DECLARATION OF CHRISTOPHER A. FRISSELL, Ph. D. IN SUPPORT OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S AND THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION'S PROPOSAL TO DISAPPROVE THE STATE OF OREGON'S COASTAL NONPOINT POLLUTION CONTROL PROGRAM FOR FAILING TO ADOPT ADDITIONAL MANAGEMENT MEASURES FOR FORESTRY.

I, Christopher A. Frissell, Ph.D., hereby declare and state as follows:

1. My current address is 39625 Highland Drive, Polson, Montana. I have been retained by the Washington Forest Law Center and Northwest Environmental Advocates to provide my expert opinion on the forestry aspects of the U.S. Environmental Protection Agency's and the National Oceanic and Atmospheric Administration's December 20, 2013, proposal to find that the State of Oregon (State) has failed to submit an approvable Coastal Nonpoint Pollution Control Program (Coastal Nonpoint Program) as required by the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), 16 U.S.C. 1455b.

2. I am an aquatic ecologist and watershed scientist with expertise in land management and conservation strategies for fishes and amphibians. I also serve as Affiliate Research Professor at Flathead Lake Biological Station, the University of Montana. My expertise is outlined in my CV, which is appended to this declaration.

3. My education is as follows. I hold a Bachelors degree in Zoology from the University of Montana, and Masters and PhD degrees in Fisheries Science from Oregon State University, where the focus of my graduate research was the cumulative effect of land use and watershed disturbance on freshwater ecosystems and fish populations.

4. I have 30 years of experience as a research scientist in the field of aquatic

ecology, fishery and conservation biology, and watershed science, having held research faculty positions at The University of Montana and Oregon State University. I have more than 40 scientific and technical publications in aquatic ecology, fishery and conservation biology, and watershed science, in professional journals, symposia, and books, and book chapters, and also am author of more than 30 research reports for various institutions and agencies. I have served as peer reviewer or reviewing editor for more than a dozen professional journals and government research publications. I have served on 13 professional and government panels that provided technical guidance about stream and river protection to state and federal wildlife and forest management agencies in three states, including technical panels that advised Oregon state agencies on water temperature standard development, and forestry landslide prevention rulemaking.

5. While on the faculty as a researcher at Oregon State University, I was funded to lead a 6-year research project on salmon habitat protection in Oregon coastal rivers. In 1992 I completed my doctoral dissertation on the cumulative effects of land use on salmon habitat in Oregon South Coast rivers. That research focused on the full spectrum of threats to physical habitat of salmon in coastal watersheds, including water temperature, sediment conditions, landslides and road erosion, large wood, and channel dynamics. For ten years I was Research Assistant and Research Associate Professor at the University of Montana's Flathead Lake Biological Station, where I continued to conduct research on salmon ecology and freshwater habitat conservation. For 11 years I held the positions (alternately) of Senior Staff Scientist or Conservation and Science Director with the Pacific Rivers Council, where I worked specifically on the interface of scientific information and land management, with considerable involvement in forest

management policy development for stream protection and salmon and trout recovery, including in coastal Oregon.

6. In preparing this declaration I reviewed the NOAA/EPA Proposed Finding of 20 December 2013, Oregon Coastal Nonpoint Program, which "contains the bases for the proposed determination by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA)….that the State of Oregon (State) has failed to submit an approvable Coastal Nonpoint Pollution Control Program (Coastal Nonpoint Program) as required by Section 6217(a) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), 16 U.S.C. 1455b." I also reviewed various relevant documents from Oregon state agencies, and supporting information from the scientific literature, as cited in the following text. And although I am very familiar with Oregon's water quality standards and forest practices program I also reviewed portions of those rules and regulations as I prepared this declaration.

OREGON'S WATER QUALITY STANDARDS

7. In this declaration my intent is to examine and comment on those elements of the Proposed Finding that relate to protection of fish and wildlife resource and other natural resource aspects of water quality with management of private and state forest lands. I provide comment to describe what practices are required by rule on those lands, and then evaluate how those practices affect threats like temperature and sediment, and finally assess whether the practices are sufficient to maintain and protect water quality requirements for Oregon coastal streams.

8. EPA and NOAA have determined that Section (b)(3) of CZARA, 16 U.S.C.A. § 1455b(b)(3), requires Oregon to adjust its forest practices programs to implement "additional management measures…that are necessary to achieve and maintain applicable water quality standards under section 1313 of Title 33 and protect designated uses." I understand water quality standards to be defined as the designated beneficial uses of a water body in combination with the numeric and narrative criteria to protect those uses, as well as an antidegradation policy. 40 C.F.R. §131.6. I also believe the Clean Water Act requires numeric criteria adopted in water quality standards to protect the "most sensitive use." 40 C.F.R. § 131.11(a)(1). EPA regulations implementing section 303(d) of the Clean Water Act reflect the independent importance of each component of a state's water quality standards:

> For the purposes of listing waters under §130.7(b), the term "water quality standard applicable to such waters" and "applicable water quality standards" refer to those water quality standards established under section 303 of the Act, including numeric criteria, narrative criteria, waterbody uses, and antidegradation requirements.

40 C.F.R. § 130.7(b)(3).

9. In preparing this declaration I also reviewed Oregon's water quality standards. Those standards include the statewide narrative and numeric criteria (set out at OAR 340-041-0001 through 340-041-0061), an antidegradation policy (set out at OAR 340-041-0004), and basin-specific rules including designated beneficial uses. Designated beneficial uses for the Umpqua River Basin are established by OAR 340-041-0320 (citing Table 320A and Figures 320A and 320B) and basin-specific criteria applicable to that basin are set out at OAR 340-041-0326. Designated beneficial uses for the South

Coast Basin are established by OAR 340-041-0300 (citing Table 300A and Figures 300A and 300B) and basin-specific criteria applicable to that basin are at OAR 340-041-0305. Designated beneficial uses for the Rogue River Basin are established by OAR 340-041-0271 (citing Table 271A and Figures 271A and 271B) and basin-specific criteria applicable to that basin are at OAR 340-041-0275. Designated beneficial uses for the North Coast Basin are established by OAR 340-041-0230 (citing to Table 230A and Figures 230A and 230B) and basin-specific criteria applicable to that basin are at OAR 340-041-0235. And designated beneficial uses for the Mid Coast Basin are established at OAR 340-041-0220 (citing Table 220 A and Figures 220A and 220B) and basin-specific criteria and applicable to that basin at OAR 340-041-0225.

