate the annual economic loss is between $157 million and $315 million.[27] At a 2% discount rate per year as recommended by Circular A-4[28] for social rate of time discount,[29] this equates to between $4.7 billion and $7.9 billion over 45 years under Scenario 1 options. Losses are up to $9.4 billion under Scenario 2.[30]

[24] IMPLAN originally stood for "impact analysis for planning" but now is a corporate brand.

[25] MB&G (2021) found 36 direct, indirect, and induced jobs are supported per MMbf. Using this value, the job loss estimate ranges from 2,406 to 4,037 under Scenario 1, and up to 4,820 under Scenario 2.

[26] Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, Index 1982-1984=100, Monthly, Seasonally Adjusted, https://fred.stlouisfed.org

[27] Including $8.3 to $14.0 million of state and local tax revenue under Scenario 1, and up to $16.7 million under Scenario 2, based on tax income per MMbf from MB&G (2021) adjusted to 2024 dollars.

[28] https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf

[29] The social rate of time discount is appropriate here instead of an industry specific discount rate because of the value of lumber products accounts for values across the regional economy including log costs, wages, taxes, and cost of investment in infrastructure. Value is not limited to timberland owners.

[30] These values do not account for potential losses from "islands" of timber that were previously accessible but are made legally or economically inaccessible by the expanded buffers. This also does not account for potential impacts of the buffers on timber management at the estate scale, such as harvest volume flow objectives, and increased road costs per board foot of timber harvested.

Table 7. Area by site index and financially optimal harvest rotation (4.5% discount rate) in western Washington, yields based on Chambers (1989), site index data from WA DNR.

Site index class	Financially optimal harvest rotation, 4.5% discount rate (years)	% area of western Washington forestlands†
I	45	4%
II	45	36%
III	50	46%
IV	55	10%
V	60	3%
Weighted average optimal financially optimal harvest rotation		49 years

† Based on data from the US Forest Service Forest Inventory and Analysis Program.

Table 8. Volume, jobs, and value loss estimates by scenario.

	Volume (MMbf)		Jobs		Value	
Scenario	**High estimate**	**Low estimate**	**High estimate**	**Low estimate**	**High estimate**	**Low estimate**
1A >3 ft BFW	107	90	1,601	1,076	$7.5 billion	$6.3 billion
1A <3ft BFW	80	67	1,194	802	$5.6 billion	$4.7 billion
1B >3ft BFW	112	94	1,682	1,130	$7.9 billion	$6.6 billion
1B <3ft BFW	80	67	1,194	802	$5.6 billion	$4.7 billion
2	134	112	2,008	1,350	$9.4 billion	$7.9 billion

Cultural impacts

The proposed Type Np rules would have cultural impacts on area tribes and rural residents who use forest resources and work in forest areas.

Tribal culture values

Tribes in Washington rely on salmonid species for subsistence and ceremonial foods. These first foods are deeply rooted into their way of life, culture, health, and well-being. Additional regulatory changes that improve salmon habitat for these Tribes provides an opportunity for Tribes to further exercise fishing practices protected by ceded land rights provided through treaties of the United States Government. However, as described below, fish populations are unlikely to increase due to the proposed buffers.

In addition to salmonid species, plants associated with wetland riparian areas will be protected by expanding stream buffers. Western redcedar (*Thuja plicata*) and nettles (*Urtical dioic ssp. gracilis* and *U. dioic ssp. holosericea*) are common in these areas. They provide a link to traditional cultural practices that provide medicines, food, shelter, and clothing. Expanding these buffers increases total acreage statewide for existing redcedar, nettles and many other traditional first foods and culturally significant species needed to maintain populations on the landscape. Additionally, expanded buffers may increase the area that accommodates wetland species used for members of Washington Tribes, assuming these buffers are in areas accessible to tribal members. Access to forestlands varies by tribe and landowner.

Rural Cultural Values

Rural communities surrounded by these forestlands rely on ownerships to provide work for local family and tribal owned logging companies, family and tribally owned mills, and forestry services companies. These communities will be negatively affected by the expansion of these buffers. In some rural areas, community culture is exemplified by individualism, self-reliance, work orientation and a strong emphasis on family (Slama 2004). Many small businesses have been operational for several family generations.

Rural cultural values for these areas provide guidance for stewardship of timberland owners. These economies rely on the availability of commercial forest ownerships to provide work, income, and a way of life that values stewardship, sustainability, and sound forest management.

Change in fish populations

Appendix 3 summarizes studies of the ecological response to riparian buffer length and width along non-fish bearing streams in the Pacific Northwest. Key effects related to fish populations in this summary are:

1. Shade on Type N streams is related to the length and width of buffers.
2. Increased shade is associated generally with lower stream temperatures. However, shade is not the only factor affecting water temperature. Other factors include the influx of ground water and hyporheic exchange.
3. Increased shade is associated with lower ecosystem primary production.
4. Increased shade is also likely to reduce understory diversity by excluding shade-intolerant species.
5. Increased buffer length increases the potential supply of large woody debris into Type N streams, while increased width may reduce windthrow in some settings. However, delivery of large woody debris from Type N streams to downstream fish-bearing (Type F) streams primarily occurs during debris flows and landslides. As a result, the impact of Type N buffers on Type F woody debris supply will vary across basins.
6. No studies have examined the fish responses to Type Np buffer length and width alone. Studies of buffers focus on just Type F stream or a mix of Type F and Type N stream

The FEMAT curves, showing ecological function as a function of distance from stream, shows that trees closest to the stream provide root strength, litter fall, coarse woody debris, and shade, while trees farther from the stream contribute primarily shade (Reeves et al. 2018). These results indicate that additional buffer length is likely more important than additional buffer width for providing ecological functions.

Although an improvement in the ecological functions in buffers adjacent to fish stream is identified by the FEMAT curves, studies of fish populations and biomass show mixed results. One reason for this variability is the lack of propagation of ecological functions downstream to fish bearing waters. For example, MacDonald and Coe (2007) considered temperature changes to be unlikely to propagate downstream, because of shading from buffers of fish-bearing streams, groundwater inputs increasing in larger basins, hyporheic exchange, thermal settling in larger pools, evaporative cooling, and inflows from unharvested basins. Three studies from Oregon highlight provided empirical support for these contentions:

1) Bateman et al. (2016) found for coastal cutthroat trout, no catchment level effects for fish density, growth rate, and survival. The only statistically significant result was an increase in late-summer biomass of age-1+ cutthroat.
2) Jensen (2018) examined four fish streams downstream from harvest units and did not find evidence for harvest effects on coastal cutthroat trout or steelhead summer growth.
3) Bateman et al. (2018) assessed stream habitat and fish population characteristics, including biomass, abundance, growth, size, and movement, for four years pre-harvest and five years post-harvest. They found evidence existed for positive effects in harvested basins compared to unharvested basins in total fish biomass, total catch, and biomass density of age-1+ coastal cutthroat trout. Bateman found no evidence of differences in condition, mean length, or threshold size for large fish of age-1+ (defined as >90th percentile of all fish captured) coastal cutthroat or any response in juvenile coho salmon.

Based on the lack of apparent change in fish populations due to buffers along non-fish bearing steams reported in research papers, it is unlikely that the proposed expanded Type Np will increase fish populations. Without these changes there is likely no fisheries-related economic benefit of Type Np buffers.

Change in amphibian populations

Appendix 3 includes summaries of findings of studies assessing amphibian populations in response to Type N buffer treatments and changes in shade. Different species showed different levels of sensitivity to changes in shade in a study by MacCracken et al. (2018). McIntyre et al. (in prep.) found mixed results looking at three species of amphibians in a study of three different treatment levels, including one treatment representing current Washington Forest Practices rules.[31] Pre-treatment estimates were compared to post-treatment estimates in three temporal blocks: one and two years, seven and eight years, and 14 and 15 years, respectively. Amphibian responses in the first temporal block were mixed, with torrent salamanders (*Rhyacotriton* spp.) increasing in the three treatments, and no consistent pattern for giant salamander (*Dicamptodon tenebrosus*) and tailed frog (*Ascaphus truei*). In the second and third temporal blocks, evidence existed for either no effect or negative effects of the treatments on density for all of the taxa, with tailed frogs larval and post-metamorphs declining more than 60% in the treatment representing Forest Practices rules and the no-buffer treatment. In this study, amphibian population abundance did not appear to be a response to stream temperature, as the stream temperature did not appear to be associated with buffer extent and the 7-day average daily maximum temperatures post-harvest were within the thermal tolerance range of species of interest and below the most common designated use temperature standard on private forestland of 16° C. Duarte et al. (2023) evaluated changes in occupancy and abundance of stream-associated amphibians under three buffer options. They found evidence that changes in occupancy are localized, finding no changes in downstream reaches to within 300 feet of treatment areas.

Confounding an analysis of the effects of buffers on amphibians is a lack of studies on the effect of buffer width on amphibian populations. Martin et al. (2021) identified only one study that evaluated amphibian responses to buffer width and this study did not report evidence of an effect. Further, amphibian populations are highly variable between locations along both harvested and unharvested streams, suggesting ecological factors other than forest management influence population responses.

Given that the effect of buffers on amphibian populations varies by species, time since treatment, and unknown local factors that interact with the buffers, a quantitative assessment of the impact of buffers on amphibian populations is not possible at this time. A qualitative analysis would also lack the necessary detail due to the same variables.

Based on the information available, it is likely that the proposed expanded buffers will benefit certain species and negatively affect other species, though which species is positively or negatively affected may differ by location. At the landscape scale, available research does not address whether amphibian populations will change significantly due to additional buffers. Undertaking a long-term, landscape-scale monitoring effort for amphibian diversity and abundance would provide the information needed to reduce uncertainty of the impacts to amphibians of timber harvest.

If a change does occur, the change in value of amphibian populations can be assessed. The benefits would likely be limited, as the additional buffers on Type Np streams would be on private lands in relatively inaccessible areas, and population changes are expected to be localized, so change in recreation (wildlife viewing) value is not expected. Likewise, as amphibians lack commercial or recreational harvests, no change in commercial value or recreation spending is expected. Amphibians provide ecological benefits, the full extent of which is likely unknown. Maintaining variable populations of amphibian species is a public good. Further study is needed to determine population viability.

We found no studies of amphibian value from the Pacific Northwest. Two studies from the southeast considering the commercial value of amphibians reported values between $0.67 and $40.42 (2024 dollars) per individual for most species (Degregorio et al. 2014, Witczak and Dorcas, 2009). However, the commercial trade of species covered by the Forest

[31] The other treatments were no buffers and 100% buffers. The study also included a control area with no treatment.

Practices HCP is likely limited due to their listed status.[32] Other species in the region may have commercial value. For species without commercial value the economic effects would be changes in existence and bequest values, as well as values related to ecological benefits provided by amphibians. These values are unknown.

Change to water quality and quantity

Appendix 3 summarizes studies of the ecological response to riparian buffer length and width along non-fish bearing streams in the Pacific Northwest. Included in this summary is a table from MacDonald and Coe (2007) that summarizes the influence of headwater streams on downstream reaches (Table 9). Riparian conditions, including buffers, have the potential to affect each aspect listed.

In a presentation to the Forest Practices Board on August 10, 2022, research leads for the Type N Experimental Buffer Treatment in Hard Rock Lithology study (known as the "Hard Rock" study) and the Type N Experimental Buffer Treatment in Soft Rock Lithology study (known as the "Soft Rock" study) reported on the findings from these studies as they relate to water quality and quantity (McIntyre et al. 2022, Ehinger et al. 2022). These findings were:

Hard rock

1) Buffers have only a small effect on discharge. Discharge is affected by the proportion of the watershed harvested.
2) Change in peak flows is driven by changes in storage (i.e., snow and snow melt) on which buffers only have a small effect.
3) Suspended sediment export appears to be driven by "random events" such as small landslides and bank sloughing. Natural variability masked any treatment effects.
4) Nitrogen export increased in the first two years in all treatments. The treatments with larger buffers had the smallest increase in nitrogen export. In years seven and eight, post-harvest, there was no consistent response by treatment.

Soft rock

1) Windthrow-driven sediment delivery was seen at treatment sites, but treatment and reference sites had higher sediment exports post-harvest.
2) Changes in nitrogen concentration and export were related to proportion of stream buffered. However, nitrogen concentrations and export were "well within" the ranges measured in other Pacific Northwest studies.

[32] None, for example, are available on commercial sales websites such as American Reptile Distributors (https://americanreptiles.com/), Backwater Reptiles.com (https://www.backwaterreptiles.com/salamanders-for-sale.html), among others.

Table 9. General magnitude of storage, transformation, and delivery of eight different components from headwater streams to downstream reaches (from McDonald and Coe 2007, p.51).

	Likely magnitude of			
Constituent	**Storage**	**Transformation**	**Delivery**	**Means of delivery**
Discharge	Low	Low	High	All flows, minimal delay
Fine sediment (<2 mm)	Low to moderate	Low	Moderate to high	All flows, but predominantly high flows
Coarse sediment (>2 mm)	High	Moderate to high	Low to moderate	High flows and mass wasting events
Large woody debris	High	Low to moderate	Low	Mass wasting or extremely high flows
Coarse particulate organic matter	Moderate	High	Moderate	Primarily high flows and mass wasting
Fine particulate organic matter	Low to moderate	Moderate	Moderate to high	All flows, especially high flows
Nutrients	High	High	Low to moderate	All flows
Temperature	Low	High	Low to moderate	Low flows

Temperature responses were seen in treatment areas in both studies, with a larger response in Hard Rock than Soft Rock locations. This result was attributed to longer buffers, greater post-harvest shade, and less windthrow at Soft Rock treatment sites. In the Hard Rock study, temperatures under the 100% buffer treatment were elevated by about 1˚C post-harvest and returned to pre-harvest conditions within three years. In the Forest Practices treatment, temperature also increased about 1˚C initially and remained elevated through year 9 post-harvest. In the Soft Rock study, the FP treatment resulted in a 0.6˚C increase and returned to pre-harvest conditions in 4 years.

Other studies have found mixed results. Some studies have similar results to the Hard Rock and Soft Rock studies. Others do not show temperature increases (e.g., Kibler at al. 2013) due to increase in summer baseflow and the presence of logging slash following harvest.

Summarizing the results of the studies listed above and in Appendix 3, it is likely the expanded buffers will have little to no effect on stream discharge. Sediment delivery would likely be within the range of natural variability, though longer buffers may increase the likelihood of windthrow. This may be partially or wholly offset by wider buffers reducing windthrow. Short-term nitrogen export would be lower with the proposed buffers. Water temperatures would be generally lower with the longer buffers, but the effects would be variable, with no change in some streams due to generally increased discharge and other factors controlling stream temperature. The duration in which the additional buffers would provide benefits would vary by site from one to several years or more, and in some cases, buffers can have a negative effect to factors, such as on discharge.

Valuing these changes presents a challenge. Keeler et al. (2012) notes that water quality is not a final ecosystem service, but instead a contributor to other ecosystem goods and services such as fish populations, nature viewing, or swimming. As such, a decrease in temperature or a short-term increase in nitrogen export must be valued, based on the changes in ecosystem goods and services these cause. Changes in water quality could affect other downstream uses such as recreation. However, the studies on changes in water quality due to Type Np buffers do not include analysis of changes in water quality conditions in downstream areas where recreation is most likely to occur. Given that harvests adjacent to Type Np streams are just a fraction of the activity (both forestry and non-forestry related) that occurs in larger downstream watersheds, and that post-harvest changes in water quality are temporary, it is unlikely that downstream uses would be demonstrably affected by the proposed buffers and, therefore, no associated cost or benefit can be assessed.

The proposed rule changes were developed specially around reducing the potential for water temperature increases greater than 0.3˚C. Setting aside the discussion of the extent to which the proposed changes would do that, it is possible to consider whether changes in water quality due to a change of water temperature ≥0.3˚C in magnitude alone would result in a change in value. While studies assessing the value of water quality exist, none assess the value of a change in water temperature specifically. Using the guidance of Keeler et al. (2012) that water quality value change should be assessed by the change in production of ecosystem goods and services, the impacts of the change in water quality must be considered. For the proposed rule change, no downstream change in fish populations is expected and other downstream users are unlikely to be affected. Some amphibian populations may benefit from full-length Np buffers. As the only ecosystem good or service related to changes in water quality is amphibian population change, water quality is best valued, based on the value of the change in amphibian population change. Note that water quality is only one aspect of buffers that could benefit amphibians and so the full value of an increase in amphibian populations cannot be attributed to water quality improvements.

Change in carbon storage

Analysis by Three Trees Consulting shows that the four versions of Scenario 1 would result in a net increase in carbon sequestration of between 0.024 and 0.047 metric tons CO^2 per acre per year (Appendix 4). These values represent the change in forest and harvested wood product carbon. Importantly, these values do not represent the change in atmospheric carbon. To find that value, the response of the economy to changes in timber supply would have to be considered, including product substitution and impacts of transportation and production of harvested wood products from other regions.

Since the focus of the analysis is change in forest carbon, the appropriate price to value the change in carbon is the forest carbon price. Washington State has a carbon market that allows for the sale of carbon credit from forest carbon projects. The carbon price at the March 5, 2025, auction was $50. Using this price, the value of forest carbon storage due to the proposed Np buffer ranges from $3.7 million to $74.5 million under Scenario 1 options, and up to $88.9 million under Scenario 2 (Table 10).[33,34] However, uncertainty is high. For example, the difference in sequestration rates between the two forest types analyzed by Hall is 14 times more than the increase in sequestration rate due to the proposed rule changes.

Table 10. Value of forest carbon storage by scenario.

Scenario	Low estimate	High estimate
1A >3 ft BFW	$5,000,000	$70,900,000
1A <3ft BFW	$3,700,000	$52,800,000
1B >3ft BFW	$5,300,000	$74,500,000
1B <3ft BFW	$3,700,000	$52,800,000
2	$6,300,000	$88,900,000

[33] The ability to sale forest-based carbon credits from the lands in the proposed Np buffers will be eliminated if the proposed rules go into effect. Once forests become unavailable for harvest, they are no longer available for carbon projects that focus on harvest reduction or extended rotations. Afforestation carbon projects would remain potentially viable in these areas.

[34] Appendix 4 includes a calculation of the value of stored carbon, based on the social cost of carbon.

Change in forest operations

The proposed Type Np rules would increase the extent of riparian buffers upslope from current buffers. Trees would be retained in areas where current harvest is allowed. This is likely to increase harvest costs for the following reasons:

1. Where cable yarding occurs, additional buffers increase the need for corridors through buffers or suspension of timber over buffers. Use of corridors through buffers can slow yarding operations.
2. Timber felling adjacent to buffers is typically slower than that away from buffers due to the need to more precisely place the tree when felling.

In addition, increased buffer extent may reduce forester and logger safety, which increases operational costs, affects workers compensation rates, and reduces the wellbeing of workers and their families. Buffers affect worker safety in the following ways:

1. Forest Engineers laying out units will spend more time navigating and working in the steep drainages that these buffers will apply to, which are typically the most dangerous areas of any harvest unit.
2. Falling trees against no-cut buffers or in areas of dispersed retention on steep slopes is more dangerous for timber fallers due to the interaction of the felled tree and buffer or disposed reaction trees resulting in more falling branches or the tree to kick back on the logger in unexpected ways.
3. Loggers responsible for laying out and rigging yarding lines will be working in more hazardous conditions as they will have to navigate and work around buffers that have trees that are potentially unstable and prone to windthrow.
4. Silviculture crews and other forestry or biology personnel working in the units after logging is completed will be exposed to the same risks, as they will also have to work around the potentially unstable trees.

The magnitude of the costs, due to changes in operations and impacts to worker safety, is unquantifiable. Increases in worker injury rates and the severity of injuries is unknown, though injuries could be severe on an individual level. Across forest operations, changes in technology have improved safety. Technology such as tethered logging has allowed loggers to work in the relative safety of cabbed equipment where in the past, workers would have been on foot. These operational changes would mitigate possible risks to worker safety.

Change in road network design

Additional buffers have the potential to increase the total length of roads and the number of landings needed to access harvestable lands. The potential extent of the change is unknown. In 2006, the Cooperative Monitoring, Evaluation, and Research Committee (CMER) had concerns that the additional buffers under Forest Practices Rules compared to pre-Forests and Fish Report conditions would result in additional roads and landings, and that these would potentially cause more erosion and an unintended increase in sediment delivery to streams. CMER requested the Buffer and Road Sediment Workgroup to assess the issue. The result of this was a proposal by the University of Washington to determine if buffers resulted in an altered road network. If buffers were found to affect road network layout, a study of the impacts of the changes on fine sediment production and delivery to type N basins was proposed. CMER choose not to pursue this exploratory study (study proposal documents provided in Appendix 5).

If additional roads and landings are needed, their construction will represent a cost to landowners. The total cost depends on the type and length of road needed. If additional all-weather rock surfaced roads are needed the cost would be approximately $100,000 per mile of road. Additional temporary roads cost about $25,000 per mile. Impacts of these additional roads on Type Np stream and other resources would depend on the length and location of the roads. At minimum, additional roads would increase road density across the landscape. According to the Forest Practices HCP Final Environmental Impact Statement, road density "can be a useful descriptor to enhance understanding of the overall level of disturbance to a watershed" and it is "one of 19 physical indicators recommended by the Services to assess a properly functioning aquatic ecosystem."[35]

Change regulatory risk under the clean water laws

Water quality in Washington is regulated under the Federal Clean Water Act and the State Water Pollution Control Act. Changes in Type Np buffers could change water quality to the extent that future regulatory action under the Clean Water Act section 303(d) does not occur. Correspondingly, retaining the current buffering rules could increase risk of regulatory action. As regulatory action under the State Water Pollution Control Act can be costly, reducing the risk of future regulation could be a benefit.

However, for risk reduction to occur, the following conditions must be in place:

1. The current Type Np buffers must be insufficient to maintain water quality consistent with the Clean Water Act and State Water Pollution Control Act, therefore requiring regulatory action.
2. The proposed buffers must make a meaningful difference in water quality, such that waters with the expanded Type Np buffers would no longer be out of compliance (or at least the number of waters out of compliance would be reduced), and hence, the Department of Ecology (Ecology) would not pursue 303(d) listings due to improvements in water quality caused by the proposed buffers (or would pursue 303(d) listing on a smaller number of waters).

The risk of each of these conditions is not specifically known. Although studies listed in Appendix 3 do indicate that the proposed buffers may reduce the likelihood of temporary water temperature changes, the studies do not show this impact propagating throughout downstream waters. These studies also indicate that the effects of buffer (e.g., shade, woody debris) are not the only factors affecting water temperature as different streams respond differently to the same buffer configuration.

Regarding the potential future use of 303(d) listing instead of the Forest Practice Adaptive Management Program, the DNR final preliminary CBA dated April 23, 2025, lists this effect as "considered and determined not probable" (p. B-1). However, the CBA notes that costs may be incurred if a Total Maximum Daily Load needs to be developed for Type Np stream.

In a comment letter on the preliminary draft CBA dated February 21, 2025, Ecology sent a comment letter that states:

> "Ecology notes that should new rules be adopted to improve the protection of Np streams in Western Washington, it is far more likely they continue to work through the Forest Practices Adaptive Management Program and the Forest Practices Board to ensure buffer requirements maintain water quality than it would be to pursue a 303(d) process for streams on forestland, in accordance with schedule M-2 of the Forests and Fish Report."

The statement is vague to the point that no specific assessment of potential impacts can be made. It is not clear from the statement how often or to what extent Ecology would pursue the 303(d) process if the proposed buffer rules are not implemented. It is also not clear how often the 303(d) process would result in a listing and subsequent change in management of forest lands. Finally, it is not clear if Ecology will stop working through the Forest Practices Adaptive Management Program if it pursues 303(d) listing. Given the lack of clarity in Ecology's potential to pursue the 303(d)

[35] HCP FEIS page 4-177. https://dnr.wa.gov/sites/default/files/2025-05/fp_hcp_feis_chapter_4.pdf

process, the potential value of avoiding this process is unknown and may range from no value to a positive value.[36] Additional clarity by Ecology on actions that it would undertake if the Type Np buffer proposal were not adopted would allow for a more precise estimate of the potential regulatory risk. In addition, the comment letter lacks detail on what aspect of schedule M-2 would be abrogated by not implementing the proposed buffers and what potential action under schedule M-2 would be taken by Ecology.

Regulatory action could take place if Forest Practices Rules were inconsistent with the State Water Pollution Control Act. Washington Administrative Code Tier II rule (WAC 173-201A-320) is key to assessing the likelihood of a regulatory action. MB&G's understanding of the application of the rule to Np streams is as follows:

1) Forest Practices Rules, which regulated Np streams are considered under WAC 173-201A-320 (2)(d) as an "other water pollution control program."
2) As a water pollution control program, a Tier II analysis has been completed under WAC 173-201A-320 (6).
3) Because a Tier II analysis has been completed, the program is regulated in accordance with WAC 173-201A-320 (6)(c), which allows for continuous improvement under an adaptive process.
4) Individual actives under these programs do not require a Tier II analysis.
5) The Forest Practices adaptive management process has historically been considered to meet the requirements in WAC 173-201A-320 (6)(c).

As long as Forest Practices Rules remain a water pollution control program, and the adaptive management process meets the requirement of WAC 173-201A-320 (6)(c), the risk of regulation is low to none.

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[36] While this analysis is not intended to assess the potential costs and benefits that may come from Ecology pursuing the 303(d) process, these benefits are possible to assess in general terms. Ecology pursing the 303(d) process, whether or not it continues to participate in the Forest Practices Adaptive Management Program, will result in increased costs to Ecology and likely to landowners. Depending on the outcome of these processes, the regional economy could be negatively affected as well. Benefits of these 303(d) processes are uncertain and likely small. For benefits to occur, one or more of the following must happen:

1. Fish, amphibian, or other species populations increase.
2. Downstream uses benefit.
3. Atmospheric carbon declines.

The specific management changes that could result from a 303(d) listing are unknown. However, given that Ecology states that implementation of the proposed buffer rules would greatly reduce the likelihood of pursuing the 303(d) process, it is likely the outcome of any listing would have an effect on water quality similar to the proposed buffers. Assuming this, benefits of any 303(d) listing would be similar to those listed in this report for the proposed buffers, with the caveat that the magnitude of the benefits would likely be lower because management changes due to 303(d) listing may apply to only selected Type Np streams.

Summary of costs and benefits

Costs and benefits of the proposed expanded Type Np buffers are listed in Table 11.

Table 11. Summary of costs and benefits of the proposed expanded Type Np buffers.

