

**SAGE Literature Review:
Effects of Salvage Logging on Riparian Zones in Coniferous Forests of Eastern
Washington and Adjacent Regions**

Findings Report

1. **Does the study inform a rule, numeric target, performance target, or resource objective (Yes/No)? If Yes, go to the next question.** If No, provide a short explanation on the purpose of the study.) Yes.
2. **Does the study inform the Forest Practices Rules, the Forest Practices Board Manual guidelines, or Schedules L-1 or L-2?**

This literature review does not directly:

- inform Forest Practices Rules, but may help ID Teams moved forward with Alternate plans for timber harvest;
- address any targets or research proposed in Schedules L-1 and L-2; or
- answer any critical questions listed in the CMER Work Plan.

The author reviewed 75 relatively recent publications that provide information about potential effects of salvage logging on riparian areas for eastside forests and comparable forests elsewhere in the Pacific Northwest.

A major finding from the review is that the literature provides relatively little specific information about the effects of salvage logging in riparian areas.

The literature contains a wide range of information about the possible effects of salvage logging on adjacent upland forests, which can be useful for developing riparian management strategies. Examples of recent salvage-related research include studies investigating possible effects on soils (e.g., erosion, compaction, hydrophobicity), and studies documenting the effects of various management practices such as differing harvesting methods and equipment, erosion mitigation practices, and varying silvicultural prescriptions.

A considerable amount of literature also describes research on post-salvage regeneration, and on fuels management practices. Conversely, less information exists about potential effects of salvage logging on riparian ecosystem structure and function, such as stream temperature regimes, water quality issues, aquatic biota, and the effectiveness of forest buffer retention zones.

3. **Was the study carried out pursuant to CMER scientific protocols (i.e., study design, peer review)? (Provide short explanation. Be clear on use of ISPR.)**

Yes. This project report was reviewed and approved by SAGE and CMER consistent with the Protocol and Standards Manual. There was no Independent Scientific Peer Review (ISPR) since literature reviews are most often used by CMER to inform larger experimental studies that later go through ISPR.

4. **What does the study tell us? What does the study not tell us?** (This is where the study and its relationship to rules, guidance, targets, etc are to be described in detail. Consider technical findings; study limitations; and implications to rules, guidance, resource objectives, functional objectives, and performance targets; in addition to other information.)

What the study DOES tell us: Below are some general observations, largely from the *Executive Summary* section of the Synthesis Report:

- A major finding from the review is the literature provides relatively little specific information about the effects of salvage logging in riparian areas. This lack of data applies not only to Washington eastside forests, but for riparian forests elsewhere in the western U.S.
- The literature contains a wide range of information about the possible effects of salvage logging on adjacent upland forests, which may be useful for developing potential riparian management strategies.
- There are examples of recent salvage-related research including studies investigating possible effects on soils (e.g., erosion, compaction, hydrophobicity), and studies documenting the effects of various management practices such as differing harvesting methods and equipment, erosion mitigation practices, and varying silvicultural prescriptions. A considerable amount of literature also describes research on post-salvage regeneration, and on fuels management practices.
- Less information exists about potential effects of salvage logging on riparian ecosystem structure and function, such as stream temperature regimes, water quality issues, aquatic biota, and the effectiveness of forest buffer retention zones. Topics such as salvage effects on soil processes (e.g., nutrient cycling, soil biota), riparian wildlife habitat, riparian restoration, and modern-day riparian fire regimes are also less well represented in the literature.
- More specific information from the Literature Synthesis includes, but is not limited to:
 - The results of this study as outlined in the Synthesis report, suggest that maintenance of riparian function can be expected after fire in other fire-prone regions. The resilience of these riparian plant communities suggests that, unless there is extensive pre-fire degradation of riparian forests, little post-fire riparian rehabilitation is necessary to ensure the continued functioning of riparian forests after fire (Halofsky and Hibbs 2009: 1357-1358).
 - Some researchers (Donato et al. 2006) have suggested that post-fire salvage logging might increase short-term reburn risk due to the intermingling of logging slash with developing tree- and shrub layers. However, Campbell et al.'s (2016) re-sampling of a previous study location (Donato et al. 2013) 10 years after salvaging found that both logged- and unlogged young stands would have high reburn potential for at least several decades after the initial stand replacement fire.
 - The synthesis report states that Wagenbrenner et al. (2016) found that ground-based logging compacted soil, reduced soil water repellency, and promoted elevated erosion rates when compared to unlogged control sites. Vegetation recovery rates were also slower in most salvaged sites, but this does not give a complete picture of the publication.