10. I understand that TMDLs further refine how water quality standards apply to sources, individually and collectively, where they have been developed and approved by EPA. Specifically, I understand that Oregon's Human Use Allowance, which allows an increment of 0.3C warming over applicable numeric temperature criteria, is divided up between sources when the Oregon Department of Environmental Quality develops a TMDL. TMDLs established by Oregon DEQ and approved by EPA are listed at OAR 340-041-0324 for the Umpqua River Basin; at OAR 340-041-0304 for the South Coast Basin; at OAR 340-041-0274 for the Rogue River Basin; at OAR 340-041-0234 for the North Coast Basin; and at OAR 340-041-0224 for the MidCoast Basin (I have reviewed some of these in detail, but not all). In nearly all of the temperature TMDLs that apply to watersheds in the Coastal zone, I understand that DEQ has allocated none of the Human Use Allowance to nonpoint sources including forestry. That is, nonpoint sources including forestry are given a load allocation of zero, meaning logging activities cannot

contribute to any increases in stream temperature in basins covered by an approved TMDL.

11. As stated in the Oregon's rules, the purpose of Oregon's antidegradation policy is "to protect, maintain, and enhance existing surface water quality to ensure the full protection of all existing beneficial uses." OAR § 340-041-0004(1). Oregon's antidegradation policy expressly recognizes that the numeric and narrative standards "are intended to supplement" that policy. OAR § 340-041-0004(1). The statewide narrative criteria then state that "the highest and best practicable treatment and/or control of wastes, activities, and flows must in every case be provided so as to maintain … overall water quality at the highest possible levels…." OAR §340-041-0007(1).

12. I note that "Fish and aquatic life," "fishing," and "aesthetic quality," are all listed as designated beneficial uses in all waters in all five coastal basins. My understanding is that Oregon's narrative standards, numeric standards, and antidegradation policy therefore must protect and support those designated beneficial uses. The statewide narrative criteria prohibit the "development of fungi or other growths having a deleterious effect on stream bottoms [or] fish or other aquatic life;" the "creation of tastes or odors *or toxic or other conditions* that are deleterious to fish or other aquatic life;" and the "formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life…." OAR §§ 340-041-0007(9), (10) (emphasis added), and (11). Oregon's biocriteria also state: "Waters of the State must be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities." OAR §340-041-0011. My understanding is that Oregon's Coastal Nonpoint Program therefore must ensure that land

and water uses in Oregon's coastal areas attain and maintain those water quality standards, including the full protection of all aquatic species including all fish.

RIPARIAN AREA MANAGEMENT

13. The federal agencies (Finding 2012) propose to find that "the State's existing measures for riparian areas around medium, small, and non-fish bearing streams do not adequately protect water quality and designated uses," citing the following: "1) the Oregon Department of Forestry's (ODF) Riparian and Stream Temperature Effectiveness Monitoring Project (RipStream); 2) "The Statewide Evaluation of Forest Practices Act Effectiveness in Protecting Water Quality" (i.e., the "Sufficiency Analysis"); and 3) the Governor's Independent Multidisciplinary Team Report on the adequacy of the Oregon Forest Practices in recovering salmon and trout, which continues to document the need for greater riparian protection around small and medium streams and non-fish bearing streams in Oregon." I agree with the finding that these sources and others demonstrate the inadequacy of Oregon's forest practices rules on private lands, particularly with regard to temperature protection, large wood recruitment, and erosion and sediment delivery. Furthermore I think the best available science demonstrates that stream buffers along small and medium fish-bearing streams, and along non-fishbearing or "Type N" streams, are inadequate to retain nutrients that are expected to be released as a consequence of vegetation and soil disturbance during logging activities, and hence that current practices contribute to nutrient loading in nutrient-impaired rivers and lakes downstream.

14. According to OAR 629-635-0310, current Oregon Forest Practices Rules for medium size fish-bearing streams on private lands in the Oregon coastal region generally call for a Riparian Management Area width of 70 feet, and rules call for a Riparian Management Area width of 50 feet for "small" fish-bearing streams. Within these designated management areas there are both lineal large tree density and basal area minimum requirements to retain some minimum quantity of standing trees. All understory vegetation is to be retained within 10 feet of the high water level, and all trees are to be retained within 20 feet of the high water level (unless they are deemed to interfere with logging operations), and all trees leaning over the channel are to be retained. The linear requirements are to retain at least 40 live conifer trees per 1000 feet along large streams and 30 live conifer trees per 1000 feet along medium streams. This includes trees left to meet the additional basal area requirements, except that trees counted toward the lineal requirement must be conifers at least 11 inches DBH (diameter at breast height) for large streams and 8 inches DBH for medium streams. The additional basal area requirement may include some a limited proportion of hardwood species and dead conifer snags, but is intended to be predominantly comprised of live conifers greater than 6 inches in diameter. The primary intent of these retention rules is to ensure some trees remain available to grow and eventually provide large wood to provide habitat and related functions in fish-bearing streams. However, more standing trees can be removed in some cases by "credit" when logs are placed in Type F stream channels in an attempt to provide fish habitat.

15. The overall effect of the above-summarized rules on the ground is to allow commercial logging, including thinning and intrusion of the verges of larger upslope

clear cuts and other intensive silvicultural treatments, within all but the innermost 20 feet of the designated Riparian Management Area of fish-bearing streams. Under the rules, and depending in part on initial stand conditions before logging, numerous trees, especially medium size or larger conifers, can be removed from many riparian areas, but relatively fewer trees can be removed from riparian areas having sparse trees, or few conifers prior to this round of logging (many streamside stands are depleted of large trees today as a consequence of previous episodes of logging, intense wildlfire, or large debris flows).