Factor	Scenario 1 benefit or (cost) / positive or negative outcomes	Scenario 2 benefit or (cost) / positive or negative outcomes
Forest land value	$657 million-$1.997 billion total	$1.105 billion-$2.385 billion total
Regional economic impacts	$4.7 billion-$7.9 billion over 45 years	$7.9 billion-$9.4 billion over 45 years
Cultural impacts – tribal cultural values	Likely a minor positive benefit, due to increase in wetland species in buffer. Value is limited due to limited access to the proposed buffer areas and variable presence of desired ecosystem goods or services.	Likely a minor positive benefit due to increase in wetland species in buffer. Value is limited due to limited access to the proposed buffer areas and variable presence of desired ecosystem goods or services.
Culture impacts – rural cultural values	Minor negative value at the state level, however in local areas could be moderate to high. Value is limited to the extent that timber harvest is a cultural value in any given community.	Minor negative value at the state level, however in local areas could be moderate to high. Value is limited to the extent that timber harvest is a cultural value in any given community
Change in water quality and quantity	Refer to amphibian benefits	Refer to amphibian benefits
Change in fish populations	Likely no cost or benefit	Likely no cost or benefit
Change in amphibian populations	Likely a minor positive benefit. Value limited to existing and bequest values, and ecological values related to variable amphibian populations. Contingent on increased amphibian populations under proposed buffers, which is uncertain.	Likely a minor positive benefit. Value limited to existing and bequest values, and ecological values related to variable amphibian populations. Contingent on increased amphibian populations under proposed buffers, which is uncertain.
Change in carbon storage	$3.7 million to $74.5 million over 45 years.	$6.3 million and $88.9 million over 45 years.
Change in forest operations	Minor negative value. Minor increase in operating costs, particularly related to cable harvest operations, and increased risk to worker safety.	Minor negative value. Minor increase in operating costs, particularly related to cable harvest operations, and increased risk to worker safety.
Change in regulatory risk under the Clean Water Act	No cost to positive due to Ecology not undertaking the 303(d) process.	No cost to positive due to Ecology not undertaking the 303(d) process.

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Appendix 1. Np Stream length and buffer area confidence intervals

Table A1-1. Estimated total length of Np stream with 95% confidence intervals.

Ecoregion	Total Np length (miles)	95% Confidence Interval	
		Upper (miles)	Lower (miles)
North Cascades	5,035	4,656	5,413
Northwest Coast	8,547	7,759	9,335
Puget Trough	313	221	406
West Cascades	8,343	7,412	9,275
Total	**26,294**	**24,795**	**27,792**

Table A1-2. Estimated total Np buffer area by scenario with 95% confidence intervals.

Scenario	Total acres	95% Confidence Interval	
		Upper (acres)	Lower (acres)
Current	197,250	184,386	210,115
1A >3 ft BFW	421,162	397,184	445,141
1A <3ft BFW	364,226	343,663	384,789
1B >3ft BFW	432,550	407,982	457,117
1B <3ft BFW	364,226	343,663	384,789
2	478,209	450,960	505,458

Appendix 2. Site class and age data.

Our estimate of harvest volume change for the regional economic impacts is based on estimates from several data sources. We assume that timber is harvested when the annual growth rate of the timber volume falls below 4.5% in each site index class based on volume by age class data from Chambers (1989; Table A2-1). This threshold reflects the higher discount rate used for land valuation purposes. When the growth rate drops below 4.5%, the incremental value gained from allowing the timber to continue growing is less than the expected return required by the discount rate. In other words, continuing to grow the timber beyond this point would yield a lower return than expected by the discount rate.

Table A2-1. Volume by age from Chamber (1989).

	Site Class				
	I	II	III	IV	V
	140	130	110	90	70
Age	Yield (mbf) per acre				
30	11.4	8.5	4.7	2.2	0.6
35	18.1	14.2	8.7	4.6	1.8
40	24.9	19.9	12.6	7.0	3.1
45	32.5	26.6	17.5	10.1	4.8
50	40.2	33.3	22.3	13.3	6.4
55	48.1	40.4	27.6	16.8	8.4
60	56.0	47.4	32.9	20.3	10.4
65	63.9	54.5	38.3	24.0	12.4
70	71.7	61.6	43.7	27.7	14.5
75	79.3	68.5	49.0	31.3	16.4
80	86.9	75.3	54.3	34.9	18.4
85	94.0	81.9	59.4	38.3	20.2
90	101.2	88.4	64.4	41.8	22.1
95	107.9	94.6	69.2	44.9	23.6
100	114.6	100.7	73.9	48.0	25.1

Using US Forest Service Forest Inventory and Analysis data we estimated area in each site index class (Table A1-2). Based on this we calculated the acre weighted average harvest rotation, which is about 49 years. As we assume the forest is fully regulated, we assume harvest of all the additional proposed buffer area would occur over this time. We assume all lands in the proposed buffers would be harvested. No additional deductions should be applied to this buffer area for additional area unavailable for harvest due to Forest Practices Rules, as the effects of these rules are captured in our analysis of FPAs.

Table A2-2. Site Index Class Distribution.

Site I	Site II	Site III	Site IV	Site V
4.0%	35.9%	46.3%	10.4%	3.4%

Appendix 3. Rocinante Consulting LLC report

This appendix contains a summary of research on buffers on non-fish bearing streams. Compiled by Rocinante Consulting LLC for the Washington Forest Protection Association.

Ecological Responses to Buffer Extent and Width on Non-fish-bearing Streams in the Pacific Northwest of North America

Executive summary

Retention of forested buffers along riparian habitats is a commonly employed practice to reduce potential negative effects of land use on aquatic systems. In the Pacific Northwest of North America, modifications to forest practices regulations in the last two decades have included expanded buffer retention on non-fish-bearing (NF) and fish-bearing (F) streams, often to address regulatory cold water standards. However, despite substantial ecological variation in the processes and functions these buffers are intended to support, prescriptions often involve continuous fixed width buffers to achieve desired outcomes. Also, most studies are conducted at reach and stream scales, even though many watershed features, such as intensity of management, vary substantially across the forested landscape. As a result, important areas of uncertainty remain and opportunities exist to evaluate how alternative buffer prescriptions can achieve desired ecological outcomes while maintaining a sustainable regional forest economy. For example, information is generally lacking about how spatial and temporal population responses, including stream-associated amphibians and resident and anadromous fish (both taxa groups are components of private land HCPs in Oregon and Washington), vary due to ecological and management practices. In particular, how sub-basin harvest, basin-wide management, and stand regeneration practices influence buffer effectiveness across a range of continuous/discontinuous extents and widths have received little research attention. Here, we review general body of knowledge for ecological responses to variability in buffer extent and width on NF streams in the Pacific Northwest of North America. Although we focus on research results for NF streams, we also evaluate the potential for propagation of effects downstream to F streams. Finally, we describe how these results inform potential alternatives for fixed width buffers to conserve aquatic conditions and function.

Summary of effects of increasing extent and width of Type N buffers

We summarize effects of increasing extent and width of NF buffers, noting that main effects will derive primarily from changing from discontinuous to continuous buffers (extent). The review found little evidence to support the contention that ecological responses of interest would change substantially due to increasing the width and length of buffers on NF streams beyond the current minimum width of 50 feet for at least 50% of the stream length.

- Shade will increase on NF streams (extent and width). Generally, shade is associated with reductions in pre- to post-harvest changes to stream temperature. However, we found little evidence to indicate that this reduction would change in a biologically meaningful manner if NF buffers were continuous and increased from 50 to 75 feet in width. Importantly, in some settings, shade is not the dominant control on stream temperature, in which case any changes made to buffer extent and/or width will not affect this response.
- Primary production will decrease given reduced light levels and, generally, a reduction in the heterogeneity of stream temperatures throughout the NF network (extent and width). Given evidence for invertebrate production in NF streams and export to F streams, this change could alter resource types and amounts delivered downstream to fish populations in the upper portion of the F network.
- Sediment import may be altered (extent and width). Relatively little information is available for this response. Sediment import from roads has been addressed through engineering modifications. Depending on vulnerability to windthrow post-harvest, increasing the extent of N buffers may increase the amount of sediment or result in no change. No information is available to address whether sediment from upslope processes (i.e., landslides) is less likely to reach streams given continuous buffers or increasing their width by 25 feet.
- An increased number of trees will grow adjacent to NF streams, increasing the potential supply of large woody debris (LWD) to streams (extent). Wider buffers may reduce windthrow mortality in buffers (in some settings) and increase the probability that riparian trees live longer and, in turn, increase the number and size of LWD (width). In some settings, wider buffers may merge with unstable slope buffers to increase the number of trees available for delivery as LWD. We note that LWD delivery to downstream reaches occurs primarily during debris flows and landslides, so the overall effect of increasing wood supply to F waters will vary across basins and watersheds.
- Modification of riparian understory vegetation cover and diversity (extent). Discontinuous buffers may support growth of light-limited understory species. Increasing shade along NF streams is likely to reduce understory species, many of which provide nesting and foraging substrates for invertebrates that, in turn, may be exported downstream to F streams. Increasing dominance of the riparian canopy by conifer species will alter leaf litter imports to streams. Ecological responses to this modification are difficult to predict but may include changes to invertebrate species and biomass exported downstream.
- Amphibian population responses are unlikely to respond to increasing extent and width of NF buffers. Population persistence is not related to buffer retention. Variation in abundance is associated with ecological conditions, some of which interact with buffer extent and width, as well as abiotic features not associated with management.

The theoretical basis for riparian buffers

Due to the ecological importance of riparian ecosystems, buffers of standing trees or intact native vegetation are often left between uplands and aquatic environments to reduce potential negative effects of timber harvest, agriculture, or other land uses (Stauffer and Best, 1980; Knopf et al., 1988). In the Pacific Northwest, USA, the Northwest Forest Plan introduced theoretical constructs based on the observation that interaction strength between riparian areas and streams diminished with distance from the channel edge (we note that the plan assumed fixed width buffers). However, the rate at which the strength of interactions diminished with distance from the channel edge varied with the ecological function being considered (Figure 1). Interactions, such as those between root strength, bank stability, and sediment production, are restricted to the zone immediately adjacent to the channel (Pollen-Bankhead and Simon 2010). Other functions, such as shade or large wood input, extend farther from the channel (Bisson et al. 1987; McDade et al. 1990). However, no direct interaction between the riparian area and stream occurs from a distance that exceeds the height of the tallest trees in the streamside area, termed a site-potential tree height in the Northwest Forest Plan (Reeves et al. 2018). As a result, the assumption that height of the riparian vegetation governed functional interactions between aquatic and terrestrial systems influenced regional variation in proposed riparian buffer widths in the Northwest Forest Plan. Similarly, the assumed influence of tree height on riparian buffer function served as the basis for variation in buffer width by site class in the Washington Forest and Fish rules (WA DNR 2001).

In a comprehensive review of the technical information informing the FEMAT curves, Reeves et al. (2018) concluded that recent research supported the shape of the original curves for all functions except wood input (policy motivations were considered, as well, during development of original curves). The authors proposed a modification to the wood input curve, with input of wood occurring from much closer to the channel than was indicated by the original curve (Figure 1).

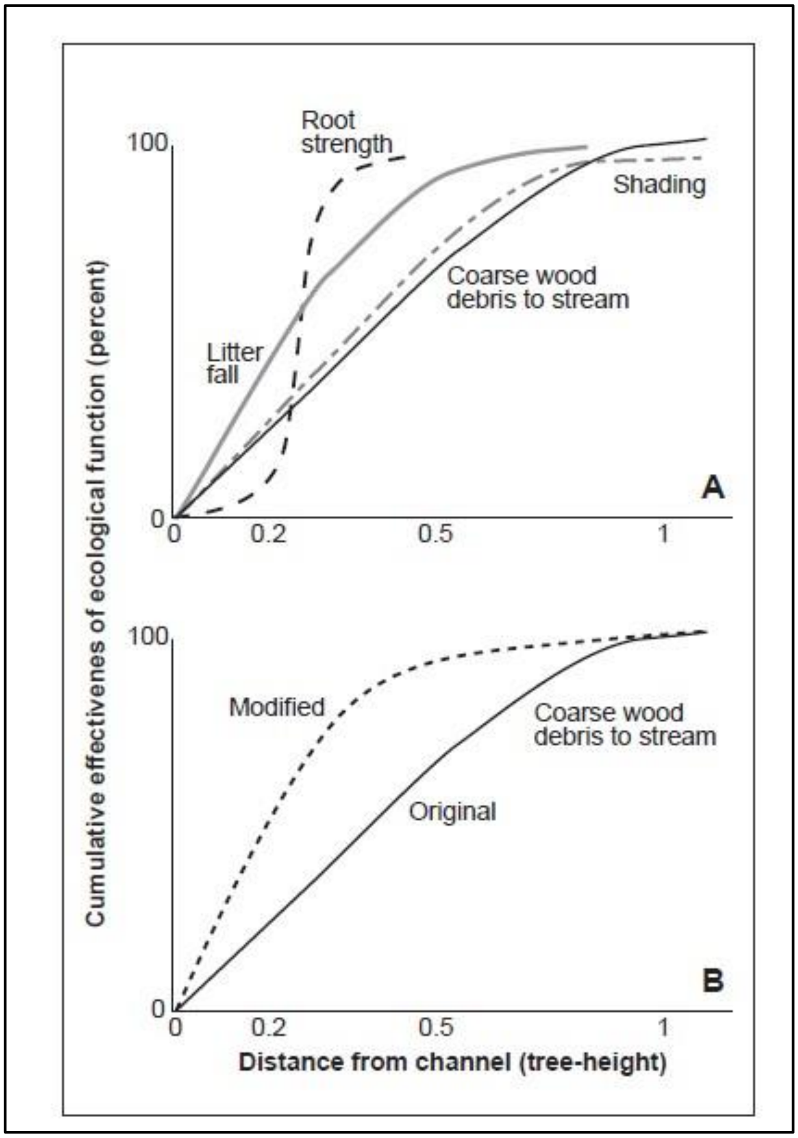

Figure 1. FEMAT curves from the (A) 1993 Northwest Forest plan and the (B) revision for wood input proposed in the 2018 update (Reeves et al. 2018).

RIPARIAN FUNCTION PROVIDED BY CURRENT RULES Riparian function provided by current rules

Shade and Thermal Controls

Stream temperature controls biological processes from individual to ecosystem scales (Beschta et al. 1987, Poole and Berman 2001, Hester, and Doyle 2011). For example, stream temperature affects fish physiology and growth rates as well as measures of population performance such as reproduction and survival (McCullough 1999, McCullough et al. 2001, Hester and Doyle 2011). Given the strong inverse association between shade and stream temperature in many systems, riparian vegetation can serve to maintain desired thermal profiles in aquatic systems. Riparian buffer designs to mitigate temperature increases evolved in response to evaluations of configuration effectiveness (Steinblums et al. 1984, Beschta et al. 1988, Groom et al. 2011a, 2011b). Importantly, NF and F streams often receive different riparian buffer prescriptions due to location within drainage networks, physical channel characteristics, and contributions to fish population performance. Also, we emphasize that despite the oft-noted association between shade and stream temperature, many research efforts document how factors not associated with forest management, including lithology, drainage area, elevation, and annual variation in climatic conditions, influence stream temperature (Johnson 2004, Boyd and Kasper 2003, Gomi et al. 2006, Janisch et al. 2012, Reiter et al. 2015; Martin et al. 2021). Finally, evaluation of multiple studies that studied similar prescriptions across space and time, and used comparable study designs and analytical tools, is more likely to provide insight about the range of expected outcomes rather than a single study (Nichols et al. 2019). For example, in a literature review of riparian buffer effectiveness at maintaining pre-harvest temperatures in NF and F streams in Oregon and Washington, Czarnomski et al. (2013) concluded:

> "Although a relatively significant amount of information is available regarding stream temperature and riparian shade responses to forest management, the ability to identify emergent trends across studies is hampered by several factors. The primary limitation is the inconsistencies between study designs and analysis methodologies, particularly the adequate measurement of, and incorporation of effects modifiers into the assessment. Deciphering observed differences in responses between similar buffer designs is extremely difficult if effects modifiers have not been controlled for in the study design and analysis. The generally low sample sizes (especially within buffer management types) and inconsistency in assessment of effects modifiers made traditional statistical models inappropriate, thereby making comparisons between studies challenging." (pp. 204-205).

Several studies evaluating temperature responses to riparian buffer prescriptions for NF streams have occurred in the Pacific Northwest in the last 20 years. Importantly, overstory tree retention along NF streams was not required until 2022 on private forest land in Oregon. In Washington, perennial initiation points (PIPs), tributary junctions, and the 300-500 feet of the NF stream above a junction with a F stream receive buffers (other sensitive site may receive protection, too, and additional buffers are added until a minimum 50% of the NF stream is buffered). Given operational and implementation challenges, as well as inherent variation in ecological settings and legacy effects of previous harvesting, designing a single study to address uncertainty in stream temperature responses to different riparian buffer prescriptions is unrealistic.

Finally, recent research efforts have focused on the relationship between forest management, stream temperature, and variation in stream discharge (Coble et al. 2020; Moore et al. 2023). Increased variation in precipitation regimes can lead to reduced stream discharge, particularly during the summer months in the Pacific Northwest of North America (an area where forecasts suggest summer droughts will increase in severity). Reduced stream volume may make small streams susceptible to warming even in the presence of buffers that were retained to provide full shading, possibly due to reduction and/or modification of hyporheic exchange (Wondzell 2011). How buffers, regeneration of upland harvest units, and climatic variation interact to influence stream discharge, and consequences for stream temperature, is an emerging research topic that has yet to receive robust evaluation across the range of stream conditions and settings occurring in the Pacific Northwest.

In British Columbia, Gomi et al. (2006) compared stream temperature responses of three riparian buffer treatments, no-buffer (*n*=4), 10 m (33 feet) buffer (*n*=1), and 30 m (98 feet) buffer (*n*=2), to controls for two pre-harvest and four post-harvest years. Substantial variation existed in the response to the no-buffer treatment, as summer daily maximum temperature ranged from 1.9-8.8 °C across the four streams. Treatment effects (standard deviation) for the different buffer treatments ranged from 0.4 °C (0.8) to 3.9 °C (1.8). For the stream with a 10 m buffer, the treatment effect was 1.0 °C (1.3); for the 30 m buffer, treatment effects were -0.2 °C (0.5) and 0.4 °C (0.7). Gomi et al. (2006) speculated that variation in effect size for streams without buffers was associated with channel morphology and non-conifer riparian vegetation. Streams with narrow channels warmed less in response to treatments and returned to pre-treatment temperatures more quickly than streams with wider channels.

Janisch et al. (2012) evaluated data collected from 2002-2008 in small watersheds (< 9 ha; 22 acres) in western Washington to estimate temperature effects for continuous (10-15 m; 33-50 feet; *n*=6) and patch (50-110 m in length; 165-360 feet; the full width of the floodplain; *n*=5) riparian buffers compared to clearcut sites (*n*=5). Several streams had low late summer discharge (average ≈ 0.3 L s^{-1}) and became spatially intermittent. In the first year postharvest, daily maximum temperatures in July and August increased in clearcut streams by an average of 1.5 °C (range: 0.2–3.6 °C), in patch-buffered catchments by 0.6 °C (range: -0.1–1.2 °C), and in continuously buffered catchments by 1.1 °C (range: 0– 2.8 °C). Average daily maximum temperature in the clearcut treatment increased 1.5 °C in the first-year posttreatment (Table 2); the largest temperature increase in a single stream was 3.6 °C. Janisch et al. (2012) attributed substantial variation within treatment groups to length of wetted channels, presence of riparian associated wetlands, residual logging slash, and post-harvest windthrow.

	Temperature response (°C)		
Treatment	**Year 1**	**Year 2**	**Year 3**
Continuous buffer	1.06	0.89	0.38
Patch buffer	0.61	0.67	0.91
Clearcut harvest	1.53	1.1	0.84
Patch buffer (one outlier removed)	0.73	0.72	0.16

Table 2. Average NF stream temperature response for three riparian buffer prescriptions and controls, western Washington, USA, 2002-2008 (Janisch et al. 2012). A debris flow removed all riparian understory vegetation from one patch-buffered catchment between Years 2 and 3, leading to large temperature increases, so we also present treatment group means for patch buffered catchments with that outlier removed from the calculation of temperature response in all three post-treatment years.

Using a Before-After-Control-Intervention (BACI) design, Kibler et al. (2013) compared multi-year data from streams in unharvested (*n*=3) and treated (*n*=5) portions of a watershed in the Hinkle Creek Watershed Study, Oregon. Between August 2005 and May 2006, operators felled trees by hand and cable-yarded trees to landings. Buffers were not left along NF streams in accordance with Oregon forest practice rules. In the first summer post-harvest, average maximum daily stream temperatures ranged from 1.5 °C cooler to 1.0 °C warmer compared to pre-harvest conditions. For two of the three control streams, the highest maximum temperatures were recorded in 2006, the first year of post-harvest for treated streams; for the third control stream, the second highest temperature was recorded in 2006 (Table 1). These results suggest that unexplained annual variation may have contributed to elevated stream temperatures. At the outlet of the harvested watershed, Kibler et al. (2013) did not report evidence for changes to minimum, mean, or maximum daily stream temperatures although 14% of the total catchment was included in the four harvest units. Kibler et al. (2013) attributed the absence of consistent temperature increases in treated NF streams to increased summer baseflows and the presence of substantial logging slash in streams post-harvest.

	Year				
Stream	**2002**	**2003**	**2004**	**2005**	**2006**
		Maximum stream temperature (°C)			
Myers	15.4	16.2	15.2	14.9	**16.6**
DeMersseman	14.5	14.6	14.5	14.4	**15.3**
NFH	17.5	**19.2**	17.5	17.5	18.7
Fenton	15.1	**16.2**	16.1	14.2	14.5
Clay	**16.8**	18.3	16.8	15.4	16
Russell	**16.3**	14.8	13.9	14	16
16BB	14.8	15.5	14.8	14.6	16.2
SFH	16.9	**18.4**	17.5	17.3	18.2
		Minimum stream temperature (°C)			
Myers	10.8	10	10.8	**11.2**	10.9
DeMersseman	10.8	10.3	10.6	**11.2**	10.8
NFH	9.9	9.8	10.2	**10.7**	8.1
Fenton	10.1	**11.6**	12.1	10.6	9.6
Clay	10.2	11.6	**11.9**	10.2	10.3
Russell	**10.1**	9.8	9.8	**10.1**	9.3
BB	**10.8**	10.5	10.5	10.7	10.8
SFH	10.2	10.1	9.9	**10.8**	8.1

Table 1. Maximum and minimum stream temperatures (°C) observed in all locations for eight streams, summers 2002–2006, the Hinkle Creek Watershed Study, Oregon (Kibler et al. 2013). Gray boxes indicate post-harvest measurements

for five streams in 2006. For each stream, the numbers in bold indicate the warmest value recorded either pre- or post-harvest.

Bladon et al. (2016) compared multi-year data from an unharvested and a treated watershed in the Alsea Watershed Study, Oregon. The treated watershed was harvested with ground- and line-based equipment and all trees in the cutover area were removed, including those along NF streams. Analyzing three years of pre-harvest and three years of post-harvest summer stream temperature data, Bladon et al. (2016) did not find evidence for differences in the 7-day moving mean of daily maximum (T7DAYMAX) stream temperature, the mean daily stream temperature, or diel stream temperature. When data were restricted to the Oregon regulatory period of July 15 to August 15, T7DAYMAX increased 0.6 °C (standard error = 0.2). Importantly, the warmest maximum daily stream temperature observed in the treated stream was 14.7 °C. In the original Alsea Watershed Study, maximum daily stream temperatures rose to 21.7 °C (1966) and 29.4 °C (1967) in the first two post-harvest years, suggesting increased effectiveness of current riparian buffer regulations when compared to historic practices. However, upslope harvesting practices also varied, making direct comparisons about buffer effectiveness challenging.

In a meta-analysis of data from the Alsea, Hinkle, and Trask Watershed studies, Bladon et al. (2018) evaluated evidence for effects of riparian buffer prescriptions on temperature in NF streams; the propagation of effects downstream to F streams; and how interactions between lithology and management practices were associated with stream temperature responses in these headwater and downstream reaches. Median 7-day moving average of daily maximum stream temperature (T7DAYMAX) was greater at seven of the eight harvested upstream locations during the post-harvest period relative to the pre-harvest period. The largest increases were recorded for clearcut sites (*n*=4) in the Trask Paired Watershed Study: increases in median T7DAYMAX ranged from 2.4–3.9 °C post-harvest. For buffered sites (10 m; 33 feet), the increases in the median T7DAYMAX ranged from 0.6–1.0 °C. The largest increase in median T7DAYMAX (0.8 °C) during the post-harvest period occurred at two sites, GSDS (1,100 m; 3,600 feet) and UMDS (990 m; 3,250 feet), in the Trask Watershed that were downstream of the four harvested sites that warmed the most post-harvest. Increases in median T7DAYMAX for two reference reaches in these basins also increased (0.6 and 1.0 °C, respectively), suggesting annual variation was associated with air temperature increases rather than harvest. Similarly, Bladon et al. (2018) did not find evidence for additional warming associated with forest harvest at five downstream sites (range: 370–1,420 m; 1,215–4,800 feet). Finally, although Bladon et al. (2018) claimed associations existed between stream temperature increases, lithology, and percent of basin harvested, a graphical evaluation of the data revealed substantial variation in these relationships (Figure 5; Bladon et al. 2018). The statistical evaluation reported by Bladon et al. (2018) was not sufficient to determine the strength of evidence for associations between these factors.

McIntyre et al. (2018) evaluated three buffer prescriptions on NF streams on consolidated lithologies across five study blocks in western Washington. Treatments were a clearcut harvest with a riparian leave-tree buffer (two-sided buffers, 15.2 m [50 feet]) along the entire stream length (100%); a clearcut harvest with a two-sided 15.2 m (50 feet) riparian leave-tree buffer along ≥50% of the RMZ (50%; current rules for NF streams in Washington); and a clearcut harvest with no riparian leave-tree buffer retained along the stream (0%). For the 50% treatment, buffers may have included sensitive sites such as slope and headwall seeps, headwater springs, Type Np intersections and alluvial fans. As monitoring occurred in 17 basins for three years pre- and nine years postharvest, this study provided an extensive spatial and temporal evaluation of stream temperature responses to different riparian buffer prescriptions. For the 100% buffer, seven-day average stream temperature post-harvest did not differ from pre-harvest temperatures in seven of nine years; for FP and 0% treatments, evidence in differences occurred in six and eight years, respectively (Figure 2). Across all years and blocks, the largest difference in mean monthly stream temperature pre- and post-harvest were 2.1, 2.7, and 3.4 °C for 100%, 50%, and 0% treatments, respectively (Table 3). Importantly, average monthly water temperature exceeded 16 °C (the current regulatory threshold) for only two months in one of the 0% treatments (CASC 0%; Table 3). McIntyre et al. (2018)

attributed rapid recovery of the 100% treatment to shading provided by understory vegetation, ground cover, and woody debris.

