Type N Experimental Buffer Treatment Study in Soft Rock Lithologies

Answers to Six Questions from the CMER/Policy Interaction Framework Document

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Presented by the:

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<u>Type of Product in Review:</u>
Prospective Answers: ☐ Charter ☐ Scoping Document ☐ Study Design
Retrospective: ☐ Completed Pilot/Study Phase ☒ Completed Final Study Report

Study Report

The results from this study are in the following Study Report:

Ehinger, W.J., W.D. Bretherton, S.M. Estrella, G. Stewart, D.E. Schuett-Hames, and S.A. Nelson. 2021. Effectiveness of Forest Practices Buffer Prescriptions on Perennial Non-fish-bearing Streams on Marine Sedimentary Lithologies in Western Washington. Cooperative Monitoring, Evaluation, and Research Report CMER 2021.08.24, Washington State Forest Practices Adaptive Management Program, Washington Department of Natural Resources, Olympia, WA.

Brief Description

We assessed the effectiveness of current forest practices riparian management zone prescriptions in maintaining riparian functions and processes in non-fish-bearing, perennial (Type Np) headwater streams on incompetent (easily eroded marine sedimentary lithologies) in western Washington (Soft Rock Study). This study is a companion study to the Type N Experimental Buffer Treatment Study in competent (erosion-resistant) lithologies (Hard Rock Study; McIntyre *et al.* 2018). We evaluated the effects of the current Forest Practices rules (WAC 222-30-021(2)) on riparian vegetation and wood recruitment, canopy closure and stream temperature, stream discharge and downstream transport of suspended sediment and nitrogen, and benthic macroinvertebrates. Results will inform the efficacy of current Forest Practices rules in meeting the objectives outlined in the Washington Forest Practices Habitat Conservation Plan (FPHCP; Schedule L-1, Appendix N).

We used a Multiple Before-After Control-Impact (MBACI) study design to compare post-harvest changes in treatment sites to those in reference sites. The two experimental treatments were:

1) Reference (REF): unharvested reference site with no timber harvest activities within the entire study site during the study period, and

2) Forest Practices treatment (TRT): clearcut harvest with a current Forest Practices (FP) riparian leave-tree buffer (i.e., clearcut harvest with a two-sided 50-ft [15.2-m] wide riparian buffer along at least 50% of the riparian management zone, including buffers prescribed for sensitive sites and unstable slopes).

The ten study sites included first-, second-, and third-order non-fish-bearing stream basins (with one treatment site divided into two sub-basins for some of the variables) located in managed forests with marine sedimentary lithologies in the southwest Willapa Hills region. The study design incorporated one or two years of pre-harvest sampling (2012-2014), a harvest period (2013-2015, depending upon the site), and up to three years of post-harvest sampling. A two-sided 30-ft equipment limitation zone applied to the entire stream length in all sites. Because of unstable slopes, total buffer area was 18 to 163% greater than a simple 50-ft buffer along 50% of the stream length. The actual proportion of the stream buffered ranged from 53 to 100%.

CMER/Policy Interaction Framework Six Questions

1. Does the study inform a rule, numeric target, Performance Target, or Resource Objective?

Yes.

2. Does the study inform the Forest Practices Rules, the Forest Practices Board Manual guidelines, or Schedules L-1 or L-2?

Yes.

The study addressed CMER Work Plan Critical Questions derived from Schedule L-1, including:

- Are riparian processes and functions provided by Type N buffers maintained at levels that meet Forest Practices (FP) Habitat Conservation Plan (HCP) Resource Objectives and Performance Targets for shade, stream temperature, and large wood recruitment?

- How do Type N riparian prescriptions affect water quality delivered to downstream Type F/S waters?

    - The Soft Rock Study focused on conditions within the Type Np stream length down to the F/N junction. There was very limited monitoring below the F/N junction.

3. Was the study carried out pursuant to CMER scientific protocols?

Yes. The study design was implemented according to CMER scientific protocols and followed the Independent Scientific Peer Review (ISPR) approved study design. Science Advisory Groups

(SAGs) (RSAG and LWAG), CMER, and ISPR reviewed and approved all chapters of the report. CMER approved the entire ISPR-approved report in August 2021.

4. A. What does the study tell us?

An overarching question for the Adaptive Management Program is "*Will the rules produce forest conditions and processes that achieve resource objectives as measured by the performance targets, while taking into account the natural spatial and temporal variability inherent in forest ecosystems?*" (FPHCP, Appendix N, Schedule L-1). A driver of this specific study was to contrast the effects of the current FP rules (especially shade and stream temperature) in Soft Rock (marine sedimentary) lithologies with those seen in the Hard Rock Study.