16. There is no tree retention requirement in the current Oregon forest practices rules for small Type N streams in the Coast Range and west Cascade regions with non-perennial flow, but these streams are required to be protected from direct sediment input and channel disturbances that can be caused by equipment operations or yarded logs. In the Siskiyou Region of the coastal zone, portions of perennial streams where the upstream drainage area is greater than 580 acres require retention of all understory vegetation and non-merchantable conifer trees (conifer trees less than six inches DBH) within 10 feet of the high water level on each side of small perennial Type N streams. Presumably it is assumed by the Oregon Department of Forestry that more rapid regrowth of riparian vegetation after logging precludes the need for vegetation in the more northerly coastal zone. There is also a requirement to leave Green Trees and Snags along Small Type N Streams subject to Rapidly Moving Landslides, with the intended purpose to provide a source of large wood that can be moved by rapidly moving landslides into Type F streams. There is a nonbinding recommendation that, "Operators are encouraged to retain portions of in-unit green live trees and snags as blocks of intact

vegetation." Along larger type N streams that do not have fish but that have perennial flow, that is their surface waters are exposed to summer warming, the rules require intermittent retention of forest including a specified minimum of medium or larger-sized trees. These retention patches are presumed by ODF to first partially reduce the solar exposure and summer warming of these streams in the reach nearest their confluence with larger fish-bearing streams, and secondly to provide forest complexity that allows debris flows or sediment-laden floods originating in headwater areas to recruit some large wood and export it downstream to fish-bearing waters for purposes of in-stream habitat creation.

17. On State Forest Lands, fish-bearing (Type F) streams are given 50- to 100-foot riparian management areas with 20-foot, no-cut buffers at the streamside. This somewhat reduces operational ground disturbance near surface waters, and usually results in higher shade and stem retention in riparian areas than rules for private forest land require. Given existing riparian forest conditions on most Oregon State Forest lands, which are marked by highly deficient conifer abundance and size compared to natural historical conditions, operations on State Forest lands commonly (but not always) result in a nearly no-cut buffer of 50-75 feet.

Overarching Concerns

18. In terms of ecological and water quality impact to streams I have at least four overarching concerns about Oregon's forest practices rules for private lands in Oregon's coastal areas: 1) they allow for potential ground-disturbing activity within close proximity of surface waters (10-20 feet), allowing sediment delivery and sediment impairment; 2) they allow opening up of canopies that increases solar penetration to

surface waters with adverse affects to thermal conditions and impair stream temperatures; 3) they reduce the capacity of streamside forests to resist and retain upslope erosion sources, including larger landslides and concentrated road runoff; and 4) they allow depletion of mature trees from existing riparian forests that would otherwise mature to larger size or fall and provide woody debris that is important for buffering streams from sediment delivery, for riparian forest successional development, and for stabilizing stream beds and banks and producing instream habitat.

Protection of Temperatures in Fish-Bearing Streams

19. Temperature is a key determinant of the ability of native fish and other aquatic species to survive and thrive in coastal Oregon waters. Native salmon and trout in particular are coldwater-adapted organisms that are threatened by water changes in various ways, but perhaps most acutely by way of increases in summer maximum water temperature during the warmest period of the year (McCullough et al. 2009). Given the thermal preferences and requirements of salmonid fishes and the current thermal regime of most Oregon rivers, it is clear that virtually any summer maximum temperature increase in coastal rivers and streams is likely to be deleterious to fishes (Poole and Berman 2001).

20. Both wider forest buffers and forest patches that are continuously distributed (rather than patchily distributed) along the stream corridor and stream network are associated with cooler and more stable summer stream temperatures. In other words, intermittently exposed stream reaches can result in net energy gain and warming that are not compensated or reduced even within shaded reaches downstream. While discontinuous buffers can be somewhat better than no buffers at all, ecologically

speaking they are demonstrably not sufficient to prevent stream warming (Wenger 1999). The appearance of thermal "recovery" downstream may occur if additional cool groundwater sources intervene, but, nevertheless, unshaded reaches generally cause accrued warming that distorts the downstream temperature gradient to a warmer condition than would have resulted under continuous forested cover (Wenger 1999, Poole and Berman 2001).

21. The most robust and direct source for evaluating the effectiveness of Oregon Forest Practices Rules is the Oregon Department of Forestry's ongoing Riparian and Stream Temperature Effectiveness Monitoring Project, or "RipStream." While not yet published in final form, preliminary and review documents can be accessed online at http://www.oregon.gov/odf/privateforests/pages/monitoringripstream.aspx. This study has generated useful information that is grounded in field empirical studies of stream temperature under varying riparian forest conditions; those data were used to calibrate a simulation model that couples a representation of riparian forest structure (in a form that can be manipulated by simulated logging of individual trees) with a shade model, and thence to a stream warming model. Published results and synthesis from the field studies have been published in Groom et al. (2011a, 2011b) and Dent et al. (2008). As structured, the RipStream modeling effort can be used to estimate the shade and temperature consequences of different distributions of retention and removal of trees within about 150 feet of stream margins. However, it still should be recognized that RipStream only accounts for the direct and immediate effects of logging on shade and stream heating caused by solar energy reaching the stream surface; it does not explain temperature impact caused by other mechanisms, such as groundwater warming or

sedimentation that can reduce interstitial streamflows and shallow groundwater storage (see Poole and Berman 2001).

22. Greatly simplifying preliminary results from RipStream presentations, it appears that in general the results are consistent that measureable stream temperature increases can be expected to occur from most logging practices that involve cutting trees within about 90 feet of streams. To ensure a modeled zero increase in summer water temperature across most sites and scenarios requires a 100-foot, no-cut buffer.