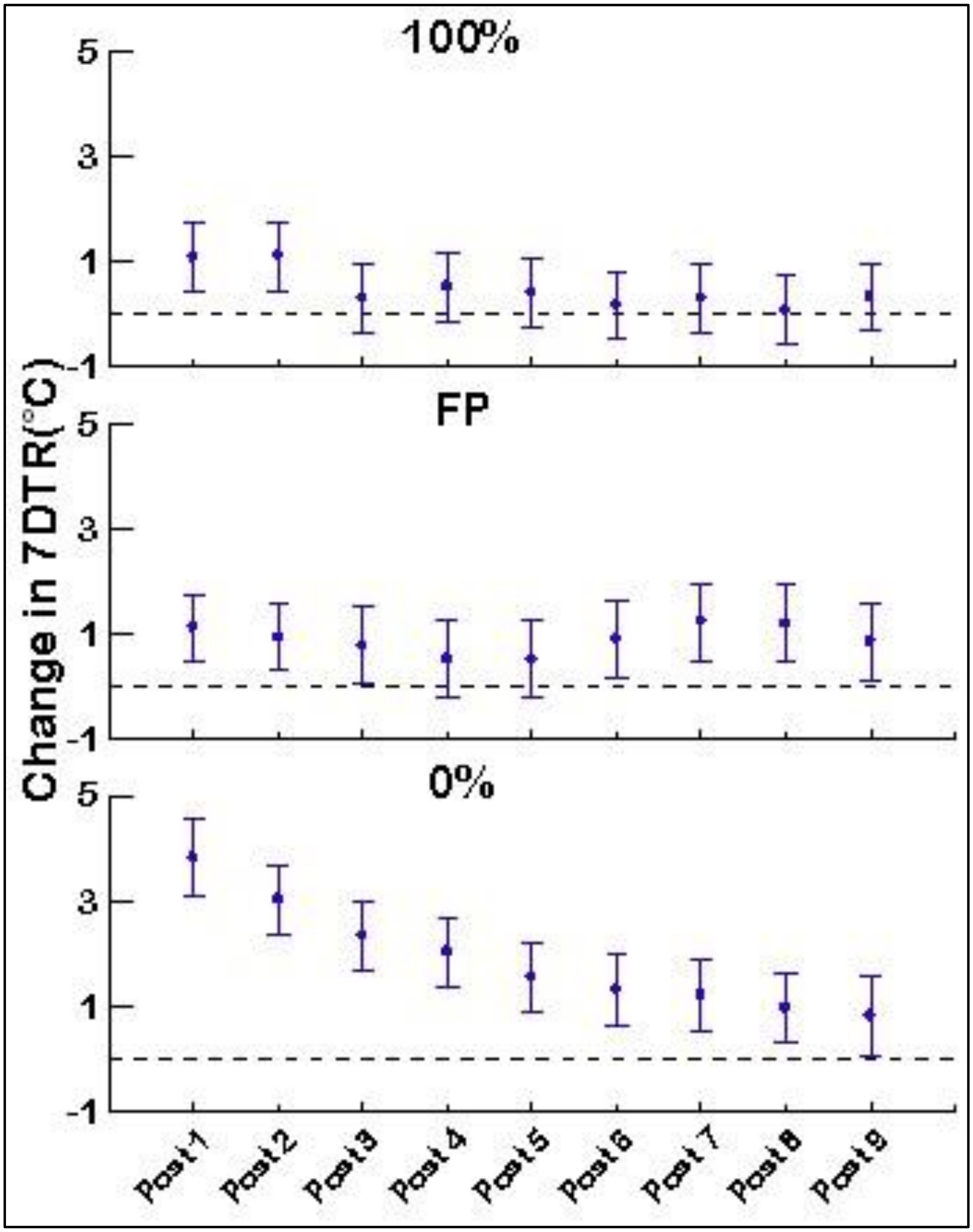

Figure 2. Pairwise comparisons of each post-harvest year (2009-2017) to the pre-harvest period for the seven-day average temperature response (7DTR) for three buffer prescriptions, western Washington, 2009-2017 (McIntyre et al., 2018).

			Post-harvest year								
Block[1]	**Treatment**	**Preharvest**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
OLYM	Reference	10.7	10.8	10.6	10.7	10.6	11.6	12.0	11.8	11.6	**11.9**
	100%	12.0	12.8	12.5	11.5	12.8	13.6	**14.0**	13.9	13.7	13.8
	FP	10.1	11.0	10.6	10.7	10.2	10.7	11.6	**11.8**	11.5	11.6
	0%	9.6	**10.9**	10.6	10.3	10.2	10.3	10.5	10.4	10.3	10.3
WIL1	Reference		Not used because of pre-harvest windthrow								
	100%	11.4	**12.5**	12.3	12.4	12.0	11.7	12.0	12.3	12.1	12.1
	FP	10.4	12.6	11.7	11.7	11.5	11.5	12.2	13.0	**13.1**	12.3
	0%	11.7	**15.1**	14.3	12.9	12.9	12.3	12.6	12.7	12.5	12.2
WIL2	Reference	11.2	11.8	11.4	11.8	11.7	11.8	12.4	12.7	**12.9**	12.5
	100%	11.5	12.7	12.3	12.3	11.8	11.9	11.8	**12.8**	12.5	12.2
	FP[2]	11.9	**13.1**	13.0							
	0%	12.3	**15.3**	13.8	13.9	13.8	13.3	14.0	14.0	14.0	13.9
WIL3	Reference		Not used in analysis because of poor model fit								
	100%	13.0	**15.1**	13.9	13.5	13.8	10.6	14.4	14.4	14.0	
CASC	Reference	11.6	12.8	11.0	9.1	11.7	12.8	12.7	**13.3**	13.2	12.8
	FP	11.2	11.7	11.2	10.2	11.5	11.7	11.8	12.1	**12.2**	11.9
	0%	13.8	14.6	**17.1**	15.4	17.0	17.0	**17.1**	16.7	16.0	16.3

[1]Replication of all four treatments did not occur in each block.

[2]WIL2-REF1 was harvested as an FP treatment in early 2016 (post-harvest year 3).

Table 3. Highest mean monthly water temperature (°C) for the pre-harvest period and each post-harvest year for three buffer prescriptions and a reference basin, Type N Hardrock study, western Washington, 2006-2008 (pre-harvest) and 2009-2017 (post-harvest). For each treatment × year combination, the highest temperature is noted in bold (McIntyre et al., in review).

Reiter et al. (2020) examined water temperature response to harvest along NF streams with and without buffers in the Trask Watershed in Oregon. Comparing distributions of summer water temperatures for six and four years pre- and post-harvest, respectively, post-harvest water temperatures at all sites, including the reference watershed, were warmer than the pre-harvest period. However, temperature distributions at buffered (12–15 m; 39–49 feet) and reference sites were similar across periods (panels C and D, Figure 3 below). Streams harvested without riparian buffers exhibited a post-harvest increase in median temperatures of ~2^{o}C (Reiter et al. 2020; Figure 5 on page 8). Several factors may have muted temperature response in streams without buffers. At some sites, overstory trees, which provided a substantial amount of pre-harvest shade, were retained along the NF stream (Reiter et al. 2020). Also, retention of understory vegetation, required along NF streams, may have provided sufficient shade to reduce temperature increases (Jackson et al. 2001, Reiter et al., 2020). In contrast to many other stream temperature analyses, Reiter et al. (2020) evaluated the distribution of stream temperatures recorded in their study not only summary measures such as the 7DAY MAX, average, and range. By doing so, the authors were able to determine the amount of overlap between control and treatment streams and how long streams exceeded critical biological (these vary by species and taxa) and regulatory thresholds (e.g., 16 ^{o}C). Doing so supports a broader conversation about variation in thermal regimes, and how critical a range of stream temperatures are even to cold-water adapted taxa such as anadromous fish (Armstrong et al. 2021).

Martin et al. (2021) used a systematic evidence review to evaluate strength of evidence for the effect of buffer retention on conserving pre-harvest stream temperatures on NF streams. Evidence, compiled across multiple studies in the Pacific Northwest, USA, and Canada that studied temperature responses to buffer prescriptions on NF streams, indicated substantial variability in the temperature response to buffer retention. Buffer prescriptions consisted of no-cut buffers, thinned riparian stands, no-buffer (clearcut), and combinations of these variations. The no-cut buffer treatments varied from 33 feet to 100 feet (10-30 m) wide and included continuous and discontinuous buffers. Thinning prescriptions included thinned riparian stands adjacent to the stream and thinned stands outside (upslope) of a stream-adjacent no-cut buffer.

The only treatment in common among multiple (seven of 15) studies was a clearcut prescription in which no buffer was retained. According to the studies, the average of mean daily maximum effect sizes for 10 different riparian treatments (including clearcuts) ranged from 0 ^{o}C to 1.7 ^{o}C. Clearcut treatments resulted in the largest effect size (>1.0 ^{o}C) except for a single study in which the effect size decreased after treatment and averaged 0.2 ^{o}C. The average of mean 7-day maximum effect sizes for 14 different riparian treatments including clearcuts ranged from − 1.0 ^{o}C to 3.4 ^{o}C. Treatment average effect sizes suggested an association with clearcuts having the largest response (≥3.4 ^{o}C) and treatments with buffers ≥100 feet (30 m, i.e., no-cut buffers with or without variable retention) had the smallest response (<0 ^{o}C). A suite of five treatments that included no-cut buffers, no-cut plus variable retention buffers, or no-cut patch buffers all ≤65 feet wide had average effect sizes ranging from 0.6 ^{o}C to 1.4 ^{o}C. However, the imprecision in effect sizes (i.e., overlap of 95% C.I. for four of five treatments) indicated that no differences could be detected across the treatments. Martin et al. (2021) concluded that evidence for buffer effectiveness was associated weakly with various prescriptive components (fixed-width or patch-buffer) as prescriptions were not designed to block solar radiation. As a result, the amount of shade provided by buffers may have varied within and across treatments. Also, only one study included in the evaluation manipulated shade directly. Finally, multiple factors, including geology, hydrology, topography, latitude, and stream azimuth, may influence thermal responses of streams to shade loss, further confounding evidence about the relative effectiveness of buffers for conserving stream temperatures post-harvest.

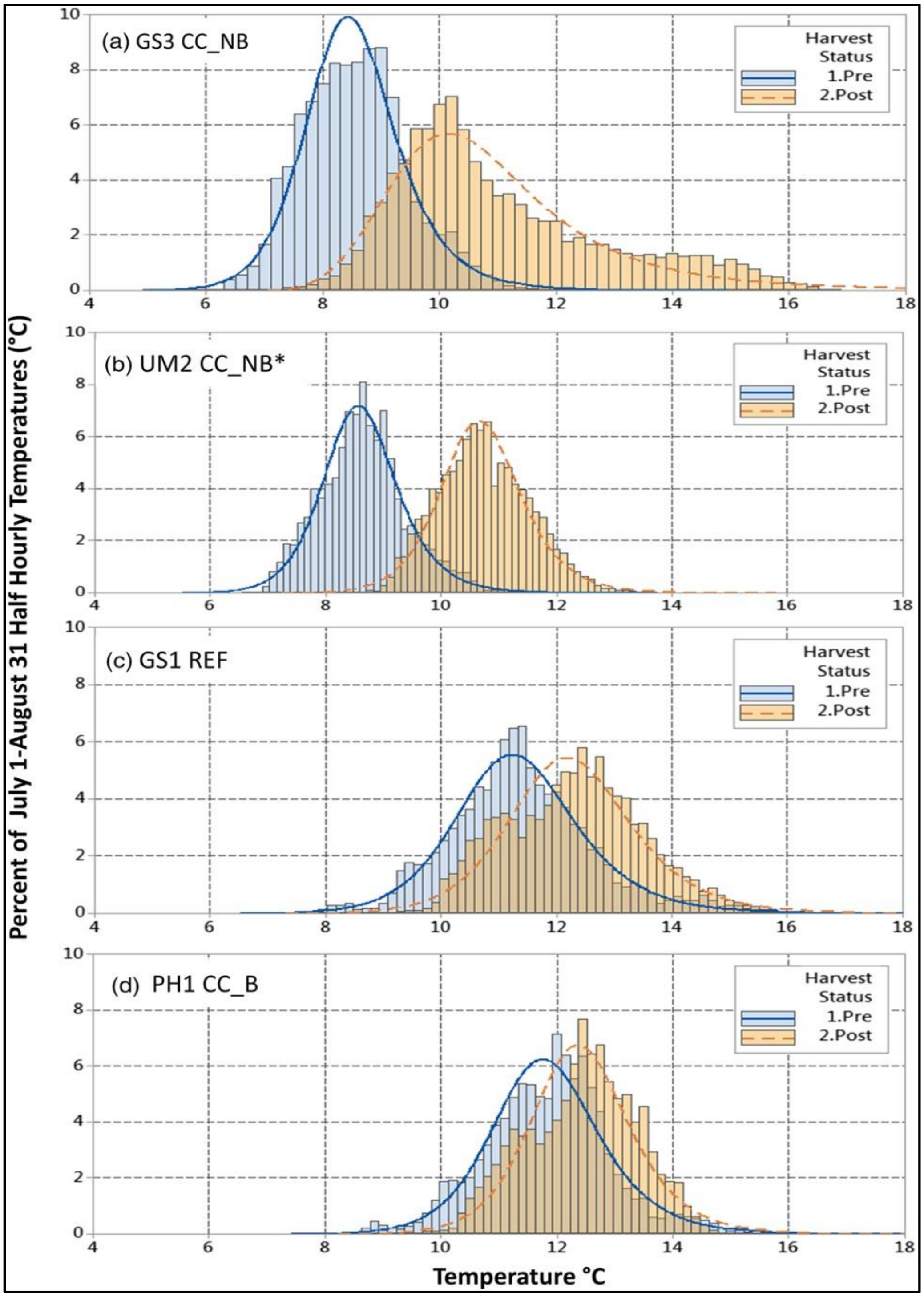

Figure 3. Examples of pre- (2006-2011) and post-harvest (2013-2016) distributions of half-hourly stream temperature data sampled from July 1- August 31 in each year in the Trask Watershed, Oregon (Reiter et al. 2020). GS3 (a) and UM2 (b) were harvested without buffers, PH1 (d) had a 15 m (49 feet) buffer on each side of the channel, and GS1 (c) was an unharvested reference site.

Ehinger et al. (2021) compared a single experimental treatment to an unharvested reference in 11 basins on marine sedimentary lithologies in western Washington. Based on current forest practice rules for private lands in Washington, the treatment prescribed clearcut harvest with a riparian leave-tree buffer (two-sided buffers, 15.2 m [50 feet]) along ≥50% of the perennial stream channel, with buffers for sensitive sites including slope and headwall seeps, headwater springs, Type Np intersections and alluvial fans. The average treatment responses (95% confidence interval) for the seven-day average temperature in the three years post-harvest were 0.6 ^{o}C (0.29, 0.95), 0.6 ^{o}C (0.25, 0.90), and 0.3 ^{o}C (0, 0.55). For all basins, pre-harvest temperatures were less than 15 ^{o}C. Average monthly temperatures were highest in July or August and ranged from 11.3 to 14.9 ^{o}C in the reference sites and 10.1 to 14.8 ^{o}C in the treatment sites. Although average monthly water temperatures were higher during and after harvest, temperatures equaled or exceeded 15 ^{o}C (increases of 1.8 ^{o}C and 0.1 ^{o}C, respectively) in two treatment sites (the regulatory threshold is 16 ^{o}C). None of the three reference streams exceeded 15 ^{o}C during the study. Canopy cover on all sites ranged from 92-99% prior to treatment implementation. Although only one treatment was evaluated in the study, operational variability across the treated units allowed the study authors to categorize the reaches where canopy measurements were sampled as having average buffer widths greater than 75 ft; 50–75 ft; and less than 50 ft. For the tree years post-harvest, average canopy cover was 60-70%, 75-85%, and >85% for the three categories.

Compared to NF streams, less research has been completed to assess riparian buffer effectiveness on maintaining temperatures in F streams in the Pacific Northwest. As part of the RipStream project, Groom et al. (2011a) evaluated prescriptions for F streams on private and state lands in Oregon. On private land, harvested sites had riparian buffers of 15 and 21 m (49 and 69 feet) for small and medium F streams, respectively (*n*=18). In the remaining riparian management area, harvest to a minimum basal area of 10.0 (small streams) and 22.9 (medium streams) m^2/ha occurred. On state lands, riparian buffers were 52 m (171 feet) wide for all F streams with an 8 m (26 feet) no-cut zone (*n*=15). To foster mature forest conditions, limited harvest was allowed within 30 m (98 feet) of the stream with the requirement to maintain 124 trees per ha (307 trees/acre) and a 25% Stand Density Index. To be included in the study, sites required two years of pre-treatment and five years of post-treatment monitoring. Post-harvest, maximum stream temperatures increased at private sites relative to state sites by an average of

0.71 ^{o}C (95% CI: 0.51–0.92). Similarly, average temperatures increased by 0.37 ^{o}C (95% CI: 0.24–0.50) and minimum temperatures by 0.13 ^{o}C (95% CI: 0.03, 0.23). Harvest on state sites did not produce a temperature change signal that differed from pre-harvest level. Groom et al. (2011a) attributed the lack of change post-harvest on state streams to higher amounts of shade compared to private streams.

In an analysis of the same dataset with a focus on stream temperature, Groom et al. (2011b) estimated that streams on private lands had a ~40% probability that a pre- to post-harvest comparison of two years of data would detect a temperature increase of >0.3 ^{o}C. The probability of other comparisons producing a temperature increase was ~5%. For state lands, harvest to state Forest Management Plan standards resulted in an exceedance probability for treatment reaches pre- to post-harvest that did not statistically differ from all other comparisons (~9% compared to ~4%).

Groom et al. (2018) used a Bayesian analytical framework to predict average temperature increases of 0.04 and 0.68°C for state and private lands, respectively. Using simulation based on empirical data, the average predicted stream temperature response on state sites was +0.19 ^{o}C (95% credible interval: 0–0.37 ^{o}C). For private sites, the predicated average response among all sites was +1.45 ^{o}C (95% CRI: 1.1–1.8 ^{o}C). Simulated riparian buffers were substantially narrower for the private compared to the public sites, resulting in lower amounts of predicted shade and a greater predicted stream temperature increase. Finally, in a pooled analysis across all 33 sites from the RipStream study, Groom et al. (2018) determined that a simulated riparian buffer of 27.4 m (90 feet) resulted in a predicted increase in stream temperature of 0.3 ^{o}C (95% CRI: 0.10–0.56 ^{o}C). Riparian buffer widths of 22.8–33.5 m (75–110 feet) maintained 0.3 ^{o}C in the 95% credibility interval range, suggesting that streams with buffers within this range of sizes would not increase in temperature greater than 0.3 ^{o}C pre- to post-harvest. The RipStream study was implemented due to concerns that riparian buffer prescriptions were inadequate to prevent degradation of cold water in salmonid streams. Importantly, although this research project estimated pre- to post-harvest changes to stream temperature for riparian buffers specific to private and state forestland, the study did not collect information about the ultimate biological effects of these changes on salmonid populations of interest (McCullough 1999). Also, we note that small to medium F streams may differ in their responses to increased buffer widths than NF streams due to differences in groundwater exchange, stream volume, riparian air temperatures, and numerous other factors.

Arismendi and Groom (2019) used data from the RipStream study to evaluate how harvest effects on temperature in F streams were propagated downstream. Using data from 16 sites, they estimated temperature changes between stations at the downstream point of each harvest unit and a second station located 183 m (600 feet; seven sites), 305 m (1000 feet; eight sites), or 344 m (1,128 feet; one site) downstream. During the pre-harvest period, the average difference in daily maximum temperature between the downstream and upstream stations ranged from −0.3 ^{o}C to +1.0 ^{o}C among sites. In the first post-harvest year, differences ranged from −1.4 ^{o}C to + 0.6 ^{o}C. In the fifth post-harvest year, differences ranged between −0.7 ^{o}C and + 0.7 ^{o}C; the average annual difference in daily maximum temperature between downstream and upstream stations was +0.2 ^{o}C. In contrast to other studies that used some or all of the same data from RipStream and found only cooling effects, Arismendi and Groom (2019) emphasized that their analysis found evidence for downstream cooling, warming, and no changes depending on stream reach and year.

Ecosystem Production

A vast body of literature has evaluated interactions among stream shading, temperature, and ecosystem productivity (reviewed in Warren et al. 2016). Insolation rate is the dominant control on stream temperature and reductions in riparian canopy cover can be expected to yield temperature increases in many instances (Caissie 2006). However, in light-limited systems such as streams of the Pacific Northwest of North America, increased insolation rates and warmer stream temperatures can increase in-stream productivity and lead to positive responses in aquatic populations, including fish (Thedinga et al. 1989, Wilzbach et al. 2005; Armstrong et al. 2021). Importantly, increased insolation may lead to positive changes in fish populations even in situations where investigators used salmonid carcasses to address potential nutrient limitation issues (Wilzbach et al. 2005).

Recent studies continue to evaluate potential positive benefits of creating "canopy gaps" in riparian buffers in order to achieve a balance between stream productivity and cold-water standards applied by regulatory agencies (Swartz et al. 2020; Sanders et al. 2024). Critically, information is available to assess the relative value of ecological responses from different portions of the stream network. For example, NF streams are known to produce and export substantial numbers of invertebrates, many of which are consumed by fish (Danehy et al. 2007). Johnson et al. (2023) compared variation in benthic macroinvertebrate density and community composition in NF streams between three treatments and an unharvested reference in the Trask Watershed, OR. Treatments included a variable buffer (width not defined; operators' discretion as to the number and placement of leave trees in the buffer; *n*=3) and either a 25 foot (7.6 m; *n*=3) or a 57 foot (17 m; *n*=1) no-cut buffer on either side of the stream. Invertebrate responses, including presence/absence of different taxa, relative abundance of different taxa, and biomass of different functional groups, did not demonstrate consistent patterns within and across treatments. However, the authors concluded that retention of some type of buffer on NF streams was critical to minimizing changes in the invertebrate community due to forest harvesting.

Similarly, Gerth et al. (2022) evaluated variation in benthic invertebrate densities, percent Chironomidae, and taxonomic richness across NF and F streams in the Hinkle Creek Watershed, OR. Study sites were located in fishless tributaries, in downstream fish-bearing tributaries, and in main stem locations. Harvests adjacent to fishless tributaries were clear cuts without riparian buffers, with post-harvest slash left over the streams; sites in fish-bearing reaches had 20-foot (6.1 m) no-harvest riparian buffers within larger 50-70 foot (15-21 m) buffers where limited harvest was allowed. Responses were mixed, with benthic invertebrate densities and percent Chironomidae increasing after harvest in NF sites while taxonomic richness declined. Despite these changes in NF streams, the authors found no evidence for differences in these responses at fish-bearing tributary and main stem F stream locations. However, the study design assumed that changes downstream were due to effects occurring in headwater locations and cannot eliminate the possibility that changes in F streams compensated for any headwater effects that were propagated downstream.

Sediment

Erosion, delivery, and deposition of sediment from channel and upslope mechanisms are critical ecosystem processes in forests of the Pacific Northwest (Swanson et al. 1987). Along with coarser substrates, sediment is an essential component of spawning beds for anadromous fish (McNeil and Ahnell 1964, Greig et al. 2007). However, chronic inputs of sediments at stream and watershed scales have deleterious population level effects on aquatic invertebrates, amphibians, fish, and their habitats (reviewed in Waters 1995). Historic forest management activities, especially those in riparian areas, increased regular sediment delivery to streams through two mechanisms. Damage to root systems along streams accelerated bank erosion (Litschert and MacDonald, 2009) and compaction reduced soil permeability and created surface flow, which transported sediment to the channel (Wemple et al. 1996, Motha et al. 2003). Similarly, contemporary forest practices may increase sediment delivery to stream via extensive road networks susceptible to surface erosion, windthrow of trees retained in riparian buffer zones, and bank erosion in streams without buffers (Grizzel and Wolff 1998, Reiter al. 2009, Araujo *et al.* 2013). Less well quantified is the degree to which historic practices altered the frequency and intensity of periodic sediment delivery mechanisms (e.g., landslides). Furthermore, weather events outside the historic range of variability have the capacity to increase size and frequency of landslides in forested landscapes (Turner et al. 2010).

Research suggests that contemporary production, transport, and delivery of forest management related sediment to streams has been greatly minimized through requiring riparian buffers and excluding heavy equipment from streamside areas. The effectiveness of these changes has been demonstrated in several recent studies. For example, Reiter et al. (2009) examined daily sediment concentration values for several locations in the upper Deschutes River watershed, Washington, an area that has long been intensively managed for wood production. This monitoring program provides one of the only sediment data sets from a managed forest in the Pacific Northwest that has collected information continuously since the establishment of forest practice regulations in the 1970s. Beginning in the mid-1980s, when a set of prescriptions was implemented to reduce sediment delivery to the drainage network, turbidity levels have declined consistently. Although these prescriptions included larger buffers and heavy equipment exclusion from riparian areas, changes in management practices for roads and unstable slopes may have also contributed to reductions in sediment run-off and delivery. Prescriptions to reduce sediment delivery to streams are similar in Oregon and Washington.

Zégre (2008) examined sediment export in the Hinkle Creek Watershed as a function of riparian buffer prescriptions for private lands. At stream and catchment scales, respectively, Zégre (2008) reported statistically significant increases in mean annual suspended sediment yield from 1,484 to 8,954 kg $\cdot$ km^{-2} (23%–42% above predicted) and 64,696 kg $\cdot$ km^{-2} (275% above predicted), with average annual yields varying from 741 kg $\cdot$ km^{-2} (13 percent above predicted) to 10,851 kg $\cdot$ km^{-2} (501 percent above predicted). Variation in sediment yield was assumed to result from legacy and current management activities including forest harvesting and road construction.

Richardson et al. (2018) evaluated long-term trends in sediment production at Loon Lake, the Umpqua River watershed, Oregon. Historic deposition rates (515-1945 AD) were lower than rates from 1945-1972, prior to the implementation of forest practice regulations. Deposition rates declined following the establishment of forest practice regulations. Similar to results from the Deschutes watershed, Richardson et al. (2018) concluded that the decrease was associated with more protective harvest practices, including riparian buffers, and improved road construction and maintenance practices.

Hatten et al. (2018) evaluated suspended sediment behavior in the Alsea Watershed, Oregon. During the study, one watershed (Needle Branch) was harvested and two watersheds (Deer Creek, Flynn Creek) served as unharvested controls. Hatten et al. (2018) did not find evidence for increases in sediment concentrations and yields from Needle Branch after logging. Mean and maximum suspended sediment concentrations observed in Needle Branch after harvest were lower than levels observed in the reference watersheds. Hatten et al. (2018) concluded that intrinsic differences among the three watersheds, including lithology and channel gradient, were strongly associated with sediment behavior than current management prescriptions (Anlauf et al. 2011, Bywater Reyes et al. 2017).

Large Wood

Wood plays an essential functional role in streams of the Pacific Northwest by influencing channel morphology and dynamics, capture, storage, and routing of sediment and organic matter, and as a habitat element for aquatic and terrestrial organisms (Swanson et al.

1976, Harmon et al. 1986, Maser et al. 1988, Montgomery and Buffington 1997, Wondzell and Bisson 2003). Large wood structures store sediment and create pools, among other habitat characteristics, for resident and anadromous fish across all life stages (Bisson et al. 1987, Fausch and Northcote 1992, Bryant et al. 2007). Historic logging practices, including splash damming, log drives, the harvest of riparian trees, and stream cleaning (Bilby and Ward 1991, Miller 2010), as well as efforts to improve riverine navigation (Harmon et al. 1986), reduced wood abundance, piece sizes, and species across Pacific Northwest watersheds. Beginning in the late 1970s, multiple studies demonstrated how large wood influenced channel form and material transport in streams (Swanson et al. 1976, Bisson et al. 1987, Hicks et al. 1991, Bilby and Bisson 1998). In response, management prescriptions promoted delivery of wood to streams, and addressed legacy deficits where they existed, as part of riparian buffer design in the Pacific Northwest (FEMAT 1993).

Wood recruited to stream channels generally originates close to the channel edge, although other delivery mechanisms, such as landslides and channel migration (Reeves et al. 2003, Latterell and Naiman 2007), can be significant sources of wood in some streams and watersheds (McDade et al. 1990, Johnston et al. 2011, Burton et al. 2016). For example, McDade et al. (1990) found that 90% of the pieces of wood in streams in western Oregon were from trees growing within ~24 m (80 feet) of the channel edge. Similarly, Murphy and Koski (1989) found 90% of wood pieces in streams within mature conifer stands in southeast Alaska originated within 20 m (66 feet) of the channel edge, with 45% of total wood input in this study due to bank erosion. In contrast, Reeves et al. (2003) estimated that upslope sources

(landslides or debris flows) occurring more than 90 m (295 feet) from the channel delivered 65% of the pieces and 46% of the estimated volume of wood to the channel. Streamside sources contributed about 35% of the pieces and 54% of the estimated volume of wood. The estimated mean volume of upslope-derived pieces was about one-third that of streamside derived pieces.