- Several studies examined the effects of seeding for erosion control after salvaging. Although managers have routinely used seeding practices and often assume them to be effective (Peppin et al. 2014), most researchers agree that seeding has only limited ability to reduce erosion (Beyers 2004; Robichaud et al. 2006; Peterson et al. 2009b; Peppin et al. 2011; Peppin et al. 2014). In addition, this relatively expensive practice is often detrimental in terms of native species displacement when non-native species are used.
 - Several publications (Berg et al. 2002; Moore and Wondzell 2005; Reeves et al. 2006) describe fire's role in contributing to the episodic recruitment of downed wood important for habitat maintenance and in-stream channelization and other hydrological processes. Populations and communities of aquatic species can be directly impacted by fires and salvage logging, by altering such processes as tree canopy influences on stream temperature. Fish, and especially salmonids, are of particular concern. For instance, Isaak et al. (2010) documented largely negative impacts from climate change and wildfires on stream temperatures and trout habitat in central Idaho.
 - Thompson et al. (2007) documented fuel dynamics in managed versus unmanaged Douglas-fir stands in the Biscuit Fire area of southwestern Oregon. The study area had been severely burned by a 1987 wildfire, and had reburned during the 2002 Biscuit Fire. The researchers found that upland areas that had been salvage-logged and planted after 1987 had reburned more severely during 2002 when compared to comparable unmanaged (i.e., unlogged or planted) areas. The results suggested that fuel conditions in conifer plantations can increase potential fire severity despite the removal of large woody material, because tree planting can promote a dense and/or continuous layer of fine-to-coarse fuels.
 - The synthesis report by Karr et al 2004 made 10 recommendations that feasibly could help mitigate impacts from salvage logging and that could help improve watershed conditions: 1) allow natural recovery to occur on its own, or intervene only in ways that promote natural recovery, 2) retain large old trees (live or dead), 3) protect soils, especially those that are shallow, severely burned, erosion prone and otherwise fragile, 4) protect ecologically sensitive areas including riparian and roadless areas, steep slopes, and watersheds with sensitive or imperiled aquatic species, 5) avoid creating new road and landings in burned landscapes, 6) limit reseeded and replanting (to foster the recovery of native vegetation), 7) do not place structures such as sediment traps, riprap, and check dams, or artificially-installed large wood in streams, 8) protect and restore watersheds before fire occurs, 9) continue research, monitoring, and assessment, 10) educate the public about riparian functioning and intrinsic value.
- Other results support an earlier contention that research on salvage logging and other post-fire studies provides largely *inferential* information that can be useful for RMZ management planning.

What the study does NOT tell us: Below are some general observations, as extracted from the *Research Gaps* section of the Synthesis Report:

- The most conspicuous research gap to date centers on the fact that virtually no salvage-related research has occurred in riparian areas *per se* (Reeves et al. 2006; Peterson et al. 2009a). The lack of studies stems from at least two major factors: 1) most wildfire and post-

fire salvage research occurs on federal lands, and 2) most federally-managed riparian areas are subject to “hands-off” protection policies where salvage logging is largely prohibited.