23. The RipStream results demonstrate that the Oregon Forest Practices Rules fail to protect summer maximum stream temperatures in perennial streams, whether fish-bearing or not, and that buffers of increased width and increased tree retention are necessary to attain and maintain water quality standards, including TMDLs that allocate zero loads (that is, no allowable temperature increase). Again, where waters have been classified as impaired and TMDLs developed for temperature, requirements for all perennial streams across the basin or watershed include zero or near-zero load for summer temperature contributions.

24. Additionally, RipStream results to date suggest that when logging in Oregon State Forests result in very large no-cut riparian buffers (that is, virtually no logging within75-80 feet of the stream edge), they may avoid temperature increases at many, but not all sites. Some sites appear to require about 100-foot no-cut buffers to prevent measurable temperature increase. However, under many circumstances State Forest rules allow substantial amounts of tree removal within 20 feet of streams, and in these situations, temperature increases are likely, depending on the extent of canopy reduction that occurs.

25. Near-stream logging can adversely affect streams and water temperature even where it does not lead to appreciable shade loss to the stream surface. Considerable attention has been paid in the scientific literature to the point that shade reduction is not the only means by which logging can alter stream temperature (Poole and Berman 2001). In addition to changes in channel structure, sediment conditions, and streambank erosion and reduced vegetative stability following logging, canopy reduction across a watershed or catchment surface can affect shallow groundwater thermal regimes. Pollock et al. (2009) found that post-logging temperature increases in Washington streams corresponded to catchment-wide extent of recent logging more strongly than to extent of logging or canopy reduction in riparian areas that would directly affect stream surface shade (See also Moore et al. 2005). Pollock et al. (2009) suggest that landslides and debris flow-induced changes to channel conditions (namely, reduced hyporheic interchange and flow storage), as well as groundwater warming may explain logging-related stream warming. Bourque and Pomeroy (2001) reported a similar correlation with catchment-wide extent of logging in New Brunswick, such that stream warming was dominated by watershed-wide factors that overwhelmed the local influence of riparian forested buffer width. This does not mean forest buffers were unimportant; even greater warming might have been observed in that study had forested buffers not been in place. Janisch et al. (2012) reported that small headwater streams in logged catchments warmed more if they drained a larger area of wetlands. More extensive wetlands would likely correspond to more extensive areas of near-surface groundwater, as well as open water surface, within these catchments. Jones and Johnson (200) reported evidence that warming of the ground near streams played a role in warming of streams that persisted up

to 15 years post- logging; this implies that narrow buffers along the stream margins might not fully protect headwater streams from logging-related warming.

26. In several of the above studies, a major causal mechanism for stream warming appears to have been the warming of near-surface groundwater in response to logging and subsequent soil warming following canopy reduction outside of the immediate streamside zone (and may possibly involve alterations in seasonal groundwater level that influenced its mixing with surface waters). While Janisch et al. (2012) pointed out that post-logging catchments may release more groundwater to streams because evapotranspiration is reduced, the temperature of shallow groundwater (2.5 m or less from the soil surface) can increase with soil warming under open land cover conditions in summer (Pluhowski and Kantrowitz 1963, Glazik 1987, and other sources cited in Rhodes et al. 1994). Therefore, under certain landscape conditions, logging could increase upland groundwater elevations and expose more near-surface groundwater to warming, at the same time it exposes the soils to greater warming because of canopy loss.

27. Vegetative shade that helps keeps streams cool is a "stacked" or redundant function—that is, while near-stream trees play the largest role in shading the water surface, standing trees in the riparian area outside of 50 feet from stream margins contribute overlapping shade to the stream. Thinning in this "outer zone" reduces shade density, and so does pose a measurable increased risk of stream warming. Even taller vegetation on distant hillslopes can contribute some shade to streams. When near-stream trees are felled or killed by natural events like flood, debris flow, windthrow, disease, or wildfire, then the shade provided by "outer zone" trees can become the only source of

shade to that spot until near-stream trees regrow and gain sufficient height and canopy closure. Arguments that shade can be "fully maintained" by leaving forest vegetation within 50 feet of the stream channel ignore the fact that removing trees outside of 50 feet depletes shade density and curtails these "stacked" shade functions, rendering streams far more vulnerable to warming whenever natural or human disturbances fell near-stream trees, which they frequently do given the high incidence and diversity of natural disturbance processes in riparian forests (Reeves et al. 2003).

28. It is important to note that thinning in the outer zone (beyond 50 feet) can open up the canopy to wind penetration and in this way promote increased windfall of trees within the adjacent, narrow no-cut zones (Scheutt-Hames et al. 2011, MacDonald et al. 2003, Bahuguna et al. 2010). Logging in the riparian area may also disperse tree diseases, such as Port-Orford-cedar root disease and other fungal diseases, which subsequently spread into inner no-cut zone. In these ways thinning depletes shade redundancy while at the same time increasing riparian disturbance, thus magnifying the potential that outer-zone trees will be needed to provide "backup shade" to streams.

29. It is also important to recognize that natural events like floods, debris flows, landslides, fire, and disease outbreaks are likely to increase, and may already be increasing, in the face of weather extremes associated with climate change (Seavy et a. 2009). In some valley settings, events like large debris flows or channel avulsions (Brummer et al. 2006) can cause stream channels to shift locations well outside the 50- or 100-foot zone, potentially resulting in sudden new channel locations inside logged forest areas where shade and other riparian functions have been dramatically reduced.

30. Climate change also affects environmental drivers other than shade that tend to favor stream warming, such as reduced and earlier season of runoff, reduced groundwater storage and stream base flows, and higher seasonal air temperature (Seavy et al. 2011). Human actions other than logging, such as upstream flow storage projects or diversions, can cause streambanks to lose stability, making streamside trees vulnerable to windfall or disease. So, in several ways, cutting trees in the "outer" zone of riparian areas does contribute materially to future stream warming. All of these sources of impact should be considered, addressed and mitigated if stream ecosystems, water quality and fish and wildlife habitat are to be adequately protected.