Several technical efforts developed models to compare wood delivery from buffers of differing widths and thinning activities (VanSickle and Gregory 1990, Welty et al. 2002, Gregory et al. 2003). As with the empirical studies of wood input, these models tend to underpredict wood input from areas immediately adjacent to the channel (Welty et al. 2002), likely due to the fact that the models emphasize tree fall and do not account for wood input resulting from streambank erosion (Murphy and Koski 1989). However, both the empirical analyses and the wood-delivery models all indicate that greater than 80% of the wood pieces found in a channel are contributed by trees growing within 26 m (85 feet) of the stream bank (Figure 4).

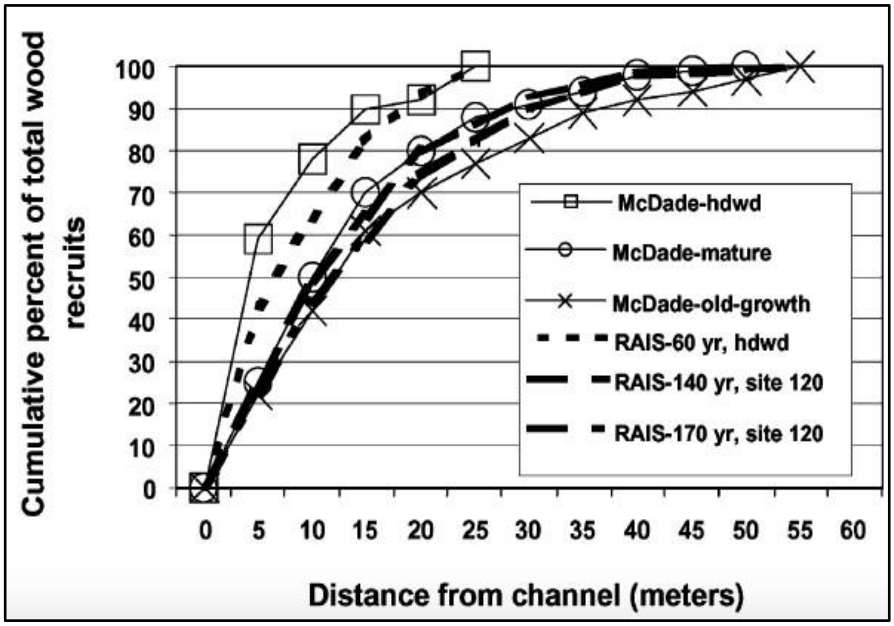

Figure 4. Input of wood pieces as a function of distance from a channel edge from Welty et al. (2002). The McDade lines represent field-measured input distances. Welty et al. (2002) used a wood input model to generate the RAIS lines.

Benda et al. 2016 evaluated the effect of riparian buffer width and thinning on wood volume contribution to stream channels, rather than the contribution of individual pieces of wood. Volume contribution is concentrated closer to the channel edge than total piece input because tree trunks taper with height; trees close to the channel deliver larger diameter pieces of wood than do trees at greater distance. This study found that 75%-95% of wood volume in channels was delivered from within 20% of a site-potential-tree-height of the edge, or ~11 m (35 feet) for a mature Douglas-fir stand (Figure 5). Buffers retained on fish-bearing streams on private forests in Oregon are typically about 31 m (100 feet) wide. This area is responsible for over 80% of the input of wood pieces and 90% of the wood volume (Figures 4 and 5).

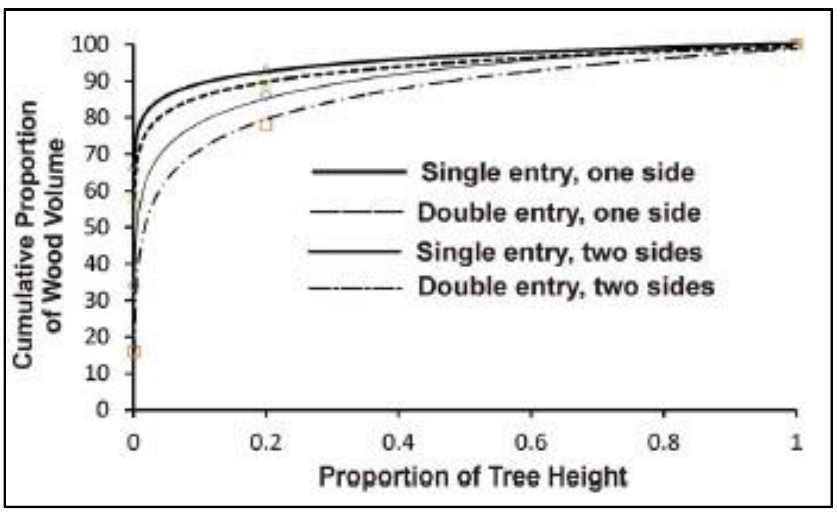

Figure 5. Source distance curves showing varying cumulative proportion of in-stream wood volume with distance from stream for single and double entry thinning, on one and both sides of the stream (Benda et al. 2016). Double entry thinning is rare on private forest land in Oregon and even single-entry thinning is uncommon. No thinning is permitted within 8 m (25 feet) of the channel.

Litter Input

Given dense canopy conditions that block sunlight, in-stream productivity in Pacific Northwest streams is often light-limited. As a result, allochthonous chemical energy contained in litter imported from riparian areas is critical to support invertebrate communities that, in turn, are the primary food source for resident fish populations and also are exported downstream to reaches containing anadromous fish (Conners and Naiman 1984, Wallace et al. 1997, Bisson and Bilby 1998). Despite this important function, the distance from which terrestrial litter is delivered to streams is the least studied of the FEMAT curves. However, two studies in the last decade have examined this question.

Bilby and Heffner (2016) determined the width of the zone from which litter is delivered to the stream is influenced by several factors, principally wind exposure. Wind speed influences distance that litter is transported from the canopy as well as litter production, as more leaves and needles detach from trees during windy periods. Stand structure also influences width of the litter delivery area as litter released from greater height will travel further at a given wind speed than litter released closer to the ground. Bilby and Heffner (2016) estimated that ~90% of litter delivered to channels originates within about 6 m (19 feet) of the channel edge (Figure 6). This contribution zone is wider for riparian zones containing tall, mature conifer trees and narrower for riparian areas supporting shorter, hardwood trees.

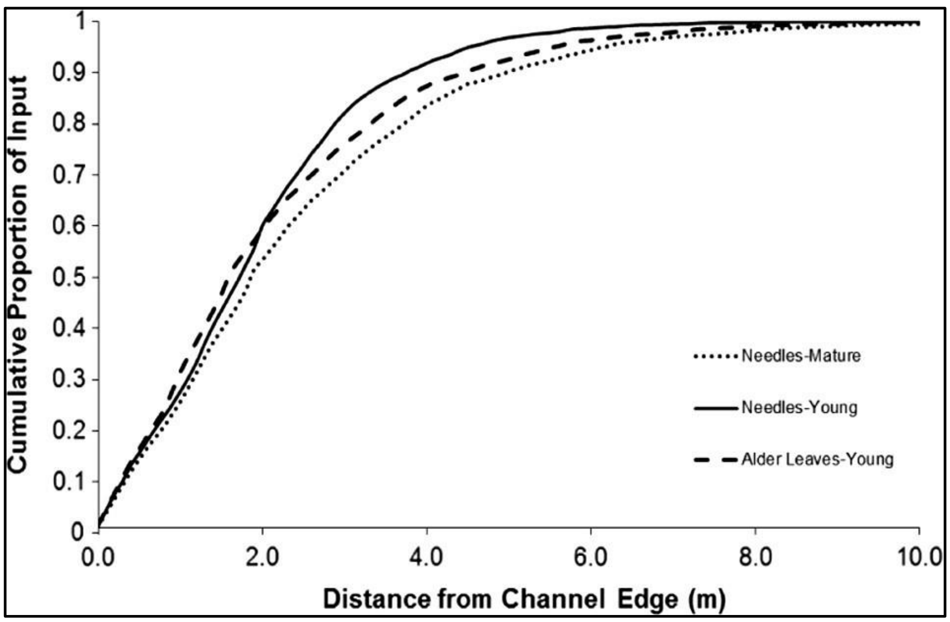

Figure 6. Cumulative proportion of litter input over a 1-year period by distance from the channel edge for three riparian stand types (mature conifer, young conifer, and hardwood) and two types of litter (Douglas-fir needles and red alder leaves) (from Bilby and Heffner 2016).

Six et al. (2022) evaluated litter delivery to non-fish streams; with no buffer (*n*=1), retention of scattered leave trees along the channel (*n*=1), and a continuous 15 m (49 feet) buffer (*n*=1), as well as two reference streams, in the Trask Watershed. Six et al. (2022) found that canopy cover retained varied by riparian buffer treatment. Clearcut harvest without retaining leave trees along the channel resulted in a reduction in canopy cover of over 55%; where leave trees were retained along the channel, post-harvest canopy cover decreased by 15%. Shade on the buffered site did not change due to harvest. Litter input to the study streams only changed post-harvest at the site where no overstory trees were retained (Figure 9, right panel). A continuous riparian buffer or the placement of leave trees along the stream channel was sufficient to maintain pre-harvest litter input rates (Figure 7, left and center panels).

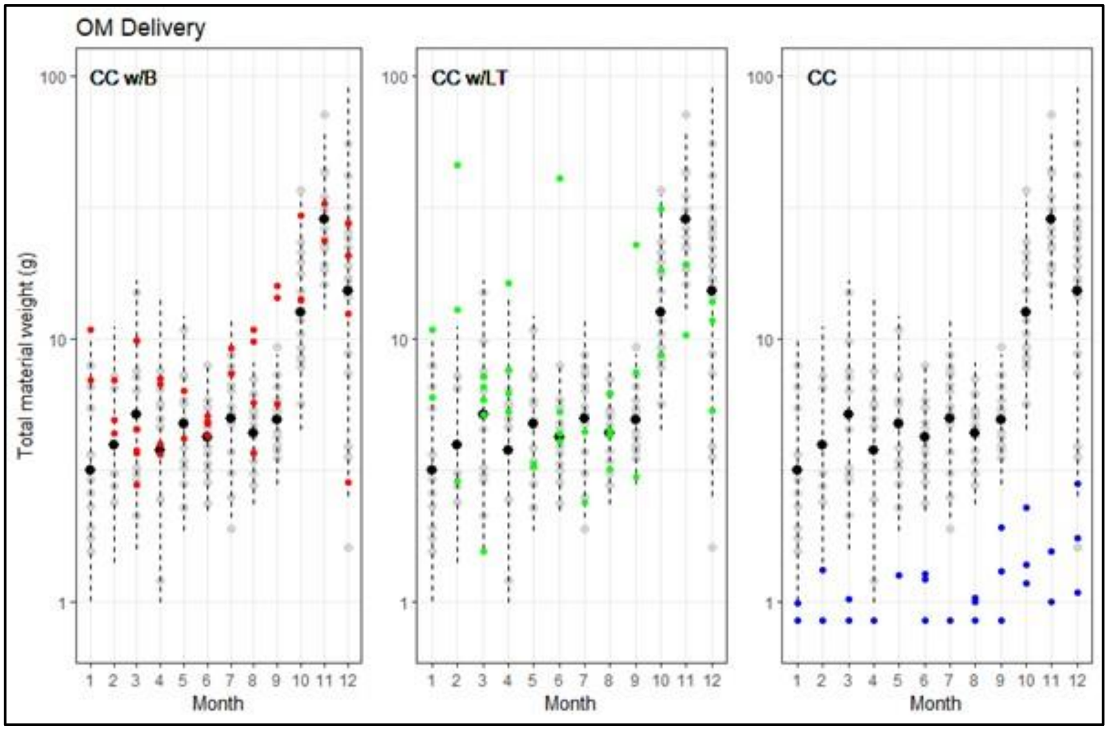

Figure 7. Organic matter litter delivery for each treatment stream (CC w/B, clearcut with buffer; CC w/LT, clearcut with leave trees; and CC, clearcut with no buffer) in the Trask Watershed (Six et al., 2022). Data points in color represent post-harvest total weight by month. Grey points are the same in each panel and represent monthly total weight values for all reference sites and pre-harvest treatment sites, with average values plotted with black symbols. Dashed intervals indicate +/- two standard deviations.

Amphibians

MacCracken et al. (2018) compared three shade retention treatments (≈ 0%, 30%, and 70% overhead canopy cover) to an unharvested reference on NF streams in western Washington. By evaluating how relative abundance, body condition, and other responses of stream-associated amphibians (larval coastal tailed frogs *Ascaphus truei*, coastal giant salamanders *Dicamptodon tenebrosus*, and torrent salamanders *Rhyacotriton* spp.) varied due to shade, MacCracken et al. (2018) were able to evaluate the putative mechanism for buffer effectiveness (i.e., conserving pre-harvest shade) rather than buffer width or placement per se. Generally, amphibian responses were more positive in the 70% compared to the 0% and 30% treatments. Specifically, tailed frogs demonstrated the strongest positive responses in either the 30% (for relative abundance) or 70% (for body condition) treatments. For giant salamanders, abundance increased significantly in the 0% and 70% treatments following shade reductions. However, growth rates declined at all treatment levels but substantially less so (35%) in the 30% treatment. In contrast, torrent salamanders had more positive responses at the 70% level (six of seven responses) than at either of the 0% or 30% treatments. In particular, torrent salamanders appeared to be the most sensitive of the three taxa to reductions in shade, as their abundance tended to decline in the 0% and 30% treatments. Due to the variation in responses (amphibians and primary productivity) to the treatments across and within taxa, MacCracken et al. (2018) emphasized that creating canopy openings in streams with dense canopy cover (>90%) would increase productivity if retained shade was similar to the 70% treatment (while increasing, on average, the seven day moving average for stream temperature less than 1.0 °C). We note that neither buffer width nor configuration of the different shade treatments were reported for this study.

McIntyre et al. (in prep.) evaluated changes in density of larval and post-metamorphic coastal tailed frogs *Ascaphus truei*, coastal giant salamanders *Dicamptodon tenebrosus*, and torrent salamanders *Rhyacotriton* spp. to three buffer prescriptions on NF streams on consolidated lithologies across five study blocks in western Washington. Treatments included a clearcut harvest with a riparian leave-tree buffer (two-sided buffers, 15.2 m [50 feet]) along the entire stream length (100%); a clearcut harvest with a two-sided 15.2 m (50 feet) riparian leave-tree buffer along ≥50% of the RMZ, including buffers prescribed for sensitive sites including slope and headwall seeps, headwater springs, Type Np intersections and alluvial fans (50%; current rules for NF streams in Washington); and a clearcut harvest with no riparian leave-tree buffer retained along the stream (0%). Pre-treatment estimates were compared to post-treatment estimates in three blocks: one and two years, seven and eight years, and 14 and 15 years, respectively. Amphibian responses in the first temporal block were mixed, with torrent salamanders increasing in the three treatments; for giant salamander and tailed frog responses, no consistent pattern emerged across the three treatments. In the second and third temporal blocks, evidence existed for no effect or negative effects of the treatments on density for all of the taxa. The effect was particularly large for tailed frog as declines for larval and post-metamorphs exceeded 60% in the 0% and 50% treatments. Importantly, stream temperature, which is one of the putative mechanisms behind stream amphibian responses to forest management, did not differ amongst the references and treatments. Across the three post-harvest time blocks, the average temperatures (one standard deviation) were 12.6 (1.8), 14.3 (1.8), 12.8 (0.8), and 14.6 (2.9) ^{o}C for the reference, 100%, 50%, and 0% buffer treatments, respectively. Given the substantial differences in average (one standard deviation) canopy cover (measured 3.28 feet above the stream surface) across the references and treatments [90 (2.7), 86 (3.5), 67 (8.6), and 26 (21) for the reference, 100%, 50%, and 0% buffer treatments, respectively], stream temperature appeared to be associated with factors besides shade and amphibians, in turn, appear to have responded to factors besides stream temperature.

Duarte et al. (2023) evaluated changes in occupancy and abundance of stream-associated amphibians (larval coastal tailed frogs *Ascaphus truei*, coastal giant salamanders *Dicamptodon tenebrosus*, and Columbia torrent salamanders *Rhyacotriton kezeri*) in NF streams associated with three treatments and an unharvested reference in the Trask Watershed, Oregon. Treatments included a variable buffer (operators' discretion as to the number and placement of leave trees in the buffer; *n*=3) and either a 25 foot (*n*=3) or a 57 foot (*n*=1) no-cut buffer on either side of the stream. No evidence existed of differences between treatments and references for tailed frog or giant salamanders; some evidence existed that torrent salamander occupancy was higher in reference streams compared to streams with variable buffers. Also, no changes were found between upstream (where treatments were implemented) and downstream reaches (separated by less than 300 feet), suggesting that any effects dissipated quickly.

Martin et al. (2021) used a systematic evidence review to evaluate strength of evidence for the effect of buffer prescriptions on conserving pre-harvest amphibian populations in NF streams in the Pacific Northwest of North America. The evidence, compiled across multiple studies, indicated variation in responses within and across taxa (based on differences in the direction and magnitude of reported responses) as well as the broad confidence interval coverage for estimated responses. Specifically, Martin et al. (2021) identified only one study that evaluated amphibian responses to buffer width (rather than a broad range of environmental covariates) and this study did not report evidence of an effect. More generally, little evidence is available to support firm conclusions about amphibian responses to shade and stream temperature as provided by buffer prescriptions, in part because only one study evaluated responses at the basin rather than the stream reach scale. A single study manipulated shade directly (rather than indirectly through different buffer prescriptions) and reported positive and negative amphibian responses to the treatments (MacCracken et al. 2018). Population persistence does not appear to be associated with buffer retention. Also, the substantial variation in local abundance found in harvested and unharvested streams suggests additional factors influence population responses and may interact with buffers when they are present.

Potential for downstream effects on fish-bearing waters

In a review of how headwater streams influence downstream reaches, MacDonald and Coe (2007) determined that a range of general probabilities existed for the delivery of habitat components for anadromous and resident fish (Table 4). For example, discharge and fine sediment were likely to be delivered downstream while large woody debris, coarse sediments, and temperature were more likely to be retained or have their effects diminish quickly.

	Likely magnitude of			
Constituent	**Storage**	**Transformation**	**Delivery**	**Means of delivery**
Discharge	Low	Low	High	All flows, minimal delay
Fine sediment (<2 mm)	Low to moderate	Low	Moderate to high	All flows, but predominantly high flows
Coarse sediment (>2 mm)	High	Moderate to high	Low to moderate	High flows and mass wasting events
Large woody debris	High	Low to moderate	Low	Mass wasting or extremely high flows
Coarse particulate organic matter	Moderate	High	Moderate	Primarily high flows and mass wasting
Fine particulate organic matter	Low to moderate	Moderate	Moderate to high	All flows, especially high flows
Nutrients	High	High	Low to moderate	All flows
Temperature	Low	High	Low to moderate	Low flows

Table 4. General probabilities for storage, transformation, and delivery of eight different components from headwater streams to downstream reaches (taken from McDonald and Coe 2007, p.51).

Generally, temperature increases in small streams due to forest harvesting are less than 5°C (Moore et al. 2005) although many studies report increases less than 2°C or no change (see Shade and Thermal Controls). MacDonald and Coe (2007) considered temperature changes to be unlikely to propagate downstream because of increased shading, groundwater inputs increasing in larger basins, hyporheic exchange, thermal settling in larger pools, evaporative cooling, and inflows from unharvested basins. We note that despite a number of research efforts to examine temperature changes due to forest harvesting, relatively few studies examine downstream propagation of temperature changes in excess of 500 m. Importantly, we were not able to identify any studies where harvest in headwater streams led to sustained temperature increases in F streams that reached critical thermal thresholds for anadromous or resident fish. Finally, we note that conclusions in MacDonald and Coe (2007) support spatial heterogeneity in buffer prescriptions. For example, given that coarse sediment, coarse particulate organic matter, and large woody debris, all of which are critical components of fish habitat, rely on mass wasting events for delivery, placing buffers on streams in basins most likely to experience mass wasting events will increase probability of delivery compared to watersheds (e.g., those dominated by competent lithologies) in which mass wasting events are less common.

Several studies assessed predictions based on the summary table presented in MacDonald and Coe (2007). Using a Before-After-Control-Intervention (BACI) design, Bateman et al. (2016) compared multi-year data from streams in an unharvested (n=3) and a treated (n=5) watershed in the Hinkle Creek Watershed Study, Oregon, to estimate downstream effects on anadromous fish. Clearcuts were located adjacent to NF streams and riparian buffers were not retained adjacent to fishless reaches (rules current prior to 2021). For coastal cutthroat trout, no catchment level effects were found for fish density, growth rate, and survival. The only statistically significant result found was an increase in late-summer biomass of age-1+ cutthroat. Similarly, Jensen (2018) examined four F streams downstream from harvest units and did not find evidence for harvest effects on coastal cutthroat trout or steelhead summer growth rates in the Trask Watershed (see previous sections for description of buffer prescriptions).

In the Alsea Paired Watershed Study, Bateman et al. (2018) assessed stream habitat and fish population characteristics, including biomass, abundance, growth, size, and movement, for four years pre- and five years post-harvest). In the harvested catchment, pools composed an average of 33% (range: 16–42%) of the 2078 m of fish-bearing stream channel during the study period. In the unharvested catchment, pools composed an average of 20% (range: 16-29%) of the 4276 m of fish-bearing stream channel. Large wood was the most common primary pool-forming agent in harvested (mean=59% of pools; range=50–73%) and unharvested (mean=41% of pools; range=29–47%) catchments. Although the number of large wood pieces was higher in the harvested (average=34, 34, and 38 pieces per 100 m of stream channel for 2007, 2011, and 2013, respectively) than the unharvested (mean=22, 23, and 23 pieces per 100m for 2007, 2011, and 2013) catchment, piece size was generally smaller (harvested average volume = 12.3, 10.4, and 15.8 m^3 per 100 m of stream channel for 2007, 2011, and 2013; unharvested average volume= 23.5, 23.6, 37.9 m^3 per 100 m). At the catchment scale, evidence existed for positive treatment effects on total fish biomass (1634 to 4092 g in the harvested catchment compared to 4533 to 3714 g in the unharvested catchment), total catch (123 to 268 individuals in harvested catchment while declining from 316 to 290 individuals in the unharvested catchment), and biomass density (2.0 to 3.8 $g \cdot m^{-2}$ in the harvested catchment while declining from 3.3 to 3.1 $g \cdot m^{-2}$ in the unharvested catchment) of age-1+ coastal cutthroat trout. Bateman et al. (2018) did not find evidence for treatment differences for age-1+ coastal cutthroat trout density (fish$\cdot$ m^{-2}), condition, mean length, or threshold for large fish (>90^{th} percentile of all fish captured) or any responses for juvenile coho salmon.

In a subsequent round of sampling, Bateman et al. (2021) examined the same catchments in the Alsea watershed to determine fish population and habitat responses to clearcut harvesting. In the treatment catchment, the total clearcut harvest encompassed 87% of the treatment catchment in six years. Survival of age-1 + coastal cutthroat trout (>94 mm fork length) and total catchment relative biomass of age-1+ (i.e., > 80 mm) exhibited similar responses in the control and treatment watersheds. In both watersheds, increases occurred in the pre-harvest period (2006–2009) through the Phase I post-harvest period (2009–2014); survival and biomass in the Phase II post-harvest period (2014–2017) decreased to levels observed in the pre-harvest period. Additionally, the study did not find evidence for differences in coastal cutthroat trout movement due to the harvesting treatment. A modest increase in annual total pool area occurred in the harvested catchment during the Phase II post-harvest period. Bateman et al. (2021) did not find evidence the 7-day moving mean maximum stream temperature changed after the Phase I and Phase II harvests. Importantly, stream water temperatures never exceeded the criterion designed to protect cold-water habitat for salmonids (16 ^{o}C). The authors concluded that forest practice rules in effect when the harvests were completed (equipment exclusion only on NF streams with no tree retention; 15 m [50 feet] buffer on both sides of F streams), paired with best management practices for harvesting, yielded net benefits for fish compared to previous practices (e.g., when the watershed was harvested previously in the 1960s).

Sanders et al. (2024) evaluated fish responses to four buffer treatments on ten streams in the Coast Range, OR. Treatments were designed to assess how alternative buffer prescriptions could increase light levels and facilitate positive increases in stream productivity and fish responses (see Ecosystem Production section). Each treatment was applied to two streams and compared to two control streams (i.e., *n*=2 for all treatments). Treatments were designated as Fixed Width (FW), Current Practice (CP), Variable Retention (VR), and Canopy Gaps (CG). Following the Oregon Forest Practices Act (rules current prior to 2021), the FW buffer widths were 15.2 m (50 feet) and 18.3 m (60 feet). Current Practice buffers are FW buffers with an inner 6.1 m (20 ft) "no touch" strip and selective thinning from 6.1 to 15.2 m (20 to 50 feet) to achieve a basal area of 3.7 m^2/92.9 m (40 $feet^2$/1000 feet) of stream. The VR buffers were designed to maintain more trees in areas of high groundwater retention or steep slopes while removing trees and creating open canopy in other stream sections. VR buffers retained the same basal area as in the FW buffers, but retention of trees in the VR buffers varied from narrow 3.0 m (10 feet) buffer sections along some areas of the stream to wider sections in other areas that doubled CP width and extended more than 30 m (100 feet) from the stream. The CG buffers are similar to the FW buffer with two 40 m long gaps in the riparian buffer where overstory trees were removed all the way to the stream channel. Gaps were placed ~70 m (230 feet) apart along the stream with the first gap occurring at least 50 m (164 feet) above the bottom of the study reach.

After harvest, Age-1 + coastal cutthroat trout showed modest increases in density and biomass due to the treatments but the purported mechanism of increased production was not supported by summaries of responses at other trophic levels. Despite reductions in average canopy cover from nearly 100% to as low as 64% cover changes in light up to 8.1-fold compared to pre-harvest levels, 7DAY MAX stream temperature increased an average of 1.1°C (range:

0°C to 2.4°C) across all sites. In the pre-treatment years, maximum daily temperatures across all sites ranged from 12.9 to 17.2°C and in the post- treatment years ranged from 13.5 to 19.7°C. In the first post-treatment year, 7DAYMAX in August increased at seven of eight harvested sites (+0.36 to +3.15°C). In general, Sanders et al. (2024) found that their results did not match predictions regarding bottom-up causes for enhanced stream productivity in small streams (i.e., light increases primary production, increasing invertebrate production and, in turn, density and biomass of fish). However, the authors did note that their results aligned with other recent studies in the region evaluating similar predictions about aquatic responses to different buffer designs.