- Regarding fire’s ecological role in riparian areas, Dwire and Kauffman (2003) state that, “*Given the critical resource values of riparian zones. . . improved understanding of fire ecology and effects in riparian areas is needed to prescribe ecologically sound rehabilitation projects following fire.*” (Dwire and Kauffman 2003: 61). Similarly, Moore and Richardson (2012) stated that more research is needed to help document the effects of various disturbances on riparian zones, and such data would help provide a scientific basis for riparian-sensitive management plans.
- On a related vein, Reeves et al. (2006) stated that studies were needed to determine if salvage logging could help restore riparian forests and make them more resilient to uncharacteristic wildfires in dry forest types. The authors concluded that, without such data, protecting post-fire riparian zones may be the most advisable policy and that “*Without a commitment to monitor management experiments, the effects of post-fire riparian logging will remain unknown and highly contentious.*”.
- The SAGE team recently posed the following question about post-salvage reforestation: *Are there biogeographic areas that require or do not require replanting after salvage harvest?* The literature provided only general guidance on this issue. For example, low-elevation ponderosa pine stands on xeric sites may often require planting, whereas natural regeneration might be relatively abundant on mid-to-upper elevation mesic sites. Note, however, that scant research exists for other forest types.
- Similarly, Keyser et al. (2009) stated that more research is needed to address the difficult challenge of regenerating xeric ponderosa pine stands after severe fires and/or after salvage logging. The authors also stated that, “the effects of salvage logging may be dependent on when and how salvage logging is conducted as well as forest type rather than an invariant set of effects inherent to salvage logging.”.
- The literature could not provide specific information to help answer the following SAGE reforestation question: *To what extent does excessive dead standing and/or down wood post-fire affect the reforestation of the upland forest stand and the riparian area? OR To what extent do standing dead or down trees help promote the establishment of new seedlings post-fire whether planted or naturally re-seeded)? OR Are there any differences in bank stability benefits provided by standing trees vs. stumps?*
- The literature was unable to provide enough specifics to help answer the following SAGE question about salvage methods: “*Are there significant differences between harvest methods in burned areas that potentially pose a greater risk to aquatic resources?*” In addition to the fact that salvage logging has not occurred in most riparian areas, uplands research typically did not conduct experiments to compare impacts from various logging methods.
- On a related vein, a question was raised regarding soil impacts from specific types of logging equipment, “*What are potential impacts from hydraulic shovel yarding relative to soil erosion/compaction . . . did they look at hydraulic shovel yarding where the logs are lifted not dragged?*” However, we found no literature on that topic.

- Some researchers have raised questions about the potential effectiveness of retaining forested buffer zones as a means of protecting riparian resources. For example, Moore et al. (2005) stated that, because substantial warming of stream temperatures has been observed within both unthinned and thinned buffers, more research was needed to document the range of factors that can influence stream temperatures. Moore and Richardson's (2012) general overview of North American riparian forests likewise states that maintaining undisturbed forested buffers does not necessarily provide effective protection. However, other authors (Reeves et al. 2006; Peterson et al. 2009a) have recommended including buffer zones as a standard element of silvicultural prescriptions, at least until research can more thoroughly evaluate the practice.
- Regarding salvage harvest buffer zone design, most publications lack specifics for eastside forests. The sole exception to date has been Mellon et al.'s (2008) study evaluating salvage effects on stream macro-invertebrates in northeastern Washington. Their results were generally supportive of the project's 45-meter-wide buffers (i.e., standard INFISH guidelines). Otherwise we did not find any information about recommended buffer widths, lengths, or other design elements.
- Several authors (Macdonald et al. 2003; Reeves et al. 2006; Wagner et al. 2014) called for more research on potential effects of salvage logging on stream temperatures and aquatic biota.
- Regarding soils, Wondzell and King's (2003) review of research on post-fire erosion processes in western U.S. forests stated that substantial knowledge gaps existed, in part, because studies tended to focus on the most-severe disturbance events. Consequently, the effects of lower severity wildfires and careful salvage logging remained poorly understood.
- Also in relation to soils, Jennings et al.'s (2012) study concluded that salvage effects may be more pronounced for soil nutrient processes than for soil microbial communities (at least on sandy volcanic soils). The authors stated that effects could be long-lasting because such ecosystems are already nutrient limited. That paper concluded that more soils research was needed, and that impacts from post-fire salvage logging need to be weighed against other values such as fire hazard reduction and commercial harvesting of trees.
- Regarding post-salvage seeding for erosion mitigation, Peppin et al. (2014) concluded that, 1) more research, 2) more long-term monitoring, and 3) better communication and collaboration between managers and scientists would likely help managers make better-informed decisions about such practices.

5. What is the relationship between this study and any others that may be planned, underway, or recently completed? Factors to consider in answering this question include, but are not limited to:

- a. Feasibility of obtaining more information to better inform Policy about resource effects.
- b. Are other relevant studies planned, underway, or recently completed? (If yes, what are they?) Yes, SAGE has discussed additional studies that would naturally follow the results of the literature review. Some examples would include:
 - What percentage of RMZ's were effected by fire compared to the adjacent upland forest?