We present applicable findings for all evaluated metrics. Where Functional Objectives and Performance Targets were present in Schedule L1 or L2, these are listed. Treatment results presented are relative to the reference (unharvested) treatment, except where otherwise stated.

Riparian Stand Structure and Wood Recruitment

Functional Objective: Develop riparian conditions that provide complex habitats for recruiting large woody debris and litter.

Performance Targets: There are no Performance Targets specific to riparian stand structure or wood recruitment for Type N Waters.

Critical Question: How do survival and growth rates of riparian leave trees change following Type Np buffer treatments?

Results:

- Implementation of complex riparian and unstable slope prescriptions resulted in different post-harvest stand conditions, referred to as buffer types. Four riparian management zone (RMZ) buffer types included: 1) RMZ FP Buffers encompassing the full RMZ width, 2) RMZ <50ft Buffers narrower than the full RMZ width, 3) Unbuffered RMZs harvested to the edge of the channel, and 4) Reference RMZs embedded in unharvested forests. Perennial initiation point (PIP) buffer types included: 1) PIP FP Buffers surrounding the PIPs at treatment sites and 2) PIP References embedded in unharvested forests.

- Post-harvest stand density decreased by 33 and 51% and basal area decreased by 26 and 49% in the RMZ FP Buffers and <50ft Buffers, respectively. In the PIP FP Buffers, density and basal area decreased by 52 and 46%, respectively.

- Post-harvest tree mortality was 31% of stand density and 29% of basal area in the RMZ FP Buffers, and approximately 50% of stand density and basal area in the PIP FP Buffers.

- Wind and physical damage from falling trees accounted for approximately 75% of mortality in the RMZ FP Buffers and 81% of mortality in the PIP FP Buffers, compared to <10% in the reference site RMZs and PIPs.

- The RMZ FP Buffers and <50ft Buffers received inputs of 23 and 10 pieces of large wood per 100 m, respectively, during the post-harvest period. The majority of recruited large wood pieces were stems with attached rootwads. Over 90% of the recruited large wood volume came to rest above the bankfull channel.

- In-channel large wood counts did not change in the reference site RMZs, increased in the RMZ FP Buffers, Unbuffered RMZs, and PIP FP Buffers, and decreased in the RMZ <50ft Buffers and the reference site PIPs through the third post-harvest year. Small wood frequency (including logging debris) was highest in the Unbuffered RMZs in the first post-harvest year but decreased by nearly 50% by the third post-harvest year.

- Wood cover (wood of all sizes over the bankfull channel) remained stable through the third post-harvest year in the reference site RMZs and Unbuffered RMZs, but increased in the RMZ FP Buffers and <50ft Buffers.

Conclusions:

- Patterns of change in stand structure, tree mortality, and wood input in the Unbuffered RMZ, RMZ FP, and PIP FP in the Soft Rock Study are consistent with the findings from the Hard Rock Study (McIntyre *et al.* 2018) and the Westside Type N Buffer Characteristics, Integrity, and Function (BCIF) Study (Schuett-Hames *et al.* 2012; Schuett-Hames and Stewart 2019). Aside from the greater inclusion of unstable slope buffers in streams with marine sedimentary lithologies, we did not observe obvious differences between competent and incompetent lithologies in the effects of buffer treatments on stand structure, tree mortality, wood recruitment, or wood loading. Consistency across all three studies in the direction and magnitude of change in stand structure, tree mortality, and wood recruitment increases confidence in our assessment of the effects of the Type Np prescriptions on stand structure and wood input. In addition to reinforcing the conclusions of the previous studies, the current study substantially broadens the geographic and geomorphic scope of where the results apply.

- Harvest of trees from unbuffered portions of the RMZ FP (≤50% of the Np stream length) returned these areas to the stand-initiation stage of development. Removal of trees reduced near-term wood recruitment potential and is likely to have the greatest effect on the quantity, characteristics, and timing of future wood input compared to buffered RMZs and PIPs. Wood recruitment in unbuffered RMZs will require establishment of a new forest stand, so in-channel wood loading is likely to decrease over time as logging debris decays.

- Differences in post-harvest wood recruitment in RMZ FP and PIP FP buffers were associated with frequency and severity of disturbance (mostly windthrow). The magnitude and frequency of future disturbances and mortality and ingrowth of new trees will have implications for future stand development, wood input, and loading.