Kiffney et al. (2024) evaluated how suspended fine particulate organic matter (FPOM > 0.50 µm and < 1.0 mm) varied in 13 headwater basins over a 10 year period (two years pre- and 8 years post-harvest) in British Columbia, Canada. Basins ranged from 0.12 to 1.1 km^2 (30-272 acres) and channel gradient ranged from 2-11%. Fine particulate organic matter is an important component of headwater ecosystems as well as downstream food webs. Suspended FPOM concentration (mg/L) was sampled before and after timber harvest in four treatments that varied in upland disturbance intensity: clear-cut to the stream edge, 10 m (33 feet) wide riparian buffer, 30 m (98 feet) wide riparian buffer, and fully forested controls (considered to contain a natural level of disturbance). Suspended FPOM concentrations were highest in the clearcut and the 10 m wide buffer after logging, declined over time, and were similar for the last three years of observation (Kiffney et al. 2024, Fig. 6). However, FPOM concentrations varied due to discharge rates. For example, as stream discharge increased from 5 to 50 L/s, FPOM concentration in the clear-cut treatment increased about three times faster than the control treatment. These results aligned with general predictions that discharge rates and fine organic particulate matter delivery are likely to be high from headwater basins (MacDonald and Coe 2007).

Conclusions

Recent evaluations of NF and F streams in the Pacific Northwest indicate that contemporary riparian buffer prescriptions can protect and enhance structural components that contribute to freshwater habitat quality and quantity, including export of water, large wood, and food resources, which support downstream populations of anadromous and resident salmonid fishes. However, we caution that these studies support only general conclusions about how buffers conserve near-stream functions and the magnitude and distance of propagation of effects downstream.

First, study designs and analyses were not able to distinguish how biological responses may have varied due to historic practices that created legacy effects (Steel et al. 2017). Second, most studies occurred in headwater catchments and anadromous fish populations are affected by factors working at larger spatial scales (Berejikian et al. 2013; Isaak et al 2018; Naman et al. 2024). Third, the overwhelming number of studies did not examine fish responses in conjunction with changes to components of fish habitat produced in headwater basins, especially those induced by forest practices (Naman et al. 2024). Finally, anadromous fish have multi-stage life histories that occur across several years in freshwater and marine environments. Also, genetic variation associated with hatchery programs, commercial harvest, and changes to oceanic thermal profiles and food resources have substantial effects on anadromous populations (Healey and Price 1995, Hilborn et al. 2004, Wells et al. 2012, Stachura et al. 2014). As a result, anadromous and resident fish populations may decrease, increase, or remain static as freshwater habitat quantity and quality change, obscuring the potential accrued benefits of spatial and temporal improvements to habitat. Reeves et al. (2018), in a review of the Aquatic Conservation Strategy (ACS) portion of the Northwest Forest Plan, identified similar challenges to evaluating the plan's effectiveness (p. 465). In fact, the monitoring component of the ACS did not conduct a formal assessment of conceptual relationships between upslope, riparian, and in-channel processes (Reeves et al. 2018, p. 473). Given the complex array of factors that affect fish populations, different, more spatially and temporally extensive monitoring schemes may be required to determine if, where, and when habitat management actions, including regulatory prescriptions for buffer retention, are associated with population changes (Reeves et al., pages 535-536).

Also, although stream temperature is often the focus of regulatory actions (with buffer prescriptions designed to retain pre-harvest temperatures), we note that multiple physical factors within streams can influence thermal loading and temperature response, including elevation, surface flow, substrate composition, slash cover, and geology (Caissie 2006). For example, on small streams, tree height, and tree density in riparian buffers can be more important than buffer width, as increasing the height of trees in relation to the width of the stream increases effective shade (Davies-Colley and Rutherford 2005, DeWalle 2010). Importantly, in the Pacific Northwest, other characteristics of the stream channel and surrounding landscape, such as topographic shading, hyporheic exchange, and connectivity to adjacent wetlands can be more impactful to stream temperature (maintaining pre-harvest stream temperatures is a primary goal for most buffer regulations) than riparian buffers, particularly for small headwater streams (MacDonald and Coe 2007, Janisch et al. 2012, Davis et al. 2016). Discontinuous headwater channels and intermittent surface flow are common on small perennial streams in the Pacific Northwest, further complicating the relationship between shade, stream temperature, and buffer prescriptions (Hunter et al 2005, Jaeger et al. 2007; Martin et al. 2021).

Paired with research emphasizing the broad natural variability in riparian systems, especially small catchments, researchers have proposed alternative prescriptions for riparian buffers to achieve desired resource outcomes (Naiman et al. 1992, Bisson et al. 2009, Richardson et al. 2012). For example, Reeves et al. (2018) indicated that second site-potential tree-height buffers on fish-bearing streams may not provide substantial additional protections beyond the first tree-height width (p. 534 and additional locations). Also, several studies have used conceptual approaches to create custom riparian buffers to intercept maximum solar radiation with the fewest number of leave trees (Davies-Colley and Rutherford 2005, DeWalle 2010). Technology advances in hemispherical photos and software have reduced technical hurdles in measuring shade, predicting solar insolation, and identifying critical areas within watersheds that merit additional resource conservation action (Benda et al. 2007, Chianucci and Cutini 2012). However, site-specific riparian buffers have not been incorporated into forest management regulations in Oregon or Washington, which rely instead on fixed buffer width prescriptions.

Finally, Swartz et al. (2024) evaluated variability in buffer width across multiple ownerships in Oregon and concluded that "regulatory flexibility, landscape complexity, and anthropogenic features collectively created more variation in the width of harvest units in this study than we expected for a region that is typically characterized as having fixed-width buffers along stream channels" (p. 11). We expect that current forest practice regulations in Washington, combined with variation in ownership at watershed and landscape scales, would produce the same results. That is, despite fixed width buffers being the dominant prescription, contemporary ecological responses to variation at larger scales are likely not the result of fixed width buffers. As a result, inference about effectiveness, or ineffectiveness, of fixed width buffers for achieving conservation outcomes at large spatial scales should be done cautiously.

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Appendix 4. Alternative Cost Benefit Analysis of Carbon Sequestration in the Proposed Type Np Buffer Rule

Background:
Washington State DNR commissioned Industrial Economics Incorporated (IEc) to develop a Cost-Benefit Analysis (CBA) of a rulemaking to amend the Forest Practices Type Np Water Buffer Rule.

The February 2025 IEc analysis was based on a low-end assumption of 123,455 acres and a high assumption of 284,717 acres. The analysis used the USDA's "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry (USDA) tool/workbook "as the basis for estimating the differences between Type F and Type N buffers alongside assumptions about typical forestland management in Washington." However, the IEc analysis did not include the following considerations:

- Material Leakage
- Adjustment to Social Cost of Carbon based on sequestration permanence uncertainty.
- Uncertainty Considerations

Alternative Analysis Assumptions and Adjustment in Analyses:
This proposed alternative analysis uses the same underlying FIA data and assumptions as described in Section 4.3 of the IEc analysis (Feb 2025) with the following changes:

1) Low-end and High-end acres assumptions were changed to 167,976 acres and 235,300 acres.
2) Material Leakage was incorporated as 10% for the low estimate and 80% for the high estimate (see appendix)
3) Adjustment to Social Cost of Carbon based on sequestration permanence uncertainty was incorporated with a Low-end adjustment of 30% and a High-end Adjustment of 50% (see appendix)
4) Uncertainty was addressed by comparing estimates using Douglas fir, planted, as the forest type instead of Spruce, Fir, Mountain Hemlock (see appendix)

Results:
Table 1 provides a summary of the different low and high ranges with the new acreage assumptions and more complete analysis. The changes are summarized separately for transparency. A complete analysis should include both material leakage and the deduction/adjustment of social cost of carbon as these can help estimate the net impact on the atmosphere. The assumption of what forest type to use shows just one example of uncertainty in the analysis, demonstrating the overall net benefit uncertainty. The highlighted rows in Table 1 reflect the scenarios that include material leakage and SOC adjustment run for the two forest types. The ranges show a net benefit between 0.15 to 0.24 mt CO_2/acre/yr on the low-end and 0.212 and 0.047 mt CO_2/acre/yr on the high-end.
It is important to understand that a range of .015 mt CO_2/acre/yr to 0.212 mt CO_2/acre/yr is not only essentially zero but also minute compared to the average sequestration rate of a forest stand per acre per year.

In this workbook, the average sequestration rate per year across all ages is 4.73 mt/CO_2/acre/yr for Spruce, Fir, Mountain Hemlock and 7.87 mt CO_2/acre/yr for planted Douglas fir. The difference in sequestration rate found between the two forest types (7.87-4.74=3.14 mt CO_2/acre/yr) is 14 times more than the high end per acre potential change between (rule vs. no rule) (0.212 mt CO_2/acre/yr) rendering the range of the analysis well within the range of uncertainty.

Table 1: Summary of Alternative Analysis

Summary

Analysis with new acre ranges	**Net benefit (mt CO2/acre/yr) between rule and NR**		**% change from average annual sequestration rate**		**Potential Value* (in millions) with Social Cost Carbon (SCC) @ $203/mt CO2**	
	Low	High	Low	High	Low	High
IEC Analysis	0.069	0.547	1.57%	12.53%	103	1159
With Material Leakage (10% with Low, 80% with High)	0.049	0.423	1.13%	9.69%	74	896
With Material Leakage (ML) and Douglas Fir (DF) carbon data	0.079	0.094	1.01%	1.19%	119	198
With Deduction for Risk of Reversal (low 50%, high 67%)	0.023	0.274	0.52%	6.27%	34	580
With Deduction for Risk of Reversal and ML	**0.015**	**0.212**	**0.34%**	**4.84%**	**22**	**448**
With Deduction for Risk of Reversal and ML and DF carbon data	**0.024**	**0.047**	**0.30%**	**0.60%**	**36**	**99**
IEC With WA carbon auction price $50/mt ton CO2 (instead of using SCC)					26	290
With Material Leakage and WA carbon auction value					19	224
With Material Leakage and Douglas Fir and WA auction carbon revenue					30	50

Conclusion

Due to the small estimated changes and large uncertainty, no dollar value should be reported in the final cost benefit analysis. Furthermore, the qualitative assessment should indicate that potential benefit is so small that if it is included as a description in the benefit section it should be reported as essentially zero. The alternative is to report as no change.

Appendix

***Incorporation of Material Leakage**:* Leakage is a deduction from the net impact done to estimate the amount of "avoided harvest" impacted by the rule that will be harvested elsewhere. As explained in the Feb 21 draft, there is literature to show that this percentage can be high (upwards of 90%). However, anything that is less than 100% can indicate that globally there is less harvest, especially in the short term. That difference means there are fewer wood products being made, which means that non-wood alternatives are produced and consumed instead of wood products. Any difference between 100% and the leakage deduction should be attributed to material leakage, which is when other non-wood materials.

The USDA workbook[37] includes substitution benefits associated with the wood products that were made from the harvest (it is listed in the Forest Management and Results Tab). These should be included when comparing a harvest versus a no harvest (or reduced harvest) scenario, such as in this regulatory alternative assessment.

The following tables include the emissions associated with materials substitution to non-wood alternatives using the Spruce, Pine, Fir classification (Table 1) and Douglas Fir, planted (Table 2) from the USDA Entity Guidelines workbook. The difference (adjusted for percent material leakage- columns 4 and 5) were incorporated into the Table "Annual Sequestration" (Step 2) in the IEc workbook[38]

Table A2: Outputs from the USDA Entity Guidelines Workbook using IEC inputs and Including Substitution Potential for Spruce, Fir, Mountain Hemlock[39]

Age Class	Net Change (Flux) Carbon Stock	Substitution Potential (M. N. in USDA workbook)	Difference	10%	80%
41-60	46	(56)	(10)	(1)	(8)
61-80	52	(62)	(10)	(1)	(8)
81-100	64	(78)	(14)	(1.4)	(11.2)
101+	107	(130)	(23)	(2.3)	(18.4)

Table A-3: Outputs from the USDA Entity Guidelines Workbook using IEC inputs and Including Substitution Potential for Douglas Fir planted.

Age Class	Net Change (Flux) Carbon Stock	Substitution Potential (M. N. in USDA workbook)	Difference	10%	80%
41-60	98	(114)	(16)	(1.6)	(12.8)
61-80	130	(151)	(21)	(2.1)	(16.8)
81-100	139	(160)	(21)	(2.1)	(16.8)
101+	173	(201)	(28)	(2.8)	(22.4)

This value indicates that the emissions associated with manufacturing non-wood alternatives to wood products are more than the initial reduction in carbon stocks from the harvest. Therefore, if there is any material leakage (meaning harvest leakage is anything less than 100%) there is a net emission to the atmosphere.

***Social Cost of Carbon*: The Social Cost of Carbon should not be applied to NCS removals without adjusting for permanence.**

The analysis applies a Social Cost of Carbon[40], which "which measures the avoided economic damages associated with one additional metric ton of CO_2 in the atmosphere."

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[37] The USDA tool is the same tool referred to in IEC and described on page 55.

[38] IEc Carbon Analysis_Draft Prelim CBA_2025.02.18.xls

[39] The net change in carbon stock is labeled "TOTAL AFOLU (Forest) BIOGENIC CARBON STOCK CHANGE (FLUX) from Management Action and harvest (tCO2eq)" The Substitution potential is labeled "LCA Quantified Substitution Potential Associated with Harvest, Transport, and Processing". Both are found in the Forest Mgmt&HWP Results Tab of the Entity Guidelines Workbook.

[40] "That is, in economic terms, the benefits of reductions in atmospheric carbon dioxide (and other greenhouse gases), reflect the value that people derive from avoiding additional climate change-related impacts (e.g., to crops, human health, infrastructure). These benefits can be monetized using the social cost of carbon dioxide ($SC\text{-}CO_2$)…"

This analysis, if directionally accurate, results not in less emissions but in more removals/sequestration. These removals may be at risk of reversals due to overstocking/mortality and even the impacts of climate change. Because SCC is associated with an additional emission of CO2, the benefit (removal) must be adjusted to be the equivalent of an emission, which means it must include an assessment of longevity. In the offset world, these metrics are adjusted by applying a risk-factor discount for permanence and requiring a long-term assessment period. Groom and Venmans[41] suggest that sequestering one metric ton CO_2 for 50 years is equivalent to permanently storing 0.33-0.5 mt CO_2.

Therefore, any sequestration value offered in this analysis should be discounted by another 50-67%.

The other option is to apply the actual values that has been placed on carbon in Washington State by using the WA carbon auction value, which most recently was valued at $50/mt CO2e.

Incorporation of uncertainty: The analysis uses the USDA's "Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry (USDA) tool/workbook as the basis for estimating the differences between Type F and Type N buffers alongside assumptions about typical forestland management in Washington." This tool/workbook uses measured FIA data, which does provide the best *objective* estimates of forest carbon based on general categories of forest type. The workbook is meant to general estimates of forest flux and is not intended to serve as a metric for monetary carbon valuation, which would require specific inventory of physical sites.

As noted in the IEC report, these scenario comparisons require significant assumptions about baseline forest management. These assumptions not only have high uncertainty, but many also have high sensitivity to results. For example, IEC used Spruce, Fir, Mountain Hemlock as the forest type with which to model the carbon dynamics. Had they used planted Douglas fir, the net benefits are much lower.

[41] Groom B, Venmans F. The social value of offsets. Nature. 2023 Jul;619(7971):768-773. doi: 10.1038/s41586-023-06153-x. Epub 2023 Jul 5. PMID: 37407820.

Appendix 5. Road sedimentation study proposal materials

Document 1: Buffer and Road Sediment Workgroup memo

SAG REQUEST

SAG: Buffer and Road Sediment Workgroup (Bill, Doug, Julie)

Contact Person: Doug Martin

Subject: UW Study - The Effects of Forests & Fish Buffer Regulations on Road Network Design and Potential Sediment Delivery to Streams

Request Date: November 13, 2006

Request

CMER approval of study plan and funding ($52,641) for the UW to conduct the proposed study: "The Effects of Forests & Fish Buffer Regulations on Road Network Design and Potential Sediment Delivery to Streams." Funding would be derived from the FY2007 project scoping allocations for two related studies:

- Type N Experimental Buffer Treatment - Incompetent Lithologies Project
- Intensive Watershed-scale Cumulative Effects Programs

Background

In late 2005, Policy requested that CMER conduct scoping for a Type N experimental buffer study in incompetent lithologies. A proposal was submitted to CMER in December 2005 that was patterned after the Type N Experimental Buffer Study in Basalt Lithology. This request was not approved by CMER because of technical concerns that the proposed study did not directly address roads. The addition of buffer regulations to Type Np streams under FFR has significantly increased the number and length of buffer strips that need to be incorporated into timber harvest plans. Buffer strips may inhibit access to timber harvest units. Therefore, more landings and roads are potentially being built under the FFR regulations than under pre-FFR rules. There is a concern that the additional landings and roads are potentially causing more erosion and an unintended increase in sediment delivery to streams. Given these concerns, CMER directed a working group consisting of Doug Martin, Bill Ehingher, and Julie Dieu to look into the issue. The Workgroup enlisted the assistance of Professor Peter Schiess (UW Forestry) who has significant experience with harvest unit and road design. Based on interaction with Professor Schiess and Luke Rogers (UW staff), the Workgroup concluded that an exploratory evaluation of potential sedimentation impacts from Np buffers could provide the context for designing treatment alternatives for the Type N Soft Lithology Study. The Workgroup also recognized that modeling sediment production from a range of treatments would also provide information that would be helpful for designing a cumulative effects study. Because road sediment is a transportation network issue, cumulative effects are probably going to depend on road network design and harvest pacing (i.e., timing and intensity of road use by location). Therefore, the Workgroup asked UW Forestry to prepare a proposal that would address the N-buffer and road sediment question.

<u>The UW proposal is not a study design to perform the Np-sediment or cumulative effects study. Rather, the exploratory analyses that are proposed in the UW study will be used to inform Np-sediment or cumulative effects study design issues</u>.

Document 2: University of Washington study proposal

University of Washington

College of Forest Resources

Proposed Interagency Agreement

Co-P.I.:	Dr. Peter Schiess, Professor of Forest Engineering Luke Rogers, Research Scientist/Engineer
Short Title:	CMER Np Sediment Study
Project Title:	CMER Study: The Effects of Forests & Fish Buffer Regulations on Road Network Design and Potential Sediment Delivery to Streams
Agency:	Washington State Department of Natural Resources
Sponsor:	Contract Negotiator CMER - Cooperative Monitoring Evaluation and Research Washington State Department of Natural Resources PO Box Olympia WA (360) 902- @wadnr.gov
Amount:	$52,641
Project Dates:	January 1, 2007 – June 30, 2007

Note: This proposal is for discussion at CMER on Nov. 28th 2006. No action is requested at this time.

Proposed Scope of Work

Background

In late 2005, Policy requested that CMER conduct scoping for a Type N experimental buffer study in incompetent lithologies. A proposal was submitted to CMER in December 2005 that was patterned after the Type N Experimental Buffer Study in Basalt Lithology. This request was not approved by CMER because of technical concerns that the proposed study did not directly address roads. The addition of buffer regulations to Type Np streams under FFR has significantly increased the number and length of buffer strips that need to be incorporated into timber harvest plans. Buffer strips may inhibit access to timber harvest units. Therefore, more landings and roads are potentially being built under the FFR regulations than under pre-FFR rules. There is a concern that the additional landings and roads are potentially causing more erosion and an unintended increase in sediment delivery to streams. Given these concerns, CMER directed a working group consisting of Doug Martin, Bill Ehingher, and Julie Dieu to look into the issue. The Workgroup enlisted the assistance of Professor Peter Schiess (UW Forestry) who has significant experience with harvest unit and road design. Based on interaction with Professor Schiess and Luke Rogers (UW staff), the Workgroup concluded that an exploratory evaluation of potential sedimentation impacts from Np buffers could provide the context for designing treatment alternatives for the Type N Soft Lithology Study. The Workgroup also recognized that modeling sediment production from a range of treatments would also provide information that would be helpful for designing a cumulative effects study. Because road sediment is transportation network issue, cumulative effects are probably going to depend on road network design and harvest pacing (i.e., timing and intensity of road use by location). Therefore, the Workgroup asked UW Forestry to prepare a proposal that would address the N-buffer and road sediment question.

Research Questions

The objective of this study is to estimate the effects of FFR-related roads on potential sediment production and delivery to streams. There are several questions which will be implemented in a phased approach since early findings could modify or make further research unnecessary:

1. Does the FFR buffer regulation alter the transportation network (e.g., location, number, and length of roads and landings) compared to pre-FFR regulations? If so, how much and in what way?
2. What is the relative change in fine sediment production and delivery from roads in Type N basins under FFR compared to pre-FFR regulations based on the differences seen in #1 above?
3. Is there a difference in the location and relative amount of sediment delivery to the stream network in a basin (i.e., cumulative effects)?
4. What landscape forms and lithologies are vulnerable to this concern?
5. What proportion of FFR lands may be subject to this concern?

Proposed Methods

The Workgroup identified two potential options for modeling sediment production potential from road transportation networks. In option one sediment production from an existing FFR harvest area would be compared to production from an alternate harvest plan for the same area, but under pre-FFR rules. This would require solicitation of data (GIS data files) from willing timber companies to developing a harvest plan database. In option two, existing timber harvest and transportation plans developed for the Washington State Department of Natural Resources by University of Washington Forest Engineering students would be used as the base data sources for this study. Several of these databases are for pre-FFR rules, therefore for comparison an alternate harvest plan would be developed under FFR rules. Because the UW already has the harvest plans, the Workgroup agreed that time and cost would be conserved if we pursue option two. Because the state lands harvest plans were developed under the state lands HCP and are not necessarily representative of FFR regulated lands. Existing HCP-based transportation and harvest plans may need to be modified for the purposes of this study. Differences in stream typing, stream buffer implementation and habitat goals will be considered in altering the plans.

Existing plans will be evaluated for their compliance with pre-FFR and current FFR regulations and altered to meet temporally relevant best management practices creating a pre-FFR and a post-FFR management plan. Comparison of these parallel timber harvest and transportation plans for differences in transportation system design will address research question #1. It is possible that there will be no significant differences in pre-FFR and post-FFR transportation networks and therefore make research questions #2-5 irrelevant. The study investigators will work with CMER representatives to evaluate the findings of research question #1 and refine research goals as necessary.

In order to develop reasonable harvest and transportation plans for the chosen study areas, assumptions will be made about timber volumes, harvest goals and economic constraints. One concern that has been expressed is that increased buffers could lead to more roads since harvest units would be less contiguous. It is possible that topographic or economic constraints could make any additional roads caused by increased buffers to be cost prohibitive. In any case, physical, biological and economic factors will be considered in the analysis to ensure that a reasonable harvest plan is developed.

Harvest scheduling and transportation planning will be done in the simplest way possible that yields reasonable results. Previous DNR harvest plans developed by UW FE students, under supervision of Professor Peter Schiess and local DNR forest engineers, have used SNAP, Network and other software packages. The project team will determine the most appropriate method of scheduling in cooperation with CMER representatives.

The resulting schedule will then be used to inform SEDMODL2 for sediment production and delivery analysis. As SEDMODL2 does not allocate sediment to streams, a custom solution will need to be developed to route sediment downstream and quantify cumulative effects (i.e., Question 3). Maps and figures detailing sediment production and delivery will be developed to communicate the results of the study.

This project will require many assumptions to be made in order to cost-effectively analyze multiple basins within the project timeline. The study investigators will work closely with CMER representatives to develop reasonable assumptions for transportation, harvest, growth and sediment modeling.

Potential Study Areas

Eight potential study areas have been identified (**Figure 5**). Some of the areas will be more appropriate for the study than others. Specifically, the Washougal, Hoodsport and Tahoma sites are likely the best candidates since they are larger and tend to be contiguous, watershed oriented landscapes. The study investigators will work with CMER to identify the most appropriate sites for this research.

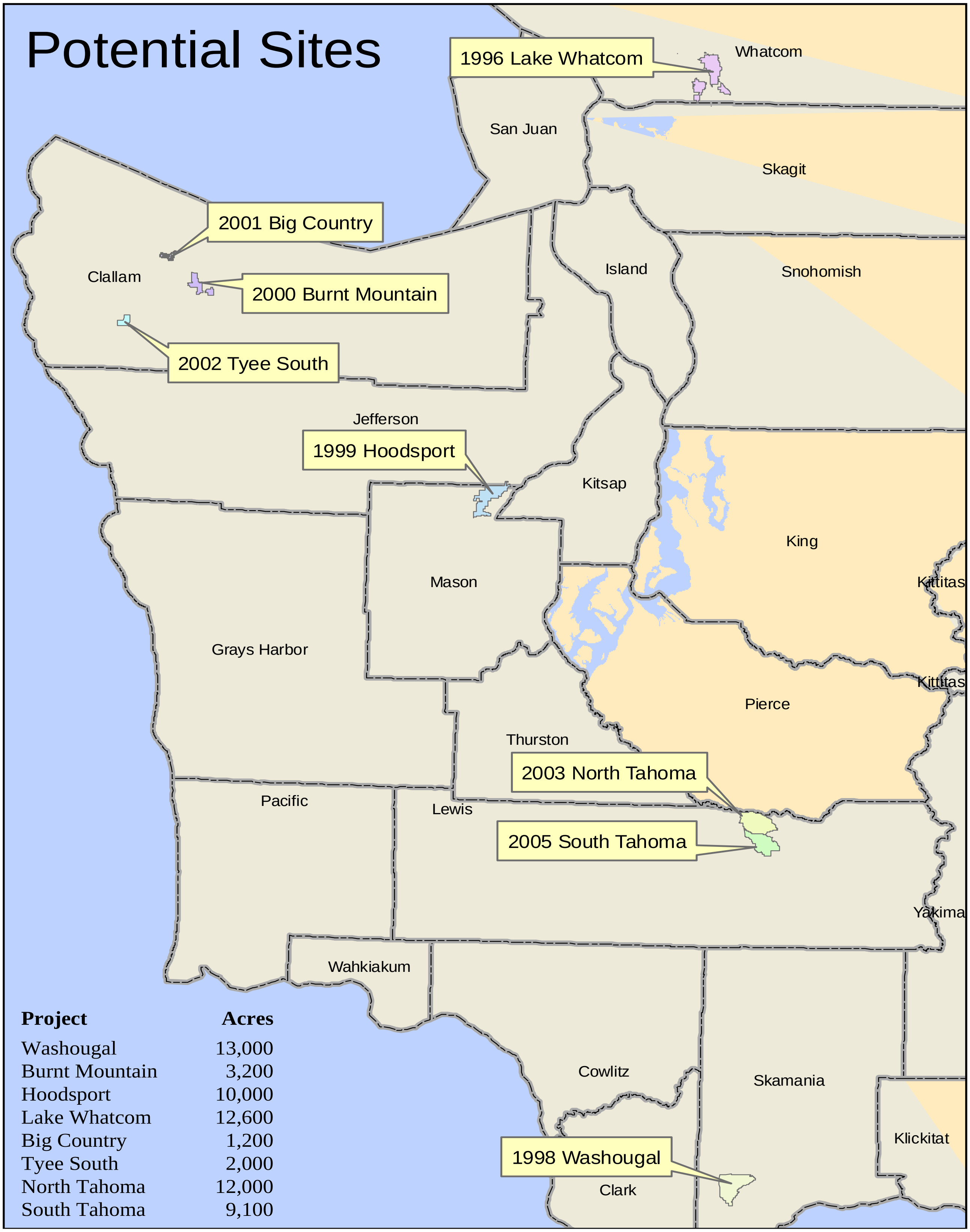


Figure 5 - Existing transportation and harvest plans for DNR which could be modified to meet project requirements.