31. In sum, present forest practices rules for private and state forest lands are inadequate to prevent water quality violations because, based on the most recent available science, they are highly likely to cause summer temperature increases detrimental to fish and aquatic species, and in violation of Oregon's narrative, numeric, and antidegradation water quality standards, in many or most cases. They retain insufficient shade to protect against shade-related temperature increase, and they provide no protection for areas of shallow groundwater to guard against possible watershed-scale warming.

Erosion and Sediment Delivery

32. Sediment causes a wide range of deleterious impacts to stream habitat that affects individuals, species, and populations of fishes and other aquatic organisms. These effects range from short-term, lethal effects on incubating eggs and fry (Cordone and Kelly 1963) in stream gravel, to more complex, indirect effects such as sediment decoupling vertical flow exchange and secondarily triggering summer stream warming (Poole and Berman 2001). Sediment is delivered to streams via both point source

(mainly roads) and nonpoint source vectors from forestry land use. Newcome and McDonald (1991) and Newcome and Jenson (1996) provide a review of the multiplicity of pathways by which suspended sediment can cause deleterious impacts to fishes, followed up with a meta-analysis that established very general but robust exposure-duration relationships governing the effect of sediments on fishes. Even very low but chronic levels of turbidity caused by suspended sediment can impair fish survival and also fishing success (Oregon DEQ 2010). There is little dispute that excess sediment can impair most beneficial uses of Oregon waters. Erosion and sediment delivery to surface waters results in adverse changes in factors governed by other numerical and narrative standards, including turbidity, temperature, channel morphology and habitat for fish and other aquatic life, and suitable conditions for fishing. Sediment strongly impacts Oregon's Biocriteria standard.

33. For sediment in streams, Oregon has several operative water quality standards. For bedded sediments that are deposited in the substrate of a streambed, Oregon has a narrative standard: "The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry may not be allowed." OAR 340-041-0007 (12). For sediment suspended in the water column the numeric standard is based on water clarity (turbidity): "Turbidity (Nephelometric Turbidity Units, NTU): No more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity." OAR 340-041-0036. The 'potability" narrative standard is written in such a way that it provides broad protection for fish and other aquatic life: "The creation of

tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish may not be allowed." OAR 340-041-0007(11). Finally, the biocriteria (or biological criteria) narrative standard is intended to protect the ecological integrity of a waterbody from the effects of various pollutant stressors, including sediment: "Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities." OAR 340-41-027. "Aquatic Species" means plants or animals that live at least part of their life cycle in waters of the state." OAR 340-41-027(6). "Resident biological community" means aquatic life expected to exist in a particular habitat where water quality standards for a specific ecoregion, basin, or water body are met. This shall be established by accepted biomonitoring techniques." OAR 340-41-027(36). "Without Detrimental Changes in the Resident Biological Community" means no loss of ecological integrity when compared to natural conditions at an appropriate reference site or region. OAR 340-41-027(76).

34. The primary relevent and current literature source for characterizing nonpoint source erosion and sediment delivery to streams relative to stream buffer design is Rashin et al. (2006). Based on systematic field surveys of ground and channel conditions, Rashin et al. examined immediate effects of logging-related ground disturbance on slope erosion, sediment routing, and headwater stream channel condition in forested industrial forestlands of Washington State. The slope erosion study employed a between-sites-comparison design with unlogged sites as controls, and the stream channel condition surveys used a before-and-after-logging design. Results were presented as a direct examination of the near-term effectiveness of forest practices rules that at the time

allowed a variety of logging actions along non-fish-bearing, headwater streams, but did not require continuous riparian forest buffers.

35. Rashin et al. (2006) found that riparian vegetative buffers (approximately 30 feet or more wide on each side of channel), including leave tree areas and with required directional felling and restrictions on log yarding or ground-based equipment use, were wholly or partially effective in preventing near-term sediment delivery from logging disturbance. Narrower buffers allow ground disturbance near enough to channels that sediment delivery was likely (much of this was associated with skid trails and soil scars from felling and log yarding). Area of exposed soil that delivered sediment to stream channels was an order of magnitude higher in sites logged without stream buffers compared to those logged with riparian buffers, as is typical practice on Type N forest treams in Oregon.

36. Effectiveness of stream buffers was breached at yarding corridors through buffers (associated with ground scars from cable yarding), and where selective logging occurred on steep inner gorge slopes within (or possibly adjacent to) the buffer areas (Rashin et al. 2006). Stream buffers were generally effective at reducing near-term sediment delivery to streams regardless of whether surrounding logging was by clearcut or partial cut. However, yarding corridors cutting through Riparian Managemen Areas, which are allowed by Oregon forest practice rules, measurably compromised the effectivenes of stream buffers in preventing sediment delivery to streams.

37. Stream buffers were most effective where timber felling and yarding activies were kept at least about 30 feet from streams and kept away from steep, near-stream inner gorge slopes. Simple exclusion of logging-caused ground disturbance from near-stream

areas and hillslopes with a high likelihood of delivery of sediment to channels accounted for most of the effectiveness of stream buffers. The primary observed causes of soil disturbance and erosion were skid trails from tractor yarding and yarding scars from cable yarding. Relict but ongoing erosion sources associated with roads, skid trails, and landslide scarps that had existed prior to the latest logging were also observed, but with lower frequency (Rashin et al. 2006).

38. Windthrow of leave trees in stream buffers was frequent, but a far less important contributor of sediment than yarding scars and other ground disturbance, because the localized, self-draining topography of root throw pits discouraged sediment routing to nearby streams (Rashin et al. 2006). This contrasted with the linear, down-slope oriented, and often larger features caused by direct logging disturbance. Windthrow of trees growing on the immediate streambank was seen to contribute sediment to streams, but this apparently was not the predominant location of blowdown. Surrounding logging prescriptions was seen to affect the windfirmness of stream buffers. Incidence of windthrow within buffers adjacent to clear cuts was an order of magnitude higher than within buffers adjacent to partial cuts, and also greater than riparian area windthrow within unlogged control watersheds. Recently, Schuett-Hames et al. (2012) reported the results of a study of windthrow in buffers along non-fish-bearing, perenial streams in western Washington. While they found a high incidence of windthrow within the first five years after logging, similar to Rashin et al. they observed only a modest incidence of sediment delivery to streams from windthrown trees within stream buffers, although there was significant loss of stream shade.