- In the absence of severe disturbance (i.e., <5%/year), the unharvested RMZ FP and PIP FP buffers will continue developing as single cohort, conifer-dominated stands, providing stable wood input over time from mortality of individual or small groups of trees. Those subjected to greater disturbance (e.g., high winds), will provide a pulse of wood input from fallen trees but future stand structure and wood recruitment potential will depend on the success of natural regeneration processes.

- Higher tree mortality in many PIP buffers was likely due to their small size and exposed locations that increased vulnerability to windthrow.

- Wood pieces suspended above the stream channel provide shade and cover and are expected to provide in-channel functions as they decay and are recruited to the stream.

- In portions of the Np stream network potentially available for harvest to the stream (where riparian buffers were not required), the requirement to buffer stream-adjacent unstable slopes produced many buffers narrower than the full RMZ width where stream-adjacent unstable slopes were less than 50 ft wide. This was not observed in the Hard Rock or BCIF studies, suggesting it may be more common in incompetent lithologies.

- The combined effect of complex FPHCP prescriptions for western Washington Type Np streams and the spatial variability in post-harvest mortality from wind is creating diversity in riparian forest structure and wood input regimes across the landscape. This mosaic of post-harvest stand structure is a marked change from the more homogenous stand structures produced by clearcut harvest of riparian stands adjacent to headwater streams in the past. As unharvested buffer stands mature, they should provide refugia of mature forest habitat and complex aquatic habitat across the managed forest landscape.

Stream Temperature and Cover

The FPHCP (Chapter 4d) states: "Direct temperature effects in Type Np waters are mitigated through the retention of RMZs and sensitive site buffers. These buffers, which range from 50 feet to 56 feet in width, are expected to provide between 50 percent and 75 percent angular canopy density (ACD) based on data from western Oregon (Brazier and Brown 1973; Steinblums *et al*. 1984). Given that a majority of shade-providing trees will be retained in these areas, temperature increases within buffered reaches are expected to be small."

Functional Objective: Provide cool water by maintaining shade, groundwater temperature, flow, and other watershed processes controlling stream temperature.

Performance Targets:

- Shade – Westside, Type N Waters: shade available within 50 feet for at least 50% of the stream length. This is self-fulfilling for any stream with 50% of its length with a 50-feet width buffer.

- Stream temperature – Water quality standards: current and anticipated in next triennial review[1]. This conflicts with the FPHCP rationale above.

Chapter 4 also addresses the Schedule L-1 priority research directive to "Test the cumulative effect (at Type Np basin scale) of the Westside Type N patch buffers in meeting temperature targets".

Results:

- Mean canopy closure at 1-m decreased in the treatment sites from 97% in the pre-harvest period to 75%, 68%, and 69% in the first, second, and third post-harvest years, respectively (see Table 4-2 and Figure 4-2 in report).

- The calculation of the Δ7DTR involved several complex statistical procedures to account for natural background variability (e.g., warm vs. cool summer temperatures). This is the best estimate of the average change in stream temperature due to harvest.

- The Δ7DTR increased by 0.6°C, 0.6°C, and 0.3°C in the first, second, and third post-harvest years, respectively. Variability among sites is quantified by the 95% confidence interval about the mean response shown in Table 1.

Table 1. Pairwise comparisons of the seven-day average temperature response (7DTR) in each post-harvest year relative to the pre-harvest period. P-values were not adjusted for multiple comparisons. DF = degrees of freedom; C.I. = confidence intervals.

Year	Estimate	P-value	95% C.I.	
Post 1	0.6	0.001	0.29	0.95
Post 2	0.6	0.001	0.25	0.90
Post 3	0.3	0.049	0.00	0.65

- The 7-day average daily maximum (7DADM) values, which do not account for natural variability, showed a similar response after harvest. The highest 7DADM never exceeded 16°C in the REF sites or during the pre-harvest period in the TRT sites (see Figure 1 below). After harvest temperature at one site (the warmest site pre-harvest and with the lowest post-harvest canopy closure) exceeded 16°C for all four years. The post-harvest change in 7DADM ranged from 1.3 to 2.2°C. Interannual variability among sites in the 7DADM is tablulated in Table 4-16 in report.

[1] The Forests and Fish Report was established in 1999 while revisions were being proposed to the state's water quality standards. This performance objective provides direct support for Forests and Fish Report's Overall Performance Goal: "c) Meet or exceed water quality standards (protection of designated uses, narrative and numeric criteria, and antidegradation)."