Desired Products

Draft and final reports that include the following:

1. Maps (hardcopy and in ArcGIS) showing the design of the transportation network and landing locations under FFR compared to pre-FFR;
2. Maps showing the differences in potential road use and fine sediment loading (i.e., relative distribution of sediment input to stream network) under FFR compared to pre-FFR;
3. Summary statistics for transportation and sediment metrics; and
4. Description of methods of analysis, assumptions, results, and discussion of potential implications of FFR to sediment production.

Timeline

The project runs from January 1, 2007 to June 30, 2007. We propose the following timeline:

- January 2007
  - Resurrect old DNR harvest and transportation plans and identify best combinations of data availability and site suitability
  - Identify and quantify biological and economic factors
  - Identify and acquire additional relevant datasets
- February 2007
  - Update identified plans for use with new software
  - Develop methodology for modeling FFR/pre-FFR plans
  - Setup growth models
- March 2007 – April 2007
  - Develop harvest plans
  - Develop transportation networks
- May 2007
  - Model sedimentation using SEDMODL2
- June 2007
  - Maps
  - Delivery of draft report and presentation to CMER or appropriate working group
  - Archiving and project wrap-up
- July 2007
  - CMER Review
- August 2007
  - Delivery of final report

Note, the timeline is dependent on timely collaboration with CMER representatives during each phase of the investigation. Also, given the findings at the end of each phase, the schedule may be adjusted.

Budget

	University of Washington - College of Forest Resources				
	Projected Budget				
	Study Title: CMER Study: The Effects of Forests & Fish Buffer Regulations on Road Network Design and Potential Sediment Delivery to Streams				
Agency: Washington State Department of Natural Resources					
For the Period:		**January 1, 2007 - June 30, 2007**			
1	**Salaries**				
	Total Staff			**$**	**29,178**
	Total Faculty			**$**	**4,151**
	Total Salaries			**$**	**33,329**
7	**Benefits**		**Rate**		
	Professional Staff		28.30%	**$**	**8,257**
	Faculty		23.80%	**$**	**988**
	Total Benefits			**$**	**9,245**
4	**Travel**				
	Vehicle	3 trips to Olympia		**$**	**300**
	Per Diem			**$**	**-**
	Total Travel			**$**	**300**
5	**Supplies and Materials**				
				$	**-**
	Total Supplies			**$**	**-**
6	**Equipment**				
				$	**-**
	Total Equipment			**$**	**-**
3	**Other Direct Costs/ Contractual Services**				
				$	**-**
	Total Other			**$**	**-**
	Total Direct Costs			**$**	**42,874**
25	**Indirect Costs @**	0% on first $5,308; 26% on remainder		**$**	**9,767**
	TOTAL COSTS			**$**	*** 52,641**

*The total cost may be reduced if the study is terminated before all phases are completed.

Appendix 6. Department of Ecology letter to DNR

Subject: Industrial Economics Incorporated 11/1/2024 Memorandum: Preliminary Findings of the Economic Analyses of the Proposed Type Np Water Buffer Rule

Dated: November 22, 2024

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600, Olympia, WA 98504-7600 • 360-407-6000

November 22, 2024

TO: Karen Zirkle, Assistant Division Manager – Policy & Landowner Services, Forest Regulation Division, Washington Dept. of Natural Resources

FROM: Kasia Patora, Lead Economist, Rules & Accountability Section, Governmental Relations, Washington Dept. of Ecology

SUBJECT: Industrial Economics Incorporated 11/1/2024 Memorandum: *Preliminary Findings of the Economic Analyses of the Proposed Type Np Water Buffer Rule*

The Washington State Department of Ecology (Ecology) thanks the Washington State Department of Natural Resources (DNR) for the opportunity to provide feedback on preliminary economic analysis work conducted by Industrial Economics Incorporated (IEc) for the purpose of comparing current and proposed rules for riparian buffers for Type Np (non-fish, perennial) waters in western Washington.

The intent of our feedback is to communicate to DNR Ecology's observations and concerns with the preliminary analysis and to constructively share ideas on potential ways to improve the quality of analysis. We have chosen not to repeat most past questions, concerns, or support (whether on the methodology related to the Type Np rulemaking or similar past approaches to the Water Typing Rule), as IEc has been documenting and addressing these as possible over time. We do note, however, that we specifically continue to support IEc's approach to use of discount rates (risk-free real social rate of time preference applied to transaction values, noting that since transaction values are impacted immediately in the model, they are effectively undiscounted) and Social Cost of Carbon (noting a history of support for its use in the courts, while we also acknowledge it does not quantify all impacts of climate change).

We believe suggested approaches and revisions would allow DNR and IEc to narrow the currently very broad range of estimated impacts intended to mitigate uncertainty around limited or imprecise data sources. This also would potentially eliminate the need to include the high-end, worst-case scenario that fails to exclude baseline requirements and impacts.

We also note that the methodology and results of this analysis will be valuable to Ecology's associated Tier II antidegradation analysis under WAC 173-201A-320. Where improved data, adjustments, or detailed understanding of uncertainty and over/under estimation are recommended and may also be used in Ecology's analysis, we believe consistency across analyses will reduce risk of incongruous findings or determinations.

Primary concerns for Ecology include:

1. The assumption of mapped streams being perennial where the DNR hydrography layer (WC Hydro) indicates a Type N (non-fish) segment,
2. Forestland subject to the proposed rule excluding DNR State Lands but not excluding other industrial forest landowners who have individual Habitat Conservation Plans that depart from Np rule protections in WAC 222-30-021*(2),
3. Underrepresenting unstable slope protection under baseline Type Np rule conditions,
4. The need to incorporate additional information from CMER Type N studies related to amphibian populations and stream temperature response following Np treatments,
5. Potential for Endangered Species Act context under the baseline, and
6. Need for clarity regarding avoided costs associated with water quality regulations.

These comments and questions are detailed below, along with corresponding recommendations.

Perennial stream assumptions

What is the level of confidence in the accuracy of extrapolating Four Peaks sites to represent the broader landscape in this case study and the underlying synthetic stream layer?

If use of alternative data (as recommended in our enclosure and in subsequent sections) is not possible, we would recommend providing some sort of estimated error by comparing a random sample of the extrapolated results with known data. You could produce such an analysis with data on hand by withholding a small portion of the Four Peaks data in each ecoregion, extrapolating the restricted four peaks sample, then comparing the withheld Four Peaks sites to the extrapolation.

After the analysis, consider where error is small and where error is large. Was error random or were they correlated with landscape features that would lead us to believe results using this extrapolation could be over or under-estimated?

Table 1, page 3, Preliminary Findings Memo. "WC Hydro identifies that 90% of Np stream reaches are greater than 1,000ft."

We have significant concerns with utilizing WC Hydro as a source for Np stream data. WC Hydro almost exclusively identifies Type N stream segments but rarely differentiates whether the Type N stream is perennial (requiring a harvest restricted buffer) or seasonal (requiring no buffer). If they exist, individual Forest Practices Applications (FPAs) associated with Type N stream segments in WC Hydro contain the information necessary to determine whether a WC Hydro Type N stream was verified as Np or Ns. Is IEc assuming all WC Hydro Type N segments are Np? If this is true, the assumption is likely to overestimate the population of Np streams in Western WA.

Table 1, page 3, Preliminary Findings Memo. (Percentage of Np streams / bankfull widths and implication for analysis)

The information in this table seems to support Ecology's earlier concern that the Four Peaks synthetic stream layer overestimates Np stream density. Streams higher in the watershed are more likely to be identified as < 3ft, so more modeled streams in these upper reaches would increase the amount of < 3ft streams.

We recommend making corrections where necessary or include a footnote or language describing how N and Np was distinguished within WC Hydro. Alternatively, we recommend utilizing field verified stream data as available in FPAs (described in the Buffer Comparison Method enclosed). FPAs are spatially available through DNR GIS Open Data, accessible through the Forest Practices Application Review System, and contain highly accurate field verified information on stream type, location and prescribed protection measures.

Overrepresentation of affected timberlands

On excluding Np stream segments intersecting with Federal, Tribal, and DNR State Trust Lands (pg. 7, Preliminary Findings Memo), we note that DNR State Lands is not the only industrial timber landowner with an individual HCP that departs from the Type Np buffer prescriptions found in WAC 222-30-021*(2).

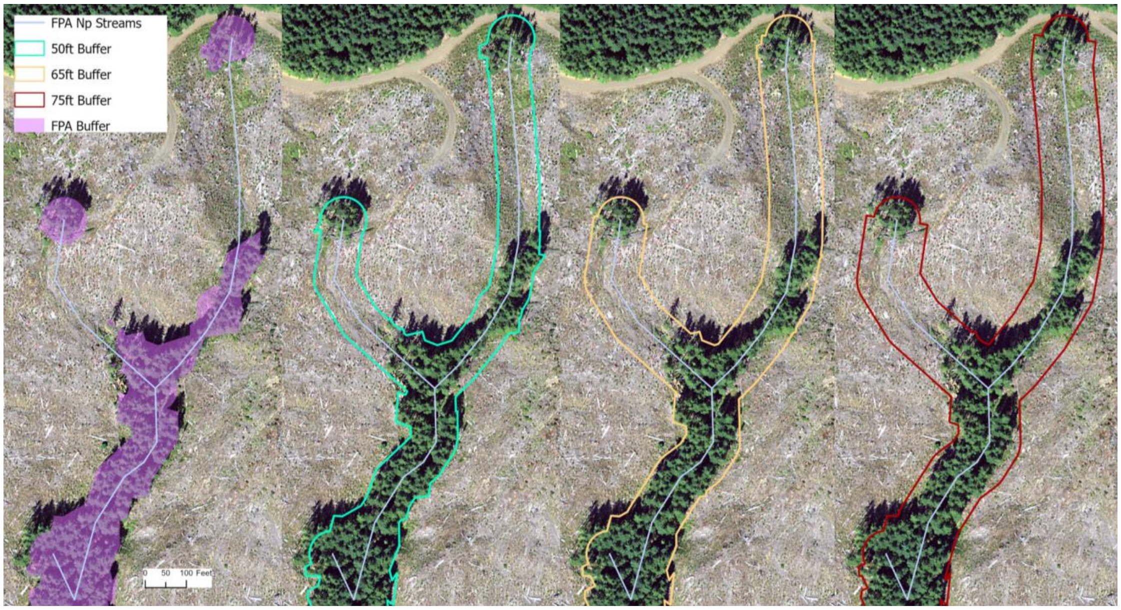
Please exclude other timberland owners and associated acreage in western Washington where landowners have individual HCPs that don't follow WAC 222-30-021*(2), or who may have an approved HCP that incorporates the baseline Np protections in WAC 222-30-021*(2) and who's HCP approval extends well into the future (individual HCPs are often approved for 50 years).

Individual landowner HCPs that should be considered in this analysis for potential exclusion include Green Diamond Timber Co., West Fork Timber Co., Port Blakely Timber Co., Seattle Public Utilities, and Tacoma Power. We recommend IEc confirm with DNR if any additional landowners have individual HCPs and if so, review those HCPs accordingly for potential exclusion from the CBA.

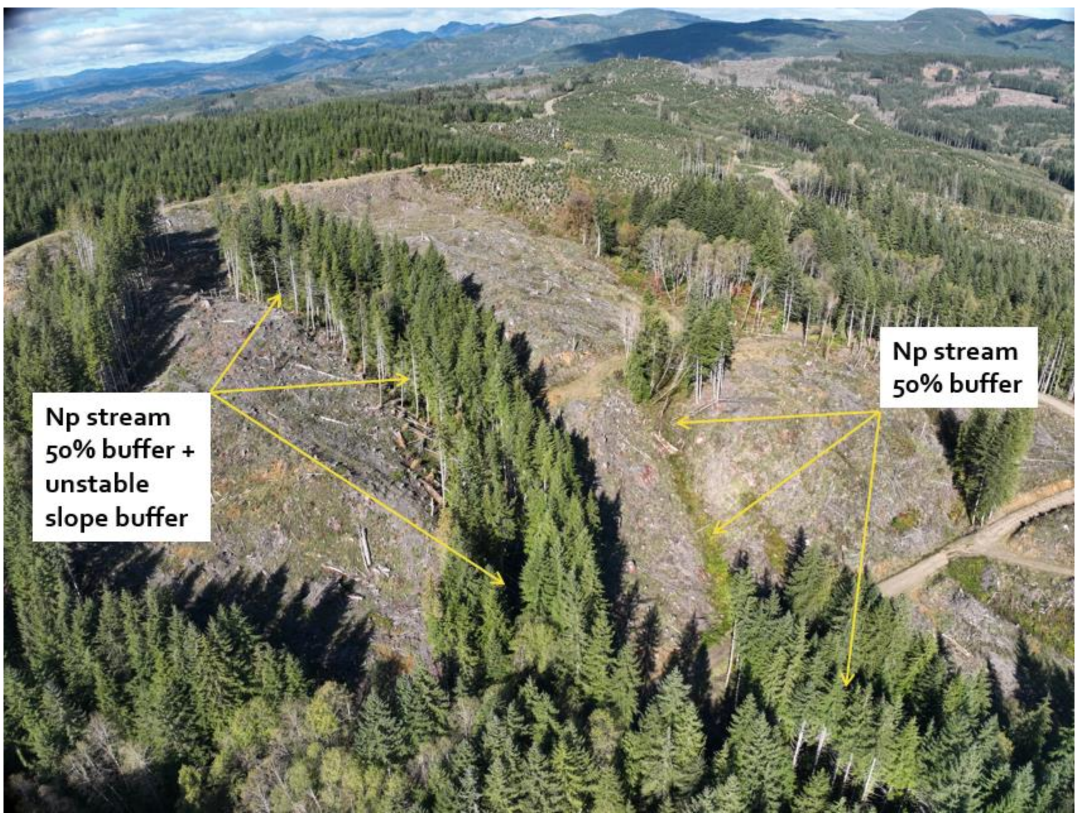
Underrepresentation of unstable slope and sensitive site protections

Please note unstable slopes identified in the DNR LSI spatial layer and WGS landslide inventory database underrepresent the presence and extent of smaller rule identified landforms that often intersect with Np streams, including inner gorges (e.g. LSI did not identify any of the inner gorges in the Soft Rock study basins). Additionally, WGS landslide inventory is only available in some of the Puget Sound counties and South Cascades, which excludes all the coast range. Limiting consideration for unstable slopes to these two spatial layers falls short of adequately capturing baseline conditions and in doing so may overestimate potential costs of the proposed rule.

We recommend accounting for baseline conditions by sampling statistically meaningful real-world data from approved FPAs for further analysis. A statistically meaningful sample population of real-world timber harvest data by ecoregion will account for all usual reasons Np streams are buffered in the real world.



Above: Example side by side comparison of buffering strategies of proposed rule on a single real world Np stream. Baseline conditions are in pink (left) and are inclusive of field-verified Np stream segment and applicable unstable slope protections in this case.



Above: Baseline example of Np stream (left) buffered by unstable slope protection for an inner gorge. The presence and footprint of these potentially unstable features are often not accurately represented by the LSI and WGS spatial layers. The Np stream on the right is not associated with unstable slopes so only requires protection via the Np rule in WAC 222-30-021*(2).

In IEc's Final Methods Memo, Table 1 compares buffer alternatives, by distance from F/N break, compared to baseline. The table goes on to say in a note that "The incremental changes described in the above table do not differentiate between the nuances of the current rule… Sensitive sites and

Equipment Limitation Zones (ELZs), as outlined in both the current and proposed rule, are also not accounted for in the buffers and incremental changes outlined above. As such, the changes described above are simplified representations of the Proposed Rule."

As with unstable slopes, and conservation land, we would expect that sensitive sites be identified and partitioned out from rule impact in "low end" scenarios. Please elaborate on any strategies already taken. If sites cannot be identified, discuss the implications to your bounding scenarios.

Additional information from CMER Type N studies – amphibians and buffer lengths

On stream associated amphibians (page 17, Preliminary Findings Memo). Hard Rock Phase II findings do not appear to have been considered. This study (McIntyre et al. 2021) found a decline in amphibian populations at Np treatment sites relative to reference sites.

We recommend reviewing amphibian response to Np stream treatment sites as documented in McIntyre et al. 2021. Species are long lived, so long term impacts are important to understanding timber harvest effects. See section 9-5.6 (Implications for forest management…) of Hard Rock Phase II for a good discussion on amphibian impacts.

Table 7 (Stream shading, Preliminary Findings Memo). Temperature thresholds are often reported as mortality agents. Increases in temperature can also affect different species in different ways at different life stages (e.g. reproductive success). If available, please provide any examples of temperature impacts to amphibians at different life stages.

Table 7 (Nutrient input, Preliminary Findings Memo). Incorrect number (314). 6 reference basins and about 30 individual streams, depending on how you count the tributaries.

On effects of buffer lengths influencing temperature response to Np treatment sites, page 15 of the Preliminary Findings Memo states that, "According to the Hard Rock Study, there was no temperature benefit to lengthening the buffer to the entire length of Np stream versus the current rule requirements." And later, "As we refine our analysis for the CBA, we intend to explore existing research on the buffer length-to-water temperature relationship as an additional means of protecting water quality in Np streams."

We recommend reviewing the temperature response reported in Hard Rock Phase II report which states that "The relative effectiveness, from most effective to least, of the three buffer treatments, in terms of the magnitude and longevity of temperature change is 100%, FP, and 0%. The Δ7DTR in the 100% treatment initially was approximately 1.0°C but the treatment effect was near zero by Post 3" (page 4-79).

Buffer length and width are not the only dimensions to consider when assessing buffer effectiveness. The main metric Hard and Soft Rock used was canopy cover, which was correlated with the temperature response. Buffer area and continuity are also important metrics. Patchy buffers may be more susceptible to windthrow and could extend the temperature response. From Hard Rock Phase II, "The primary driver of higher post-harvest temperatures was the loss of riparian cover due to harvest and post-harvest tree mortality" (page 4-79).

We also recommend reviewing the Soft Rock report. Some of the greatest temperature increases were measured in the unbuffered reaches, see table 4A-2 in chapter 4A of the Soft Rock report.

Potential costs associated with ESA listings

We recommend a qualitative analysis for implications of Endangered Species Act listings of the Cascade and Columbia torrent salamanders.

In an evaluation of a petition to list in 2015 the Fish and Wildlife Service (FWS) states that they "found that the petition presents substantial scientific or commercial information indicating that listing the Columbia torrent salamander (*Rhyacotriton kezeri*) as endangered or threatened may be warranted based on Factor A. However, during our status review, we will thoroughly evaluate all potential threats to the species" (2015-23315.pdf). The same finding was reported for the Cascade torrent salamander (*Rhyacotriton cascadae*) with the addition of Factor E. These species are currently on the FWS National Domestic Listing Workplan Fiscal Years 2024-2028.

Benefits values discussed should include direct values for retention of identified (or similar, using benefit transfer methodology) species as well as indirect values for their ecosystem contribution, biodiversity, existence, or other context. Avoided cost values should consider potential avoided additional harvest restrictions and foregone value. We recommend appropriate discussion of uncertainty and variability accompany illustrative values, acknowledging the complex nature of species preservation and resulting forest management.

Avoided costs associated with water quality regulations

We recommend revising the approach to costs of compliance with water quality regulations.

The last sentence of the second paragraph, Preliminary Findings Memo page 22 starting with, "Ecology notes…" reads as if maintaining Clean Water Act Section 303 Assurances is not a probable benefit of the proposed rule. We suggest the following revised language to clarify Ecology's communication with IEc and DNR from September 4, 2024:

"Ecology notes that should new rules be adopted to improve the protection of Np streams in Western Washington, it is far more likely they continue to work through the Forest Practices Adaptive Management Program and the Forest Practices Board to ensure buffer requirements maintain water quality than it would be to pursue a 303(d) process for streams on forestland, in accordance with schedule M-2 of the Forests and Fish Report."

Correspondingly, we recommend including illustrative costs (e.g., case studies) associated with TMDL implementation that could be avoided. We acknowledge these costs are highly waterbody-specific, and full quantification may not be possible with a high degree of confidence. Discussion of associated uncertainty and variability in size and frequency would help to contextualize these illustrative costs.

Maintaining Clean Water Act Section 303 Assurances provides the continued regulatory stability that has been in place for decades. We recommend including additional discussion of costs and risks associated with regulatory instability (e.g., Clean Water Act litigation risk) that could be avoided or reduced with the adoption of rules that improve the protection of Np streams. IEc might look to historic context such as instability that existed prior to the Forests and Fish law.

Although Ecology appreciates the work that has gone into the preliminary cost-benefit analysis thus far, we strongly encourage DNR and IEc to consider our recommendations to improve the strength of the analysis. Improving the quality and accuracy of this analysis will provide for a better informed position for subsequent Forest Practices Board rulemaking decisions.

The following enclosure contains a step-by-step process developed by Ecology for the purpose of comparing western Washington baseline Np buffer conditions to Np buffer options under the proposed rule. This method incorporates field verified data from approved Forest Practices Applications with completed timber harvest activities and utilizes Washington Department of Fish and Wildlife's High Resolution Change Detection Model to identify post-harvest Np buffer areas. Advantages of utilizing this alternative approach to better understand incremental Np buffer changes under the proposed rule include:

1. Adequately capturing the presence and location of field verified Np streams,
2. Adequately capturing the presence of unstable slope and sensitive site buffers,
3. Nullifying the preliminary need for bankfull width and basin size data because incremental changes associated with all buffer options (excluding partial harvest option 1a) can be represented as a range (e.g. 30-55%, in Table 2 of the Enclosure). If desired, further analysis may be considered for bankfull width, basin size, and the partial harvest option.
4. All additional modeling and analysis for the CBA will be built off a field verified stream layer and current buffering practices on Forest Practices HCP lands.

If IEc is interested in further exploring this alternative buffer comparison approach and has questions, please reach out to Ecology Water Quality Program staff Welles Bretherton at welles.bretherton@ecy.wa.gov or Chris Briggs at chris.briggs@ecy.wa.gov.

Enclosure: Ecology Np Buffer Comparison Method

Np Buffer Comparison Method

Test Watershed

We used the Washington State Department of Fish and Wildlife (WDFW) High Resolution Change Detection (HRCD) model to create 1m resolution Np buffer polygons in the Mitchell creek Watershed Administration Unit (WAU). These polygons were associated with Forest Practice Applications (FPAs) classified as effective from 2011-2017 (Figure 1). This included approximately 5 years of harvests prior to the 2017 NAIP imagery used in the HRCD model.

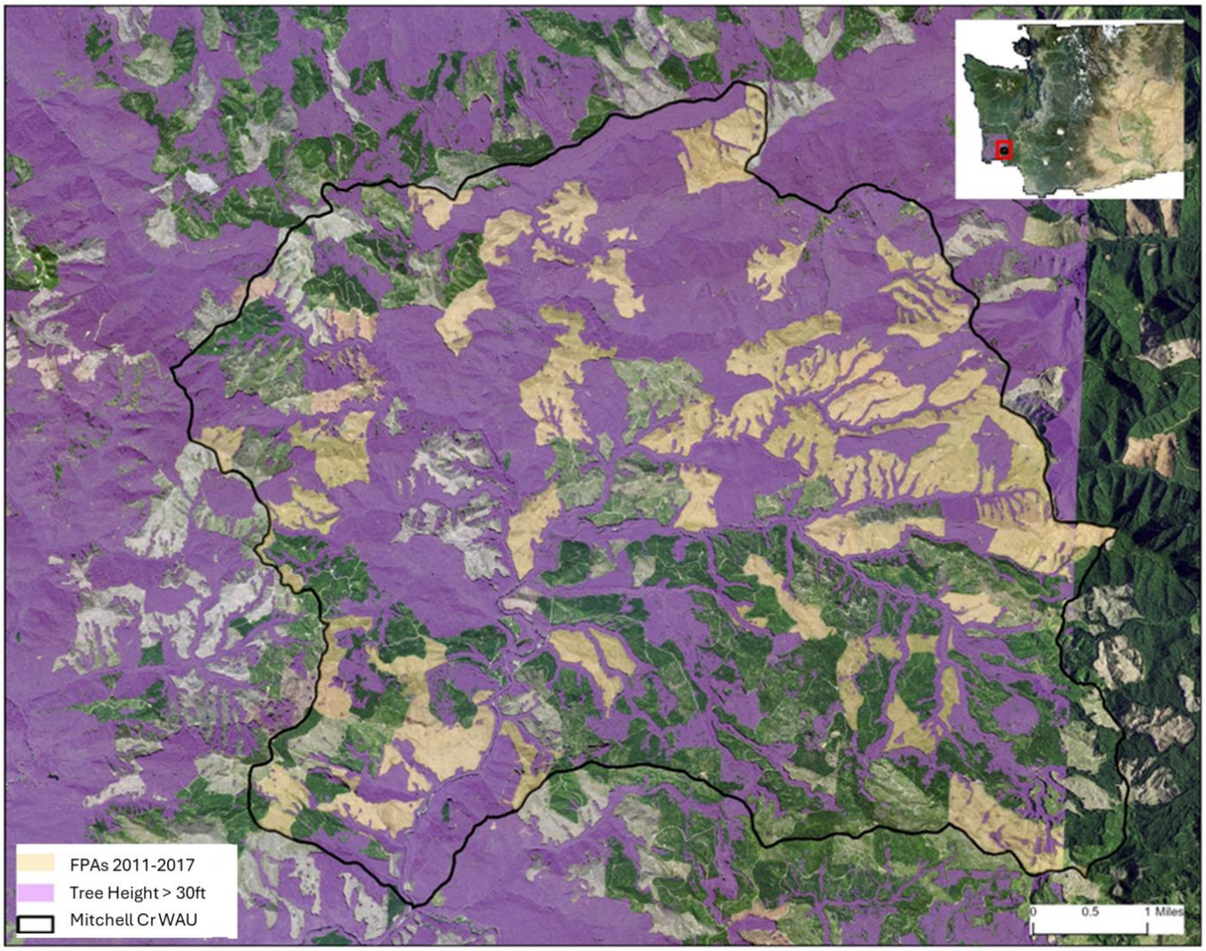


Figure 1. Mitchell Creek WAU test area. Locations of the FPA harvests included and the areas the HRCD model determined to have trees greater than 30ft tall (HRCD 30).

HRCD 30 areas adjacent to the FPAs were selected (Figure 2). We then clipped out all the N streams from the Washington State Department of Natural Resources (DNR) hydrography layer (WC Hydro) in the Mitchell Cr WAU. We used the link in the DNRs FPA by classification layer attributes table to open the PDF that contained the individual harvest activity maps within the approved FPA. Using this map, we could then edit the Np stream layer to match Np streams displayed on the harvest activity map. This does require some effort to manually clip, change, delete, and edit stream segments and vertices of the stream layer. However, this is vital to ensure that the Np stream layer used in this analysis reflects, as accurately as possible, what was true on the ground at the time of harvest. DNRs Compliance Monitoring Program reports an accuracy of over 90% for the baseline Type Np prescription, so the Np streams in the activity map should reflect that level of confidence. In addition, the edited stream layers matched well with HRCD 30 layer and the NAIP imagery (Figure 3).