39. Rashin et al. (2006) reported that where riparian vegetative buffers were not

left, erosion and channel response were clearly linked to surrounding logging practices. Specifically, clearcuts tended to generate more sustained active erosion and sediment delivery than partial cuts. In winter-cold, interior forests, logging over snow and frozen ground appeared to substantially reduce observed erosion and sediment delivery.

40. Despite that most streams in the Rashin et al. study were small headwater channels with steep channel slopes (exceeding six percent), surveys revealed numerous instances of fine sediment accumulation on streambeds, both in pools and across the entire bed, associated with localized sediment sources, and in some cases accumulations of logging slash. In addition, the extent of actively eroding streambanks increased in streams logged without buffers. These observations contradict the oft-repeated but seldom-tested presumption that sediment entering steep headwater streams is "rapidly flushed out" and therefore is assumed to have little effect in instream biota and water quality. Gomi et al. (2005) have previously commented that sediment routing and fate in headwaters streams in the Pacific Northwest has received insufficient study relative to the inherent risks fine sediment poses to aquatic resources.

41. The Rashin et al. (2006) study is conservative in the sense that "controls" were previously-logged, second-growth sites, and hence "background" or baseline incidence of erosion was likely elevated over natural rates in watersheds not previously disturbed by logging and roads (see below, Keppeler 2012). This means that "background" sediment conditions in the Rashin (2006) study were likely already well elevated over conditions that would have prevailed in undisturbed natural forest. Nevertheless the analysis provides a useful basis for evaluating future management of the existing, largely second- or third-growth, road-private forest landscape.

42. The most important caveat is that Rashin et al. (2006) only evaluated localized erosion and sedimentation within the immediate two years after logging. Many potential sources of impact to streams, including those that result from hydrologic change caused by vegetation removal, and those that propagate over time and space, were not accounted for in the study design. Hence it is also important to recognize that some additional effects could occur that might not be fully mitigated by 30-foot riparian buffers for Type N streams. Such processes include headward channel incision or gullying, landslides that increase with root strength depression occurring several years after harvest, and streamside erosion increases resulting from debris flow scour (Gomi et al. 2001, May 2002, May and Gresswell 2003), or the passage of coarse sediment waves (Beschta et al. 1995, Frissell 1992).

43. Oregon forest practices rules for state and private forest land intended to protect medium and small Type F streams, and all Type N streams, are inadequate to protect streams from sediment delivery associated with the inevitable ground disturbance caused by logging, which is exacerbated to a limited extent by indirect and delayed effects of logging, including windthrow. Oregon forest practices rules applicable to private lands in Oregon's coastal areas allow logging and yarding activities to occur within 30 feet of streams and the available scientific literature demonstrates that such practices will result in delivery of sediment to streams in a manner that will adversely impact aquatic species and violate Oregon's numeric, narrative, and antidegradation water quality standards.

44. Each incident of sediment delivery to streams from man-caused erosion sources is highly likely to violate one or more of Oregon's water quality standards for

sediment. Multiple episodes or sources are highly likely to lead to violations of all of Oregon's standards for sediment and biocriteria. Excess course or fine sediment can result in the formation of "appreciable" bottom deposits that impair fish egg and embryo survival and may eliminate bottom crevices young fish need for overwinter rearing and escaping predators. A ten percent increase in turbidity over background is easily obtained from nearly any active erosion source that delivers fine-grained soils to surface waters. And the narrative biocriteria standard is almost certain to be violated, as sediment levels in excess of those that would naturally occur are virtually certain to lead to declining survival or complete loss of some life stages of fish, stream amphibians, and other sensitive species—and their decline or loss causes detrimental changes in the biological community.

Production of Large Woody Debris Necessary to Maintain Riparian Processes, Channel Morphology, Habitat, and Water Quality.

45. Downed woody debris helps provide stable and complex habitat structure on riparian forest floors, streambanks, and in streams and wetlands. Dead and downed wood in riparian areas also serves as a substrate for biological activity and partitions habitat so that more fish and wildlife can co-exist in limited space. Woody debris can help retain moisture and provide microsites to support sensitive species and processes, such as nutrient cycling. Woody debris helps trap sediment and nutrients from overland flow and in-channel flow. It is vital for fluvial processes like stream diversion and island formation that are critical for overall habitat diversity and biological diversity, including the development and retention of subsurface, or hyporheic, flow paths (Naiman et al.

2002, Montgomery and Abbe 2006, Pollock 2012, Pollock and Beechie 2012, Spies et al. 2013).

46. Photosynthesis of trees grows large wood. Mortality of trees from all sources recruits wood to streams and adjacent riparian areas. The timing and character of wood input is determined by factors including: forest productivity, mortality processes, disturbance regime and episodic disturbance events (large fires, floods, or wind storms), and management interventions. Larger, longer tree boles (commonly, greater than 20 inches diameter and a length that exceeds the active channel width of the stream) may be necessary as stable "key pieces" (or anchoring pieces) against which debris jams are formed in larger, wider streams; but in small and medium sized streams, these functions can be performed by small and intermediate-sized boles. Even in larger streams, smaller wood performs numerous physical and biological functions, such that management actions that trade off small wood recruitment for large wood recruitment can be self-cancelling in their restoration value. Numerous studies have demonstrated the present-day acute shortage of wood *across all size classes* in Pacific Northwest streams within areas affected by logging, roads, dams, and other human influences, relative to wood abundance and functions in natural systems.