- Spring and fall temperatures were elevated at most locations in all treatment sites. In sites with nearly all (92 – 100%) of the stream length buffered the greatest temperature increase was in the spring, while the sites with less buffer warmed more in the summer.

- In the two sites where stream temperature was monitored downstream of the F/N break, TRT6 and TRT7, the downstream temperature change ranged from -0.2°C to +0.3°C. Both streams were buffered along 96% or more of their length and experienced less than a 1.0°C change in July mean monthly temperature response at the F/N junction (see Section 4-4.2.4, Table 4-9 and Figures 4-16 and 4-17 in report).

Conclusions:

- The riparian buffer treatment was ineffective at preventing increases in summer stream temperature.

- Mean post-harvest canopy closure was related to the proportion of stream buffered and to post-harvest windthrow within the buffer.

- The immediate post-harvest reductions in canopy closure were consistent with the intensity of buffer treatments (i.e., greater reduction in shade is streams with lower proportion of stream buffered) and were of similar magnitude to the BCIF Study (Schuett-Hames *et al.* 2012), the Type 5 Study (Janisch *et al.* 2012), and the Hard Rock Study (McIntyre *et al.* 2018).

- Changes in temperature were correlated to changes in canopy closure, but hyporheic exchange, discharge, extent of surface water and stream aspect may have been a factor at some locations (See Table 4-11 and Figures 4-6 and 4-7 in report).

- The analysis of variance estimated an increase in the mean annual seven-day average temperature response as low as 0.3°C (see Table 4-16 in report). This was lower than the 0.8°C change detected in the Hard Rock Study and was largely due to the greater number of treatment sites in Soft Rock Study (seven FP sites in SR vs. four in HR). The reader should review Table 4-16 in the final report for a sense of the post-harvest temperature change in individual sites relative to the reference sites.

- There was no evidence of a difference in how stream temperature responded to the loss of canopy closure between the Soft Rock Study and the Hard Rock Study. However, the data indicated that the temperature response at the unbuffered Hard Rock Study sites was greater than at the buffered sites in both studies even when accounting for the proportion of stream and length of stream with surface flow.

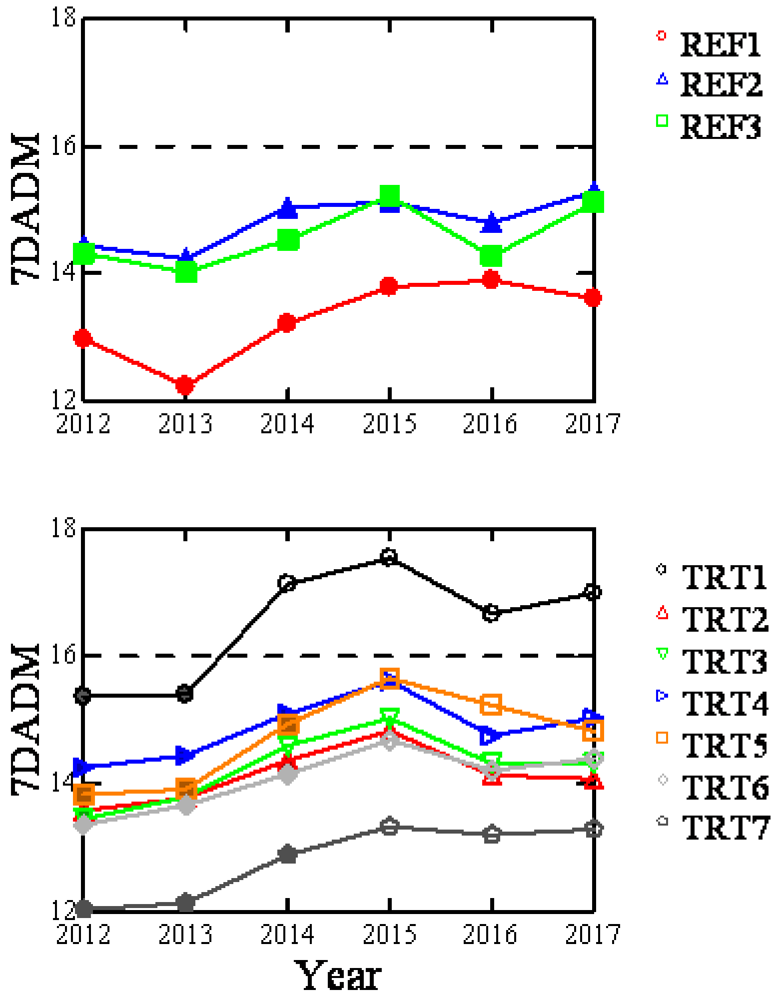

Figure 1. Seven day average maximum daily temperature (7DADM) at the F/N junction plotted over time for each site. Filled symbols are pre-harvest. Open symbols are during or post-harvest. Dashed horizontal line is 16°C.