- Is there a significant difference in percent shade Post-fire vs unburned areas and what (if any) variables including upland forest influence this difference?
- Do burned uplands exhibit different post-harvest compaction and/or sediment delivery issues if harvested outside of frozen conditions?
- What percentage of live crown (bark char) is needed for a tree to recover after being effected by fire? Does it differ by species? Are current guidelines adequate for RMZ's in eastern WA?
- Does fire on steep slopes, increase the risk of slope stability failures?

No further scoping has been completed on any of the questions listed in this section. These questions will be grouped and prioritized at a later date.

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?

The purpose of this literature review was to respond to concerns from IDT/SAGE members about how to best manage post fire salvage logging under Alternate Plans in and adjacent to RMZs.” The results of this literature review demonstrate that while there has been some increased understanding of soil compaction and erosion processes post-fire, and some increased understanding of the need for active reforestation where fire intensity was high, the existing literature is not sufficient to answer the key questions which were posed in this review. As a focused literature review, this project does not provide new effectiveness, validation or extensive monitoring research. This literature review and synthesis project was initiated, in part, because forest managers wanted to understand how to best manage post-fire salvage logging in and adjacent to RMZs.

In general, the results from this literature review support Peterson et al.’s (2009a) caveat that, “Few data exist on the effects of post-fire logging on aquatic ecosystems, although effects can be inferred from the literature on riparian fire, fire effects, and logging effects.” (Peterson et al. 2009a: 22). However, new science has emerged since 2009 that furthers our understanding of the potential effects of salvage logging in RMZs.

**Pasted below is the Executive Summary from the literature review Synthesis Report:*

Executive Summary

This Synthesis Report represents the contract final report for Washington State Department of Natural Resources [DNR] contract number PSC 93-095317, titled *Literature Review and Synthesis Related to Salvage of Fire Damaged Timber*. For this literature review project, contemporary research information was requested by the Eastside Scientific Advisory Group (SAGE) to help support the work of the Cooperative Monitoring, Evaluation, and Research (CMER) committee of the DNR Forest Practices Board.

This report provides an overview of the goals, objectives, methods, and results of the project. We reviewed 75 relatively recent publications that provide information about potential effects of salvage logging on riparian areas for eastside forests and comparable forests elsewhere in the Pacific Northwest. A major finding from the review is that the literature provides relatively little specific information about the effects of salvage logging in riparian areas. This lack of data applies not only to Washington's eastside forests, but for riparian forests elsewhere in the western U.S. The lack of riparian-specific research is likely related to the fact that most modern-day fires have occurred on federal lands, where salvage logging and salvage-related research have been largely absent. Otherwise, the literature contains a wide range of information about the possible effects of salvage logging on adjacent upland forests, which can be useful for developing riparian management strategies. Examples of recent salvage-related research include studies investigating possible effects on soils (e.g., erosion, compaction, hydrophobicity), and studies documenting the effects of various management practices such as differing harvesting methods and equipment, erosion mitigation practices, and varying silvicultural prescriptions. A considerable amount of literature also describes research on post-salvage regeneration issues, and on fuels management practices. Conversely, less information exists about potential effects of salvage logging on riparian ecosystem structure and function, such as stream temperature regimes, water quality issues, aquatic biota, and the effectiveness of forest buffer retention zones. Topics such as salvage effects on soil processes (e.g., nutrient cycling, soil biota), riparian wildlife habitat, riparian restoration, and modern-day riparian fire regimes are also less well represented in the literature. Therefore, after describing the state of relatively recent research on salvage logging in relation to riparian areas, this report concludes by listing some current research gaps that have been identified by various study authors and other professionals.

In addition to this Synthesis Report, the literature review project produced the following products: 1) a companion document called the Summary Reports Compendium, which is a repository of short summary reports for each piece of literature in the project database, 2) an *Excel* database housing key data elements for the literature (e.g., authors, publication years, summaries), 3) a User Guide that explains how to efficiently locate and summarize information in the *Excel* database, and 4) a literature collection composed of downloadable digital copies (pdf files) of each piece of literature reviewed during the project. Please note that all of the above products have been stored at <https://app.box.com/folder/21660988802> and can also be obtained by contacting Angela C. Johnson (Project Manager, Adaptive Management Program; Angela.Johnson@dnr.wa.gov).