47. While most trees that reach streams when they fall originate within the nearest 50 or 100 feet of the stream channel (and most available studies only examined the immediate source of such dead wood pieces), up to a third of trees that fall within this inner zone in a northern California watershed were triggered by trees falling from farther away (Reid and Hilton 1998). Moreover, to maintain a nearly natural incidence of tree fall, one would have to extend one step further to "buffer the buffer." Therefore the sum

result to fully protect woody debris source dynamics would be closer to three site potential tree heights, or 450 feet, not one tree height (150 feet) as commonly assumed.

48. Recent research from NMFS scientists and a federal interagency panel of scientists (Pollock 2012, Pollock and Beechie 2012, Spies et al. 2013) provides new and specific insight into the adequacy of Oregon forest practices tree retention requirements intended to maintain the supply of large wood that is deemed necessary to restore and maintain fish habitat, water quality, and hydrologic functions in fish-bearing Oregon coastal streams. These researchers modeled the responses of forest riparian stands to various logging simulations, including thinning prescriptions that are commonly intended to produce growth release in leave trees, while at the same time taking smaller or medium-sized trees for commercial harvest. While modeling to date has focused on riparian management scenarios for federal lands, which do not specifically simulate treatments on state and private forest lands in Oregon, the results are nevertheless instructive: Virtually any thinning regime reduces natural self-thinning mortality in riparian stands, hence depletes long-term large wood and snag recruitment compared to wood recruitment rates from unlogged stands. These simulations suggest this remains the case across a variety of initial (pre-logging) stand conditions. While thinning within one site potential tree height has the largest effect on the results (ca. 100-150 feet depending on site), additional effect is noted outside of this zone.

49. The Pollock modeling method appears well suited to, and could be tailored to run, specific simulations of logging that are typical of management under Oregon state and private forest practices riparian rules. But modeling runs reported to date are of sufficient scope to indicate clearly that current Oregon Forest Practices rules and State

Forest practices across all stream types cause widespread depletion of large wood recruitment to streams compared to recruitment rates that would be seen in no-cut riparian buffers and natural stands.

50. Current Oregon forest practices rules for small Type N streams lead inexorably to severe if not complete depletion of large wood recruitment to those streams. Such depletion of wood debris harms headwater amphibian habitats (Olson et al. 2007, Welsh 2011), reduces stream system capacity for sediment retention (May and Gresswell 2003), reduces long-term water storage, which results in flashier, larger delivery pulses of sediment to downstream fish-bearing waters, and reduces shallow alluvial aquifer flow storage that can help buffer low and peak flows in downstream, fish-bearing waters (Poole and Berman 2001, Wondzell 2011).

Nutrient Retention and Riparian Buffers

51. Two nutrients are of principle concern in terms of forest management, although they occur in variant forms that can affect or reflect their fate and effects in soil and water: Phosphorus (P) is generally associated with soil disturbance and erosion from forest management activities, including roads, which are a chronic source of erosion and sediment delivery to waters. Nitrogen (N) is broadly generated and freed into soil water, groundwater, and thus into surface water as an inevitable consequence of any kind of vegetation disturbance. Logging of large trees and fire are associated with particularly elevated mobilization of nitrogen into runoff.

52. It is commonly stated, and correct, that on a per-acre basis, forest management mobilizes less nitrogen and phosphorous than most other land uses. However, in western Oregon, because forestry disturbs many more acres of land over a

given period of years than other land uses that occur in limited, often low-lying areas, forestry is commonly identified as one of the larger, if not the largest, single source of nitrogen and phosphorus pollution from a whole-watershed perspective in Oregon's coastal areas (e.g., Oregon DEQ 2007, pp.87-89). Forestry in combination with natural forest vegetation disturbances like wildfire, windstorms, and disease or pest outbreaks in a watershed can have cumulative effects on nutrient loading to streams, wetlands, rivers and lakes, and these effects are further additive with other sources including septic and sewer systems, runoff from roads and urban areas, and channelization and wetland loss.

53. Proportional losses of nutrients into waters are dramatically higher with the initial disturbance of intact natural vegetation—as occurs with logging of even small areas of forest—than when vegetation is further altered in extensively-disturbed ecosystems such as croplands or urbanizing areas (Wickam et al., 2008). This is because undisturbed natural forest vegetation has exceedingly small baseline nutrient losses (i.e., undisturbed natural forest cover, with its dense and highly biologically integrated subsurface root and microbial systems, is highly retentive of nutrients). As a result, increased area of logging or other forest disturbance in a watershed can dramatically increase nutrient loading to downstream waters compared to similar changes of disturbance on other land use types, where background losses are already quite high and sustained. For example, clearcut logging increased nitrogen loading to an adjacent stream by about 7-fold in one Idaho study, while partial cutting caused a more than 5-fold increase (Gravelle et al. 2009). Downstream of the cutting units, cumulative nitrogen concentrations increased from pre-logging background levels by about 450-500 percent.

54. Chronic leaching of nitrogen into streams is also observed after fertilization of forestry plantations. Plantations leach supplemental nitrogen to streams particularly during winter when plant uptake of nutrients is slow.

55. Although it has been relatively little studied in the Pacific Northwest compared to other parts of the world, much is known about the phenomena of eutrophication, which is the ultimate result of increased nutrient delivery to fresh and marine waters. Increased nutrients, particularly when nitrogen and phosphorous are combined, can cause a host of undesirable effects where they accumulate in downstream waters (Kubin 2006; and see Daggett et al. [1996], and Oregon DEQ [2007] for a description of deterioration of water quality in Oregon coastal lakes resulting from nutrient and sediment pollution).