Discharge and Sediment Export

Functional Objective:

- Hydrology: Maintain surface and groundwater hydrologic regimes (magnitude, frequency, timing, and routing of stream flows) by disconnecting road drainage from the stream network, preventing increases in peak flows causing scour, and maintaining the hydrologic continuity of wetlands.
- Sediment: Provide clean water and substrate and maintain channel-forming processes by minimizing to the maximum extent practical the delivery of management-induced coarse and fine sediment to streams (including timing and quantity) by protecting stream bank

integrity, providing vegetative filtering, protecting unstable slopes, and preventing the routing of sediment to streams.

<u>**Performance Target**</u>:

- <u>Peak flows</u> – Westside: Do not cause a significant increase in peak flow recurrence intervals resulting in scour that disturbs stream channel substrates providing actual or potential habitat for salmonids, attributable to forest management activities.

Results:

- Both the treatment and reference sites exported more sediment in the post-harvest period, probably due to greater precipitation in the post-harvest period.

- We saw no erosion events during the pre-harvest period but there was evidence of sediment entering the stream in TRT3 and TRT4 during the post-harvest period (5 to 20 m^3 annually). The sediment entering the treatment sites appeared to be from root pits created by fallen trees adjacent to the stream. REF1 had no location specific stream adjacent erosion events during the study, but we did see strong evidence of mass wasting in REF2. Our sediment delivery estimates indicate that the amount of sediment that entered REF2 from a series of mass wasting events was significantly greater than sediment delivery from windthrow in the treatment sites.

- The site with the greatest post-harvest period suspended sediment export was an unharvested reference site that happened to have streamside mass wasting upstream of the monitoring station.

- Windthrow-driven sediment delivery was observed in the two treatment sites, but the magnitude of that sediment delivery was estimated to be much less than the amount of sediment delivered by the single mass-wasting feature in the reference site.

- The marine sedimentary lithologies sampled in the Soft Rock Study were more erodible than the competent lithologies sampled in the Hard Rock Study.

Conclusions:

- The relative lack of rain in the pre-treatment period, the shorter than expected pre-treatment calibration periods, and differences in precipitation between sites made it impossible to draw any solid conclusions about the rule effectiveness with respect to discharge or suspended sediment export using the data collected.

<u>***Nutrient Export***</u>

There are no Resource Objectives, Critical Questions, or Performance Targets that address nutrient export specifically. We assessed the quantity of instream nitrogen exported from Type N Waters for two reasons: 1) nutrient concentrations may affect instream productivity at the site level, thereby influencing the biotic response to harvest; and 2) excess nutrient loads can encourage increased accumulations of algal biomass, which may depress dissolved oxygen concentrations in coastal receiving waters.

Results:

- Mean total nitrogen (N) concentration increased by 9 to 188% in the TRT sites compared to a -25 to 8% change in the REF sites after harvest (see Table 6-3 in report).

- Mean nitrate-N concentration increased by 2 to 200% after harvest, compared to a -29 to 9% change in the REF sites.

- Mean total-N export increased 218 to 436% after harvest at the TRT sites compared to a 124% to 214% increase in the REF sites (see Table 6-6 in report).

- Mean nitrate-N export increased 169 to 445% after harvest at the treatment sites compared to a 129% to 224% increase in the REF sites.

Conclusions:

- Nitrogen concentration and export were well within the range measured in other studies in the Pacific Northwest.

- The unusually dry pre-harvest period and the shorter than expected pre-treatment period made it difficult to attribute post-harvest changes in N export solely to the harvest.

- The change in total-N and nitrate-N concentration was likely a result of reduced nitrogen uptake. The estimated change in export was related to the proportion of the stream buffered (less buffered = greater increase in export) and to the unusually dry weather and low stream discharge in the pre-harvest period.

Benthic Macroinvertebrates

There are no Resource Objectives, Critical Questions, or Performance Targets that address macroinvertebrates specifically, but we assessed the response of benthic macroinvertebrates in Type N Waters to evaluate the effect of harvest on food resources for stream-associated amphibians and downstream fish. Timber harvest may influence benthic macroinvertebrate communities through changes in organic matter inputs and primary production, as well as changes in shade, temperature, discharge, sediment, and wood inputs.