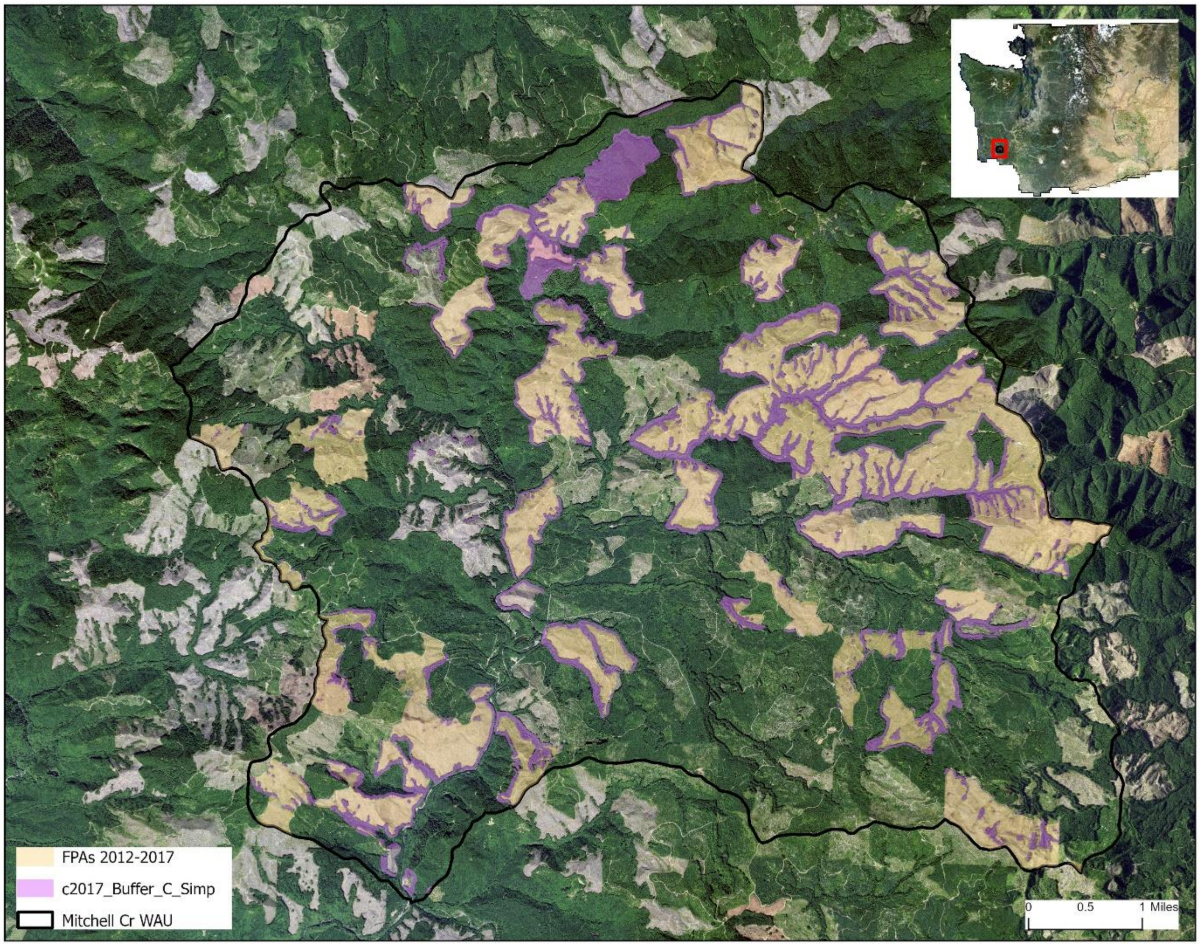


Figure 2. Test area with FPA associated buffers.

Once the Np stream layer matched the activity maps of the selected FPAs, we then buffered that layer to 100ft. We then clipped the HRCD 30 to the 100ft buffer layer to capture all the buffers left by the harvest that were 100ft or less. This ensures that any buffer that was around 75ft would be captured in the change detection calculations. The result was a representation of real-world Np buffers (<100ft) left after harvest in the Mitchell Creek WAU from ~ 2012-2017 (FPA Buffer). We then buffered the Np streams by 50ft, 65ft, and 75ft to represent most of the buffering strategies in the proposed rule change (Figure 3). We simplified the analysis to just buffer widths, regardless of BFW or basin area, to bracket the estimated change from the low end (50ft) to the high end (75ft). the actual change would be somewhere within this range. Each buffering strategy was merged with the real-world FPA buffers to account for any additional buffers that were left due to other rules like sensitive sites or Rule Identified Landforms (RILs, another phrase for unstable slope buffers).

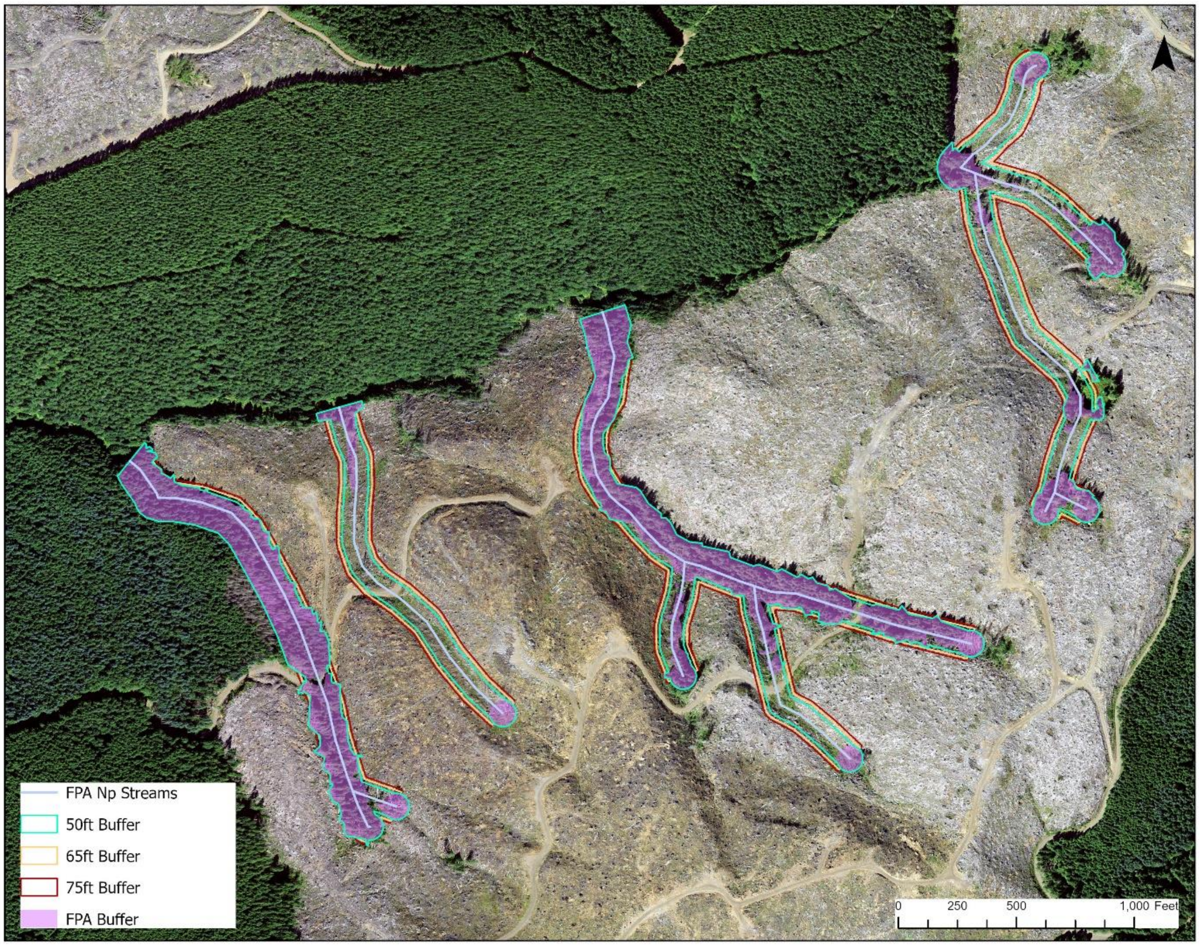


Figure 3. Current buffers left after harvest compared to the different buffer widths proposed in the new rule (does not include thinning strategy).

We then compared the FPA buffers to what would have been buffered if the proposed rule had been applied to these harvests. Overall, 490 acres of buffers were left around Np streams under current forest practices rules in this test watershed and a total of 10,852 acres were harvested. An estimated 4.32% of the land was taken out of production under baseline conditions due to buffers adjacent to the Np streams in the harvested areas. Under the proposed rule there would be an additional increase of 1.29-2.37% (Table 1). This also represents a 30-55% increase in Np buffer area from the current rule (Table 2).

Table 1. Comparison of the harvested area vs the unharvested area (due to buffers near Np streams) under the current rules and the proposed Np buffer rules (50ft, 65ft, and 75ft) Additional percent unharvested is the increase in the area taken out of production from the 4.32% left under the current forest practice rules. Percentages are from the total area under management around Np Streams (Harvested Area + FPA acres).

Buffers	Acres	Additional acreage	Additional % Unharvested
FPA	490	-	-
50ft	637	147	1.29%
65ft	702	213	1.87%
75ft	759	269	2.37%
Harvested Area	10852	% Unharvested	4.32%

Table 2. Percent increase in buffer area from the current rule under the different buffering strategies.

Buffer Type	Current buffer (ac)	Proposed Rule Buffer (ac)	Percent change
50ft	490	637	30%
65ft	490	702	43%
75ft	490	759	55%

Since the test area was situated in the Willapa hills and did not include a random sample design, the inference is limited and may or may not be representative of the broader eco-region. However, if this method were applied in a random sample design it should provide a reasonable estimate of change in buffer area associated with the proposed rule. While there is always going to be uncertainty in any method, it can be reduced by building models from known data sources. Using a stream layer that has been field verified in combination with a 1m resolution Np buffer layer will reduce that uncertainty.

GIS Method

Data sources

- WDFW HRCD layer (HRCD)
  - Western WA counties
  - From 2017 NAIP imagery
  - https://hrcd-wdfw.hub.arcgis.com/
- DNR watercourses (WC Hydro)
- FPA - All Harvest by Classification (FPA)

Procedure

Buffer acreage

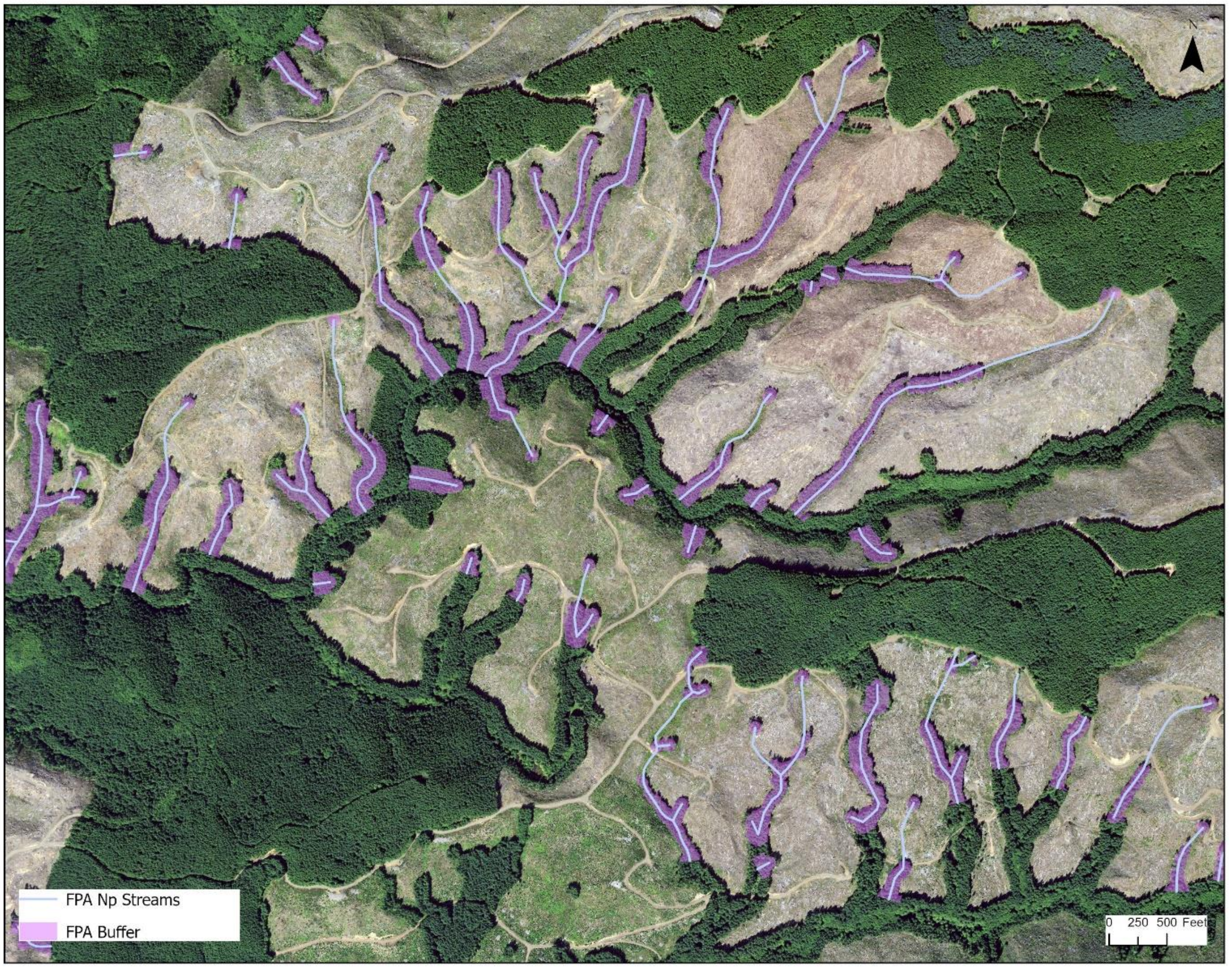
- HRCD - Select by attributes
  - Modeled Height >=30ft
  - Export to new feature class
- Clip FPAs to target area
- Create Definition Query for FPAs
  - Effective date = to 2011-2017 and
  - CLASSIFCA not = to IVG
  - DECISION = to APPROVED
- Buffer FPAs by 200ft
  - To ensure capture of all Np buffers
- Dissolve FPA buffer
  - All features
- Clip HRCD 30 by Dissolved FPA buffer
- Dissolve Boundaries of HRCD clip
  - to simplify polygons
- Eliminate Polygon Part
  - to fill in gaps

- Run definition query on WC Hydro
    - FP_WTRTY_C not = to F and
    - FP_WTRTY_C not = to S
- Clip WC Hydro to FPA buffer layer
- Manually edit new Hydro layer (Hydro)
    - Open the PDF in FPA attributes table
    - Scroll to activity map
    - Delete all Stream segments not included on FPAs as Np streams
    - Adjust the remaining Np streams to fit activity map
    - Drop points at confluences and Perennial Initiation Points (PiPs)
        - Points to be buffered later
        - HRCD does not pick up PiPs well
    - Repeat
- Buffer Hydro by 100ft
- Clip simplified HRCD 30 to 100ft Hydro buffer layer
- Buffer PiP and confluence Points to 56ft
    - Buffer required under forest practice rules
    - Assumes PiP buffer placed correctly
- Merge simplified HRCD clip with PiP buffers
    - **FPA buffer**
- Buffer Hydro by 75ft
- Merge 75ft buffer with FPA buffer
- Dissolve merged buffer
    - **75ft Buffer**
- Buffer Hydro by 65ft
- Merge 65ft buffer with FPA buffer
    - Dissolve merged buffer**65ft Buffer**
- Buffer Hydro by 50ft
- Merge 50ft buffer with FPA buffer
- Dissolve merged buffer
    - **50ft Buffer**
- Run Calculate Geometry to get acreage for each buffer layer

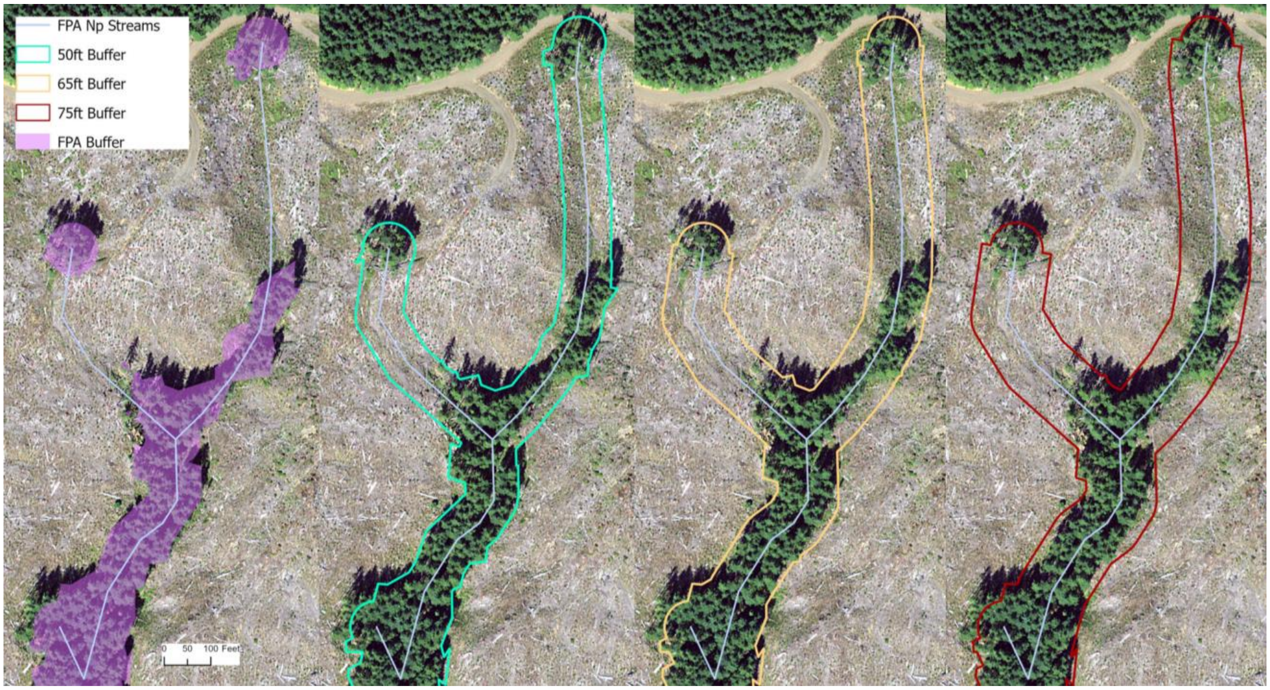
FPA Acreage

- Clip target FPAs by original HRCD layer
    - Ensures FPA area only includes harvest
- Run Calculate Geometry to get acreage

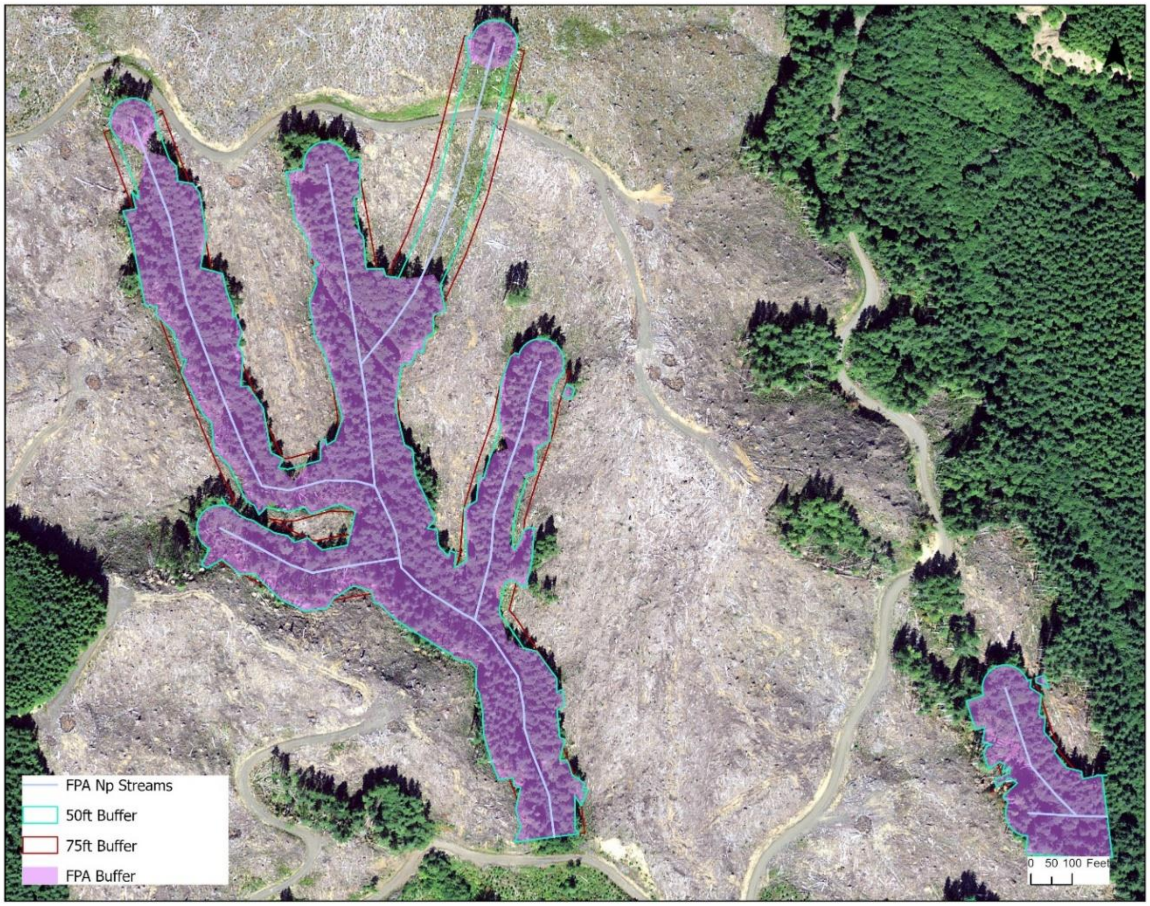
Additional Maps



Map 1. Overview of part of the test area showing FPA buffers derived from the HRCD 30 layer.



Map 2. Side by side comparison of the buffering strategies on a single Np Stream.



Map 3. Wide Inner gorge area. Shows very little difference in area between the buffering strategies (FPA, 50ft, 75ft).

Appendix 7. Report review process and acknowledgements

This report was developed and edited by MB&G staff. Land valuation information was provided by MB&G appraisal staff.

The analysis of forest practices applications was developed following review of the letter from Ecology in Appendix 5, and a meeting with Ecology, DNR, WFPA, and MB&G staff. The analysis was designed by Rocinante Consulting and MB&G, with input from WFPA, Martin Environmental LLC, and JMurray Forestry LLC. Statistical analysis was completed by Rocinante Consulting.

Third-party review of this report was provided by Sándor Tóth, Ph.D. MB&G was provided with the transcript to the June 6, 2025, meeting that contained comments from Board Member Bowen regarding an earlier of draft of this report. This version of the report includes updates that respond to these comments.

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Attachment C - Detailed Review of Technical Components of July 2025 Draft Tier II Analysis

We evaluated five areas of concern with the technical analysis presented in the Ecology Preliminary Draft Tier II Antidegradation Analysis (hereafter, Tier II analysis).

Synthesis of Results from Hard Rock and Soft Rock Studies

The synthesis of results presented in the Tier II analysis was incomplete and, in some instances, misinterpreted the Hard Rock and Soft Rock studies. First, the Tier II analysis did not provide a complete presentation of results from the Hard Rock study. Temperature responses from the Hard Rock Forest Practices and 100% buffer treatments were presented, and the relatively better performance of the 100% buffer treatment was noted (p. 30). However, we note that the 0% buffer also performed similarly to the 100% buffer, a result that was not presented in the Tier II analysis. When examined together, all three treatments show similar seven-day average daily maximum (7DADM) temperature responses (Figure 1). As expected, the warmest harvest unit received a 0% buffer. However, the six coolest harvest units received 0, 50, or 100% buffer treatments. In addition, we note that the responses of the 50% buffer treatment were similar to the reference (Figure 2). The existence (in a small sample) of a reference unit with a generally colder temperature than other reference and 50% buffer units contributed to the finding of a statistical difference in temperature between the current Forest Practices buffer and the reference.

The results from the Soft Rock study showed a similar pattern (Figure 3). Again, the warmest harvest unit was treated (clearcut harvest with a two-sided 50 ft [15.2 m] wide riparian buffer along at least 50% of the perennial stream channel, including buffers prescribed for sensitive sites and unstable slopes). However, the coldest harvest unit across all years of observation was also treated and four of the five coolest harvest units were treated (across all treated sites in the SR study, the buffer area was 18 to 163% greater than a simple 50-ft-wide buffer along 50% of the stream length; p. 2-9, Ehinger et al. 2021).

Figure 1: Seven-day average daily maximum (7DADM) temperature responses by year for the 0%, 50%, and 100% treatments, CMER Hard Rock study, 2006-2023. Horizontal dashed line is at 16 °C.

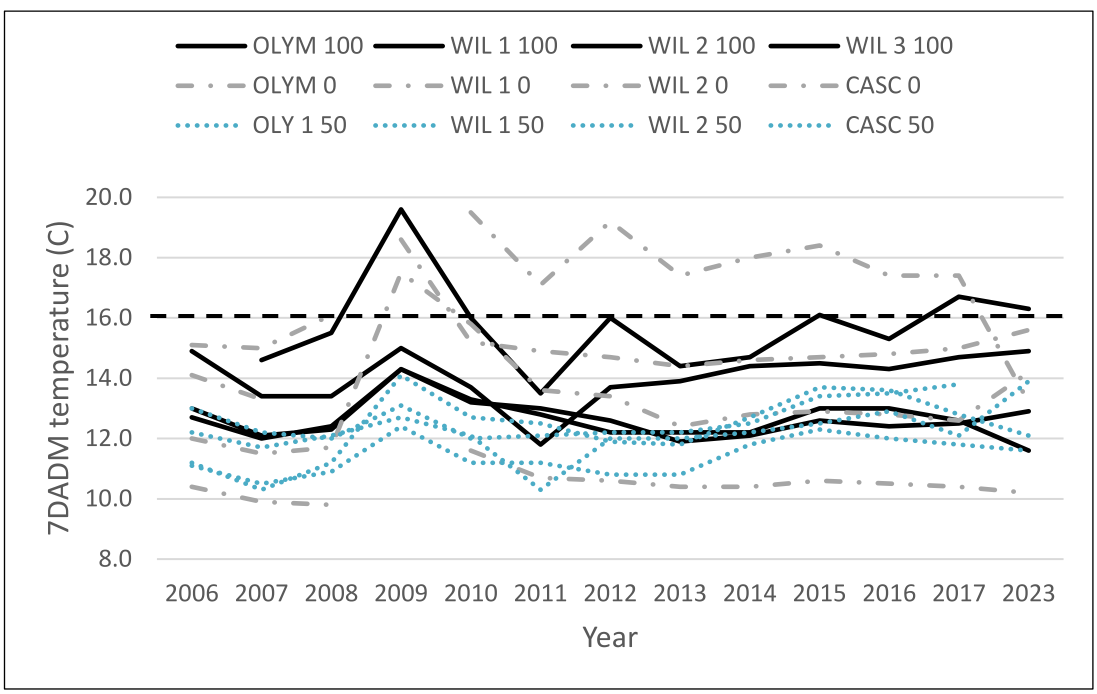


Figure 2: Seven-day average daily maximum (7DADM) temperature responses by year for the references and 0% and 50% treatments, CMER Hard Rock study, 2006-2023. Horizontal dashed line is at 16 ºC.