Results:

- We found no major changes in benthic macroinvertebrate assemblages in our study sites after harvest.

- Ephemeroptera-Plecoptera-Trichoptera (EPT) richness and the Shannon H’ diversity index decreased in all sites; both reference and treatment sites over the same period of time.

- The response of the other metrics, including total richness, EPT percent, the fine sediment biotic index (FSBI), functional feeding groups, and major macroinvertebrate orders did not change.

Conclusions:

- Overall, there were no major reductions in the benthic macroinvertebrate metrics (total richness, EPT richness, EPT percent, the Shannon H' diversity index, or the FSBI) or shifts in the functional feeding groups or orders associated with the riparian buffer treatment.

- The lack of response in the macroinvertebrate assemblages may reflect the extensive buffers, increase in wood cover, and vegetation regrowth that provided enough shade to inhibit primary production and instream structure to retain particulate organic matter.

4. B. What does the study not tell us?

This study did not thoroughly evaluate the effects of harvest on downstream (i.e., in Type F streams) water temperature. Only the two locations mentioned above and detailed in Section 4-4.2.4 and Table 4-9 in report were monitored in the study.

In general, when applying these results, or those from any study, one should consider the pre-harvest physical setting (e.g., amphibian populations, stream temperature, riparian shade, lithology, aspect), applied harvest prescription(s) (timing, buffer locations, dimensions, density), and time elapsed since harvest.

The study was designed as an experimental study to complement the Hard Rock Study. Experimental studies select sites similar to one another so the observed effects (e.g., stream temperature) are more likely to be due to the treatment (e.g., harvest) rather than to inherent differences among the sites. This increased the statistical power of the study by reducing variability in response, but resulted in only a segment of the population (Type Np streams underlain by marine sedimentary lithologies) being studied.

The range of experimental treatments may also limit the scope of inference if these differ from forest practices in use by landowners. Our experimental treatment included a clearcut harvest, a two-sided 50-ft (15-m) wide no-harvest riparian buffer along at least 50% of the Type Np stream length, and additional buffers for sensitive sites and unstable slopes. The extent of unstable slopes in the Soft Rock Study sites often resulted in buffers that were wider than the 50-ft minimum buffers otherwise prescribed for Type Np streams or, in some cases, narrow (<50-ft) (unstable slope) buffers were left on stream reaches that otherwise would not have been buffered. As described in the study report, variability in the application of the Type Np rules does affect the post-harvest response of riparian canopy closure and stream temperature.

Spatial Scope of Inference: As a result of the site selection process and the harvest treatment applied in the study the spatial scope of inference is most applicable to perennial, non-fish-bearing stream basins with marine sedimentary lithologies meeting the site selection criteria used in the study. The transferability of the study findings to other Type N basins must be done carefully because the physical characteristics, management history, and harvest intensity among

Type N basins, across the landscape, are highly variable. Therefore, extrapolating the study across the landscape requires knowledge of the physical and environmental variability among headwater basins to provide a spatial context for inference.

Temporal Scope of Inference: The temporal scope of inference is limited to the three-year post-harvest period. The results may not be applicable over a longer period as riparian processes (e.g., stand development, windthrow, sediment and organic matter inputs, etc.) are likely to change over time.

5. What is the relationship between this study and any others that may be planned, underway, or recently completed?

The Soft Rock Study, Hard Rock Study (McIntyre *et al.* 2018; McIntyre *et al.* in review), BCIF Study (Schuett-Hames *et al.* 2012; Schuett-Hames and Stewart 2019), and Buffer Integrity-Shade Effectiveness Study (underway) are expected to provide an assessment of riparian prescription effectiveness for western Washington Type N Waters.

- ***Feasibility of obtaining more information to better inform Policy about resource effects.***

Reference sites have been or will be harvested in the near future making them unsuitable for use as reference sites going forward.

- ***What are the costs associated with additional studies?***

Analysis and report of temperature data collected through six years post-harvest are underway. There are no plans for additional study beyond the five years post-harvest.

- ***What will additional studies help us learn?***

Results through five years post-harvest will provide additional information for understanding the effectiveness of the current Forest Practices.

- ***When will these additional studies be completed (i.e., when will we learn the information)?***

June 2022

- ***Will additional information from these other studies reduce uncertainty?***

Data collected through summer 2020 will reduce uncertainty associated with trajectories of stream temperature and canopy closure at six years post-harvest.

6. **What is the scientific basis that underlies the rule, numeric target, Performance Target, or Resource Objective that the study informs? How much of an incremental gain in understanding do the study results represent?**

<u>*What is the scientific basis that underlies the rule, numeric target, Performance Target or Resource Objective that the study informs?*</u>

RMZ requirements for Type N Waters were developed to maintain important ecological processes and provide levels of large wood, shade, and other riparian functions adequate to meet conservations objectives (FPHCP, Chapter 4d – Rationale for the Plan). The management approach for westside Type N riparian prescriptions employs a patch-cut strategy, where a portion of the riparian stand in a Type N basin RMZ may be clearcut, providing that sensitive sites and at least 50% of the perennial stream length is buffered with a two-sided 50-ft buffer. The underlying assumptions of the current rule prescriptions for Type N Waters were based on limited experimental research studies related to riparian ecological processes, habitat needs of covered species, and forest management effects on larger streams (FPHCP). The following information is based on that found in Chapter 4d of the FPHCP. For discussions that include relevant literature published between the finalization of the FPHCP in 2005 and now, see the chapters for the individual response metrics in the study report.

<u>Large Wood</u>: Wood is a key element in the creation and maintenance of instream and riparian habitat, trapping and storing sediment and organic material, stabilizing streambeds and banks, dissipating stream energy, forming pool habitat, providing cover, and serving as a food source for aquatic insects (Bisson 1987). The recruitment and retention of wood was a primary consideration for development of the leave tree requirements for RMZs. Forest Practices rules are intended to provide sufficient large wood recruitment to create, restore, and maintain riparian and aquatic habitat for species covered under the plan. Rule buffer width for Type N Waters was largely determined by a study conducted by McDade and colleagues (1990), who found that 70% of instream wood from mature conifer forests had a source distance of 50 ft or less. The conclusion based on this finding was that between 35% and 70% of the potential large wood supply within each Type N network would be retained in streamside buffers where the Type N rules had been applied.

<u>Shade</u>: Riparian forests and the shade they provide are key factors affecting the thermal regime of aquatic ecosystems (Brown 1985), reducing incoming solar radiation and moderating water temperatures. Reductions in streamside shade may alter the thermal regime of a stream (Beschta *et al.* 1987). Based on these findings from two studies (Brazier and Brown 1973; Steinblums *et al.* 1984), it was anticipated that riparian buffers retained on Type N Waters under Forest Practices rules would maintain between 50% and 75% of the pre-harvest Angular Canopy Density (ACD). It was anticipated that shade reduction along small clearcut streams in western Washington would recover within five years, due to the rapid growth of understory vegetation (Summers 1982; Caldwell *et al.* 1991).

<u>Stream Temperature</u>: The FPHCP concluded that there was a reduced risk of temperature impacts to Type N Waters compared with Type S and Type F waters and that temperature increases within buffered reaches of the RMZ would be small. Further, based on the findings from three studies (Caldwell *et al.* 1991; Dent and Walsh 1997; Robison *et al.* 1999), downstream temperature effects that might negatively affect aquatic resources in Type S and F Waters were expected to be minimal. Based on the findings of one study (Summers 1982), if temperature increases associated with timber harvest did occur in Type N Waters, recovery to pre-harvest levels was expected to be rapid. Caldwell and colleagues (1991) concluded that shade reduction along small clearcut streams in western Washington would recover within five years.

Suspended Sediment: Protection measures in the FPHCP minimize the risk of accelerated surface erosion and modified hydrology by minimizing harvest-based disturbances (e.g., log yarding activities and other equipment use) in and around typed waters. Along Type N Waters, direct physical disturbance is minimized in RMZs with a combination of a two-sided 50-ft riparian buffer and a two-sided 30-ft equipment limitation zone (ELZ) throughout the Unbuffered RMZ. The ELZ requirement was based on a combination of study results, including those of Kreutzweiser and Capell (2001) who found that measurable increases in fine sediment levels in streams adjacent to clearcut harvesting were minimal when there was careful use of equipment in streamside areas. Another study concluded that riparian buffers of 10 m alleviated chronic sediment delivery to streams from harvest-related erosion (Rashin *et al.* 1999).

Peak Flow: At the time of rule development, conclusions from research into the effects of forest practices on peak flows in the Pacific Northwest were variable. Some studies documented increased peak flows following timber harvest (Ziemer 1981; Hetherington 1987). Others found decreased peak flows (Cheng *et al.* 1975) or no change (Wright *et al.* 1990). The physical characteristics of a watershed, including topography, soils, geology, and vegetation, all influence water routing, resulting in the conclusion that the response of peak flows to timber harvest would be watershed-specific. Forest Practices rules address timber harvest effects on peak flows through the rain-on-snow and green-up rules, the latter of which minimizes the effect of harvest by limiting the size and timing of clearcut timber harvest across the state.