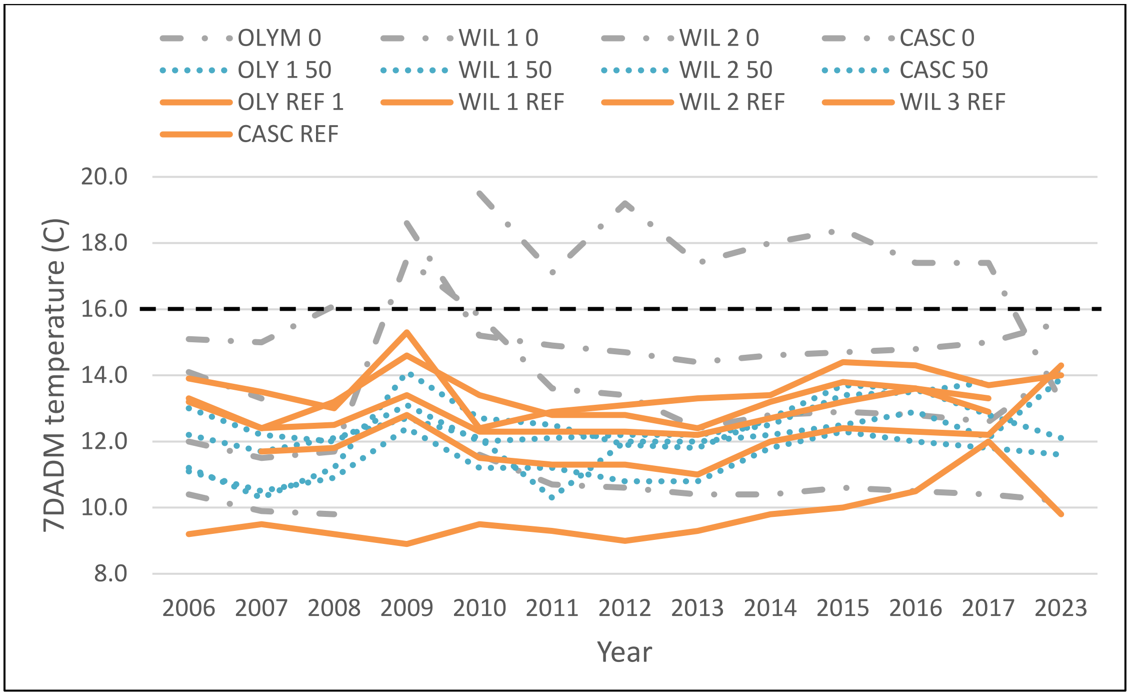
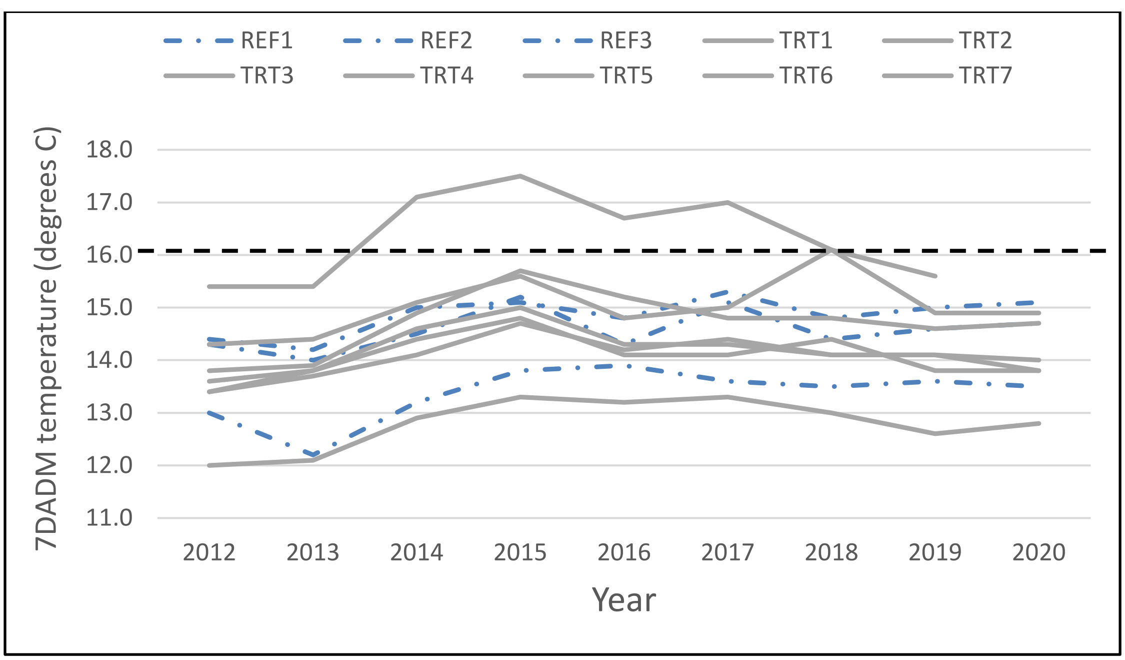


Figure 3: Seven-day average daily maximum (7DADM) temperature responses by year for the treatment (current Forest Practices) and references, CMER Soft Rock study, 2012-2020. Horizontal dashed line is at 16 ºC.



Similarly, as a way to demonstrate general temperature responses on treated harvest units compared to the reference, the Tier II analysis presented the number of instances where the mean monthly temperature response was greater than 0.5 ºC compared to the reference (p. 34). This summary is misleading because an increase from 11 to 11.8 ºC is tallied the same as an increase from 16.5 to 17.3 ºC. A more nuanced view is provided by the distribution of 7DADM estimates for all of the reference and treatment units from the Hard Rock and Soft Rock studies. For Hard Rock (Figure 4), the 7DADM exceeded 16 ºC in 15/213 (7%) instances (Table 4-11; McIntyre et al. 2021); for Soft Rock (Figure 5), the 7DADM exceeded 16 ºC in 6/89 (7%) instances (Table 4A-7; Ehinger et al. 2021). We note that the use of 30–80-year-old second growth stands as reference conditions in the Hard Rock and Soft Rock studies is itself an untested assumption. For example, whether using riparian stands that remain after natural disturbances (e.g., fire or wind-throw events) as reference conditions is appropriate or not for Type Np streams is a productive line of inquiry for the Tier II analysis to pursue (Bennett et al. 2004; Drever et al. 2006; Sibley et al. 2012).

Figure 4: Frequency distribution of even-day average daily maximum (7DADM) temperature responses (*n*=213) from the CMER Hard Rock study, 2006-2023. Vertical dashed line is at 16 ºC.

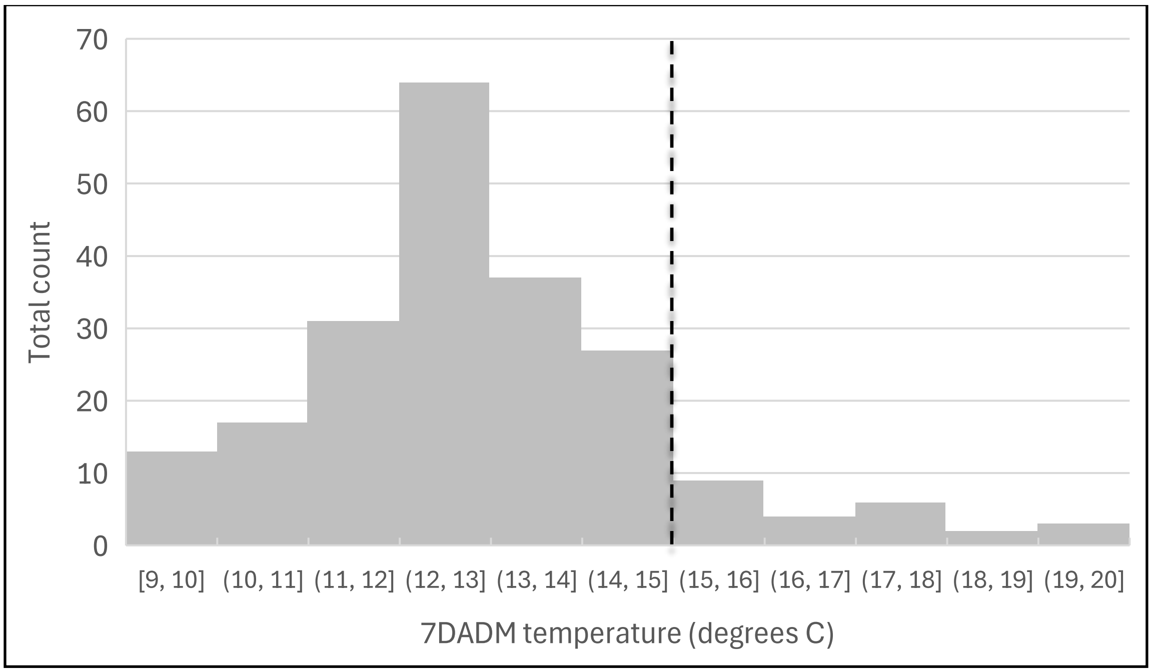


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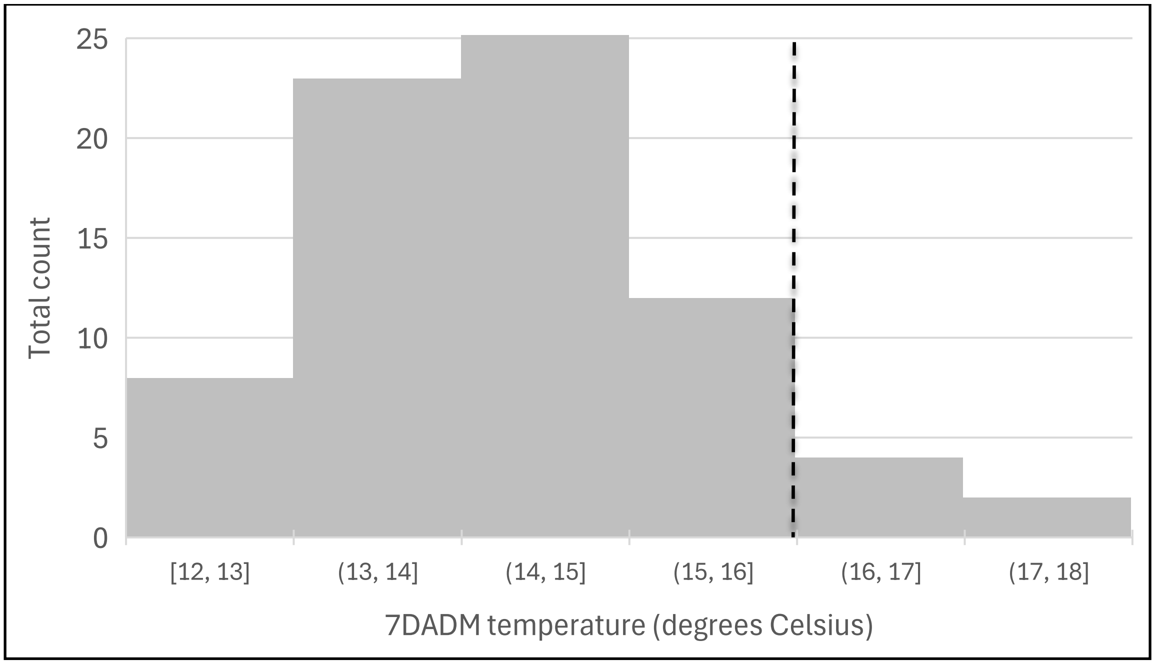
Figure 5: Frequency distribution of the seven-day average daily maximum (7DADM) temperature responses (*n*=89) by year from the CMER Soft Rock study, 2012-2020. Vertical dashed line is at 16 ºC.



Second, the discussion of how site-specific conditions may or may not have influenced the temperature responses observed at harvest units is misleading and indicative of a profound misunderstanding of the experimental designs implemented in Hard Rock and Soft Rock (pp. 35-43). In both studies, the experimental designs support inferences about the average estimated temperature responses (and related uncertainty) due to buffer treatments as implemented. We emphasize that factors such as canopy shade, windthrow, topography, and lithology (among others) were not manipulated directly in either study (some of these factors cannot be manipulated in an experiment), therefore causal inference about those factors cannot be made. Both studies support inference about how the populations (from which the harvest units were drawn for the studies) would respond on average to the buffer prescriptions that approximate those prescriptions implemented in the two studies. What the Hard Rock and Soft Rock studies most assuredly do not support are suppositions about how factors *besides the buffer treatment* may have caused an estimated temperature response (as claimed on p. 35 of the Tier II analysis). Although variability in biological and physical factors within and across treatment groups was incorporated in error estimates (95% confidence intervals) for the treatment responses, direct conclusions cannot be reached about how these factors influenced the responses. More generally, a misunderstanding about associations between site-specific conditions, causal mechanisms, and responses falls within a broader discussion of scope of inference, a topic we address later in this response.

Scope of inference

The Tier II analysis relied heavily on the Hard Rock and Soft Rock studies to argue that larger buffers are required on Type Np streams to maintain water temperature standards. Generally, the Tier II analysis misunderstood that inference from the Hard Rock and Soft Rock studies involves statements about the average response (with estimated uncertainty) of additional harvest units drawn from the same population (e.g., with similar underlying characteristics) and harvested in the same manner (e.g., retaining one of the buffer treatments). Instead, the Tier II analysis attempts to extrapolate, based on results from the two studies, how other locations would respond to buffer treatments by matching lithology, basin size, stand age, presence of amphibians, and other factors (p. 43-44 and pp. 48-50). Doing so misrepresents the scope of inference from the two studies.

In the Hard Rock study, appropriate scope of inference involves not only a consideration for site-selection criteria (primarily competent lithologies that underlie 29% of FFR lands in western Washington; p. 2-20, McIntyre et al. 2021) but also how the treatments were implemented. For the Hard Rock study, investigators stated: "To maximize the influence of the buffer treatments and to reduce confounding effects we designed the study so that harvest units would encompass the *entire Type N basin when possible*" (p. 2-5; McIntyre et al. 2021; italics added). Additionally, the study considered basins 30–120 acres in size (12–49 ha) for inclusion in the sample. A subsequent analysis of basins >30 acres in size and harvested from 2010-2022 found only 17% of basins were 30-120 acres in size; 19% had >85% of the Type Np basin in the FPA; and 1.5% met both criteria (Cramer and Fransen, 2022). Based on this sample, the maximum post-harvest temperature response of 1.2 ºC (95% confidence interval: 0.3-2.1) estimated for the current Forest Practices buffer *may occur* in less than 2% of the basins on the FFR landscape (assuming that the units harvested from 2010-2020 are representative of the overall population). We emphasize that, in this small subset of units to which the Hard Rock results apply, an increase of 0.3 ºC, or more, is possible.

Similarly, the Soft Rock study drew its sample from a relatively small portion of the landscape. For example, the Soft Rock study selected harvest units that occurred on marine sedimentary lithology which underlies 18% of the industrial forest landscape in western Washington (p. 2-4; Ehinger et al. 2021). Importantly, the Soft Rock study was unable to include a random selection of harvest units in the study (p. 2-12; Ehinger et al. 2021). As a result, the investigators stated: "However, the fact that the sites covered a relatively narrow range of forest conditions in western Washington means that direct inference is limited to similar conditions. This does not imply that results are not informative to other situations, but that the application of the results of this study should consider the variable in question, physical site characteristics, type and extent of forest harvest, and the physical processes involved" (p. 2-12; Ehinger et al. 2021). Based on this advice, the Soft Rock results are unlikely to apply to all of the potential harvest units that occur on marine sedimentary lithology. For those units that have similar criteria to the 10 units included in the Soft Rock study (including harvest of the entire Type Np basin,) the maximum post-harvest temperature response of 0.6 ºC (observed in post-years 1 and 2) estimated for the current Forest Practices buffer *may occur.* We emphasize that, based on the 95% confidence intervals (0.3-0.9 and 0.3-0.85 in post-years 1 and 2, respectively), an increase of 0.3 ºC post-harvest, or more, is possible.

<u>*Magnitude of Biological Effects*</u>

The Tier II analysis did not provide any narrative arguments or technical information to describe how the temperature responses, where and when realized, for current Forest Practices buffers (1.2 ºC [95% CI: 0.3-2.1] and 0.6 ºC [95% CI: 0.3-0.9] for Hard Rock and Soft Rock, respectively) have substantial and lasting negative effects on biota of interest including salmonids and stream-associated amphibians. For example, little evidence exists about the magnitude of temperature transferred downstream (e.g., from Type N to Type F waters) and over what distance (Bladon et al. 2018). Also, the Tier II analysis did not provide any discussion of how temperature increases of less than 1.5 ºC, even if delivered downstream in the Type N system or to Type F waters, would have negative effects on any portion of the salmonid life history cycle (McCullough et al. 2001; Kroll et al. 2009). In the Hard Rock study, inference about temperature and amphibian responses is based on the buffer treatments as the buffer lengths and extents were the factors manipulated directly in the experiment. As a result, statements about a causal relationship between temperature and amphibians cannot be made because both are responses to the treatments implemented in the study. In a recent paper, Martin et al. (2021) reviewed multiple papers that evaluated associations between amphibian and temperature responses and various buffer prescriptions on small streams in the PNW. Martin et al. (2021) concluded that available evidence was insufficient to make predictive statements about how uniform buffer prescriptions would perform due to biological and physical variation inherent in small streams. Similarly, Kroll (2009), in a review of forest management effects on stream-associated amphibians, identified only one study that presented strong evidence for an association between buffer prescriptions and amphibian responses. Finally, we note an absence of any discussion in the Tier II analysis of how canopy shade and stream temperature interact to affect primary productivity and, in turn, individual and population performance of salmonid fishes (Thedinga et al. 1989, Wilzbach et al. 2005; Hester and Doyle 2011; Warren et al. 2016; Armstrong et al. 2021). Primary production will decrease if light levels and heterogeneity of stream temperatures throughout the Type Np network are reduced. Given evidence for invertebrate production in Type Np streams and export to Type F streams, this reduction in primary productivity could alter resource types and amounts delivered downstream to fish populations in the upper portion of the Type F network.

Predicting future responses
The attempt in the Tier II analysis to link stream temperature responses to factors such as lithology, aspect, valley wall slope, and bankfull width is unproductive given the management prescription in question is extent and width of buffers retained on Type Np streams (p 48-51). We acknowledge understanding if, and how, buffers are associated with temperature responses in small streams is challenging (see above discussion). For example, first year post-harvest temperature responses in the Hard Rock and Soft Rock studies did not have any relationship with canopy closure (%), percent of channel with buffer, or total buffer length (Figure 6). Similarly, an evaluation of all of the July MMTR from the Hard Rock study indicated that, above 70% canopy closure, no association existed between the temperature response and canopy closure (Figure 7). Specifically, temperature responses could be greater (warmer), equal to (no change), or less (cooler) than 0 ºC in treatments compared to the reference, suggesting that other factors influenced temperature responses in addition to shade (when shade was >70%) provided by the buffer prescriptions. Critically, when shade was >70%, increases of less than 0.3 ºC were as likely as increases greater than 0.3 ºC.

Figure 6: July mean monthly temperature response (MMTR) vs. canopy closure, percent of stream buffered, and total buffer length for the Hard Rock (black) and Soft Rock (red) studies (p. 4-31; Ehinger et al. 2021). Values are from the first-year post-harvest.

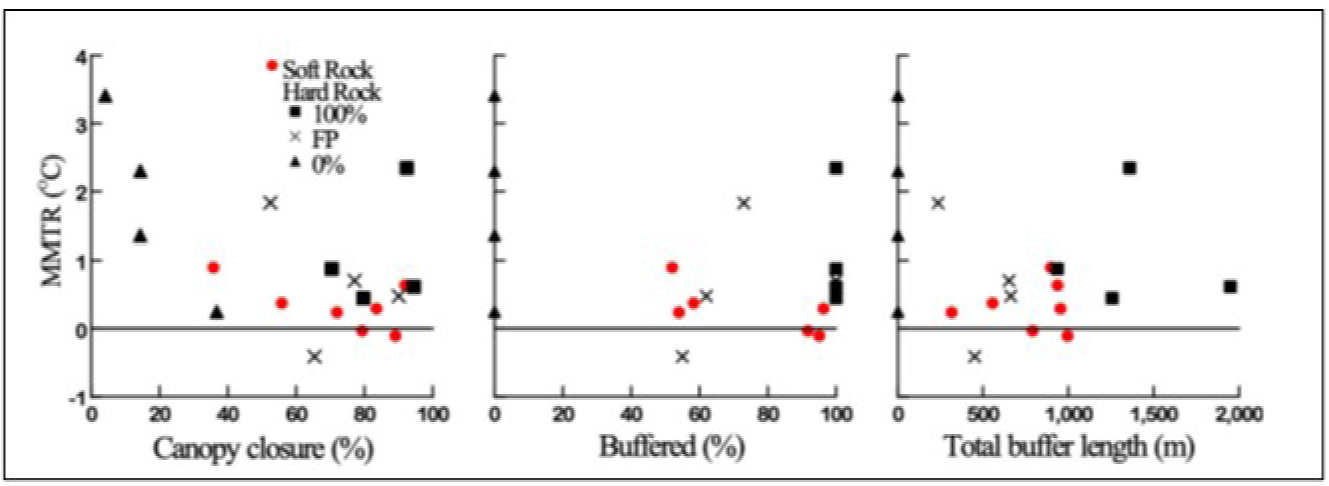


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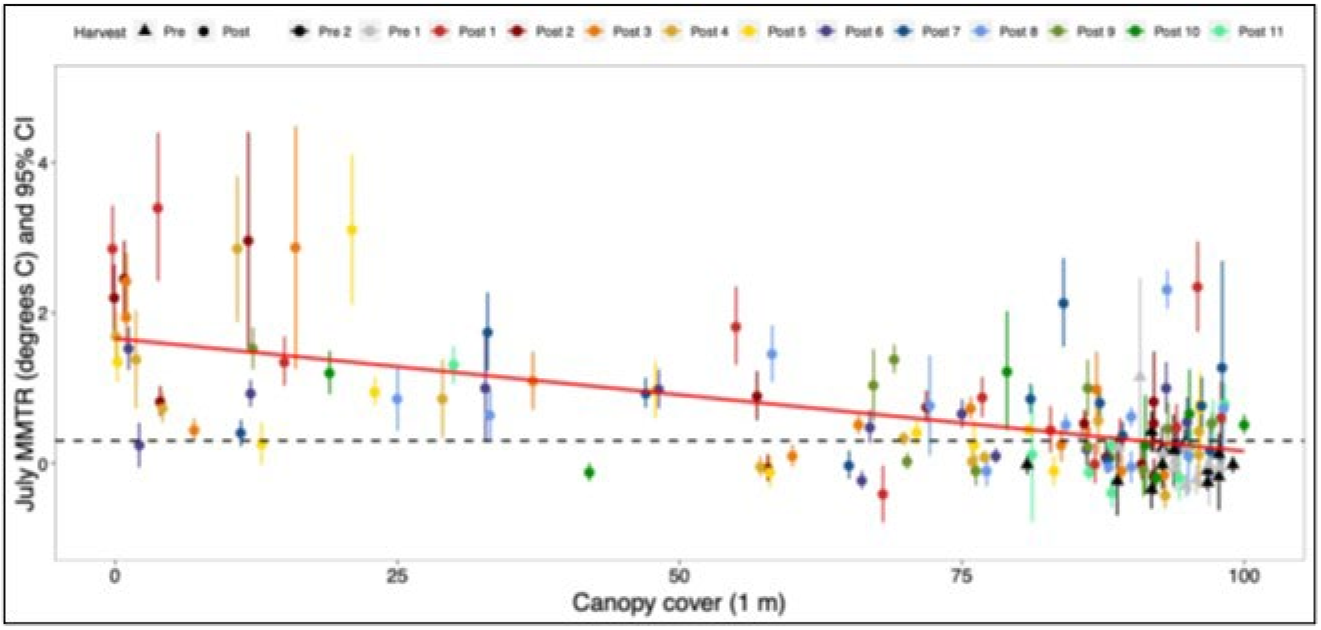
Figure 7: July mean monthly temperature response (MMTR) vs. canopy closure (1 m above stream) for all pre- and post-harvest years in the Hard Rock study, 2006-2017. Values are estimated temperature responses on treatment compared to reference units. Dashed line is at 0.3 ºC.



Instead, a purposeful technical synthesis of available information to predict temperature responses as function of buffer characteristics (e.g., extent and/or length) can provide accurate information about temperature responses to management prescriptions. For example, using a statistical model, with appropriate summaries such as 95% prediction intervals (Groom et al. 2018), to understand how out of sample basins would respond to treatments is more reliable than the Tier II approach of narrative associations about locations that may or may not be similar to the populations from which the Hard Rock and Soft Rock studies were selected. At the very least, an attempt to understand how harvest units included in the Groom et al. (2018) analysis compared to harvest units in the Hard Rock and Soft Rock studies, and whether the prediction curve could be applied with or without adjustments to harvest units in Washington, could provide useful context for decision-making (the Type Np workgroup evaluated this option; Barnowe-Meyer et al. 2021). For example, measured buffer widths from the Hard Rock and Soft Rock studies could be used to predict temperatures for reference and treatment units, and these predictions could be compared to the estimated temperatures calculated from empirical data presented in the Hard Rock and Soft Rock final reports.

Appendix C

The Tier II analysis presented a narrative argument for allocation of sufficient shade on Type Np streams to conserve thermal regimes in the South Fork Nooksack River (p. 100-103). Specifically, the Tier II analysis stated: "Without a new Np buffer rule, there is potential for additional 303(d) listings for Np streams and other waters of the state (RCW 90.48.020) if water temperatures increase above water quality criteria" (p.101). The implicit argument is that increasing buffer extent and width will increase shade and decrease temperatures on Type Np waters (and, consequently, the temperature of water exported to Type F streams). We recognize that shade and stream temperature are related in many systems, and that riparian vegetation can serve to maintain desired thermal profiles in aquatic systems. Riparian buffer designs to mitigate temperature increases evolved in response to evaluations of configuration effectiveness (Steinblums et al. 1984, Beschta et al. 1988, Groom et al. 2011a, 2011b). However, in addition to the oft-noted association between shade and stream temperature, many research efforts document how factors not associated with forest management, including lithology, drainage area, elevation, and annual variation in climatic conditions, influence stream temperature (Boyd and Kasper 2003, Gomi et al. 2006, Reiter et al. 2020; Martin et al. 2021). In fact, the majority of the Tier II analysis attempted to match results from the Hard Rock and Soft Rock studies to other areas of the landscape based on these factors rather than canopy shade specifically.

Finally, recent research evidence suggests strong associations can exist between forest management, stream temperature, and variation in stream discharge (Coble et al. 2020; Moore et al. 2023). For example, increased variation in precipitation regimes can lead to reduced stream discharge, particularly during the summer months in the Pacific Northwest of North America (an area where forecasts suggest summer droughts will increase in severity). Reduced stream volume may make small streams susceptible to warming even in the presence of buffers retained to provide full shading, possibly due to reduction and/or modification of hyporheic exchange (Wondzell 2011). This possibility was ignored by the Tier II analysis. We urge consideration of how buffers, regeneration of upland harvest units, and climatic variation interact to influence stream discharge across the managed forest landscape, and potential consequences for stream temperature in watersheds of interest. A broad array of tools (e.g., Ver Hoef and Peterson 2010; Steel et al. 2016) exist to examine potential consequences for stream temperature, and other responses of interest, resulting from modifications to buffer extent, width, and placement in the watershed.

Attachment C - LITERATURE CITED

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