How much of an incremental gain in understanding do the study results represent?

This study expanded on our understanding of the degree to which Type Np Forest Practices rules meet the Resource Objectives and Performance Targets outlined in Schedule L-1 of the FPHCP (Appendix N). While previous studies may have evaluated many of the metrics we included in this study as they relate to forestry practices, the Soft Rock Study provides results in context of the specific Forest Practices rules for riparian prescriptions required on Type N Waters in marine sedimentary lithologies in western Washington.

We also expanded on the knowledge gained from other CMER studies, for example by supplementing the findings from the Hard Rock Study and the BCIF Study by increasing the sample of riparian vegetation and wood recruitment from clearcut, 50-ft buffer, and PIP buffer RMZ reaches. Recent CMER studies, including this one, are among a few that address the prevalence, characteristics and short-term function of small wood in headwater streams.

In relation to specific assumptions regarding FP treatment response specified in the 2005 FPHCP and listed above, we found the following:

Large Wood: The FPHCP rationale for large woody debris recruitment in Type Np Waters was based on existing information on source distances for wood recruitment (McDade *et al.* 1990), which indicates that approximately 70% of large wood from old-growth forests came from within 50 ft of the stream. Since between 50 and 100% of the Np stream length is buffered under FP rules for Type N Waters, it was estimated that the prescription would provide between 35 and 70% of potential large wood recruitment. We did not attempt to validate the source distance curves since that was not an objective of this project, however, we did provide estimates of large wood recruitment pieces and volume in reaches with RMZ and PIP buffers. A separate study with an appropriate design will be necessary to validate the source distance curves for Np streams in western Washington forests.

Shade: Canopy closure was measured more thoroughly in time and space than most published studies, resulting in better estimates of recovery after harvest.

Stream Temperature: The study produced accurate estimates of seasonal post-harvest temperature change as well as changes in the seven-day average daily maximum temperature.

Technical Implications and Recommendations:

Research/monitoring suggestions.

- Buffered versus unbuffered Np reach-scale effectiveness: An evaluation of within-stream variability and characteristics between buffered and unbuffered reaches and between wood-obstructed and unobstructed reaches may prove informative for understanding the effects of alternative riparian buffer prescriptions. Even with forest practices rules intended to minimize slash input into streams, we still observed heavy slash loading in some stream reaches. Current and future evaluations could assess persistence of these wood-obstructed reaches through time and investigate overall stream coverage through time. Additional metrics could include differences in the structure and characteristics of different reach types, such as wood loading and function, water temperature, and hydrology.

Suggested rules/board manual sections to review/revise.

- We agree with the suggestion in the Hard Rock Study (McIntyre *et al.* 2018) and BCIF Study Findings Report (Schuett-Hames *et al.* 2012) that CMER and Policy should review and potentially revise some of the Type Np Performance Targets for westside and eastside Type N Waters, both in context of the study results and other current scientific research. Such a review would be appropriate once the studies outlined under #5 are completed. They could propose changes to Performance Targets and/or new measures if appropriate. This recommendation is consistent with commitments already made by CMER and Policy in response to the Stillwater Sciences Independent Review of the “CMER adaptive management program review of science” (Stillwater Sciences 2009; CMER 2012). We recommend the following considerations:
    - Performance Targets for some metrics were tied to the objective of providing 50% of the riparian function available within 50 feet of the stream, and are more closely related to compliance targets than Performance Targets *per se*. For example, shade and litterfall Performance Targets merely restate the prescriptions, so if the harvest is done in compliance with the rules, the Performance Target will be met, at least immediately following harvest.
    - Schedule L-1 specifies that there will be idenfication of timelines for Performance Targets that can be met within short, mid- and long-term time periods, a process that has not yet occurred, but that is likely very important for evaluating the effectiveness of rules through time.

- Clarification is needed on whether some Performance Targets apply to Type N Waters. For example, it is unclear if the the Performance Target for In-stream LWD applies to Type N Waters.

Evaluation of whether key aquatic Resource Objectives (Schedule L-1) are being met.

We discuss key aquatic Resource Objectives for all metrics in our responses to questions 4 (*"What does the study tell us?"*) and 6 (*"How much of an incremental gain in understanding to the study results represent?"*).

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