56. When delivered to steep headwater streams, nutrients commonly move swiftly through them (Gomi et al. 2002, Freeman et al. 2007. While traveling downstream, some portion of nutrients leach from stream waters into riparian aquifers where they may be taken up by the roots of riparian plants (Gomi et al. 2002, Wondzell 2011). Some portion is taken up by in-stream algae and other aquatic plants, cycling the aquatic food web. In anaerobic microhabitats, some nitrate-N may be taken up by denitrifying bacteria and reduced to elemental nitrogen, N_2, and lost to the atmosphere. P is commonly attached to inorganic or organic particles and can be deposited in overbank areas and cycled back into terrestrial vegetation. But most of these riparian and in-stream cycles of uptake tend to keep much of the N and P in or within close proximity of the stream system. Nutrients taken up in near-stream vegetation, unless they are consumed by animals and moved away from the stream, tend to return to the stream with leaf drop

or litterfall. Nutrients cycled in aquatic plants and animals generally return to solution in the water when the organisms die. Hence a large proportion of nutrients that enter headwater streams probably work their way to downstream receiving waters.

57. Increased algal growth in streams associated with nutrient inputs can result in increased oxygen consumption at night when the expanded plant community is respiring but not producing oxygen through photosynthesis. Large day-to-night swings in oxygen concentration and even pH can result, producing stressful conditions for fishes and other aquatic organisms. When these nutrients eventually work their way downstream to large pools, backwaters, wetlands, and coastal lakes, they can produce acute eutrophic effects (Freeman et al. 2007). These effects include explosive growth of nuisance algae and aquatic macrophytes, oxygen depletion, high concentrations of plant-derived solutes in the water that result in acidic conditions, discoloration, and unpalatable odor and flavor in drinking water (Oregon DEQ 2007).

58. Filtration and chemical treatment of water from eutrophied lakes and rivers to make it suitable for municipal or domestic use can be very expensive and often only marginally effective. Finally, increasingly chemically stressful conditions associated with eutrophication could be one reason why extensive areas of habitat in coastal rivers and lakes that appear otherwise suitable for salmon and trout—and were historically productive for those species--appear to go largely unused by them today. Adding to the difficulty, some other fishes such as minnows and suckers, and invasive species like carp and smallmouth bass, may be more tolerant and favored by eutrophic conditions, including expanded aquatic weed beds. Nitrogen loading can also cause eutrophication in estuaries (e.g., oxygen depletion in the Coquille estuary in Oregon,

ODEQ 1994), and can contribute to large-scale hypoxia of nearshore and offshore marine habitats (Cloern 2003, Committee on Environment and Natural Resources 2010). More study of nutrient loading and impacts in Oregon waters is strongly needed.

59. The prospect of incipiently eutrophic conditions in mainstream rivers has been little investigated in western Oregon. However, many if not most western Oregon lakes are listed today as water quality limited primarily due to nutrient loading from catchment sources and resulting eutrophication and water quality impairment (e.g., Oregon DEQ 2007). Source studies for coastal lakes commonly identify forestry as the largest aggregate source of N and P. Coastal lakes are highly efficient nutrient traps and suffer acute symptoms of eutrophication that are impossible to ignore (Daggett et al. 1996) whereas more chronic, seasonal, or intermittent eutrophication impacts in rivers and marine habitats may be more easily overlooked if they are not the subject of specific, properly designed studies—and they have not been, for the most part. It should be further noted that increased water temperature exacerbates biological oxygen demand, intensifying the undesirable and ecologically harmful effects of nutrient loading and eutrophication.

60. Historically when salmon died after spawning they contributed nitrogen, phosphorus, carbon, and other nutrients derived from their growth at sea to freshwater ecosystems. However, for several reasons these nutrients affected freshwater ecosystems much differently than nutrient leaching from logged forests. First, salmon carcasses contributed nutrients at very specific, predictable times of year and locations, which allowed stream organisms to time their life cycles to efficiently capture and process much of their nutrient load. Second, most nutrients in salmon carcasses (and eggs) are bound in

large solid form that makes them suitable for capture and transport by terrestrial and avian predators and scavengers, who moved many of the nutrients far upslope from streams and rivers into terrestrial systems. Third, while some nutrients do leach and escape from carcasses in dissolved form, their predominantly solid form also makes carcasses and eggs easily captured and retained by passive physical processes in streams, where they are subsequently consumed by animals and plants locally. By contrast the dissolved form of nutrients that enter streams after logging through runoff and soil water discharging to streams are less easily retained and more rapidly exported downstream. Finally, the large acreages subject to logging in many watersheds, often at rotation intervals much shorter than natural forest disturbance and successional cycles, results in delivery to streams of much larger quantities of nutrients over much more extended time periods compared to the discrete pulses historically delivered by salmon. In sum, the regime and the form of delivery makes the fate and effects of nutrients delivered by salmon carcasses and eggs potentially much different from those of nitrogen and phosphorus solutes delivered from logged lands.

61. Roots and rhizomes of forest vegetation can effectively uptake N from soil and groundwater, particularly in riparian areas where phreatic water is often nearer the surface and rooting zone that it sometimes is in upland areas (Wenger 1999, Gomi et al. 2002, Freeman et al. 2007, Nieber 2011). P, on the other hand, typically occurs attached to particulate solids and as a result it is physically entrained by vegetation and by surface roughness and ponding at the soil surface created by downed woody debris or rock fragments. Vegetation and debris is less effective at filtering overland flow as slope steepness increases (Nieber 2011), hence P delivery to streams is commonly higher with

steeper side slopes both because soil disturbance and erosion rates are higher and surface retention of particles is reduced, so that more soil reaches streams. Steep side slopes render riparian forest less effective at N uptake because subsurface, N-laden water flows more quickly through soil pores to surface water channels. Deep surface flow that runs below the forest rooting zone, such as along the zone of soil-bedrock contact, can also reduce the efficiency of uptake of N by forest vegetation.

62. Experimental studies of nutrient uptake as water passes through forested buffer zones have established that wider buffers are needed where slopes are moderate or steep than where they are gentle and subsurface percolation is slow (Nieber 2011). Research in the Upper Midwest and other regions has established some general information on uptake rates relative to forest buffer widths that were not available 10 or 15 years ago. A recent meta-analysis of multiple field studies showed that, as a general rule, in terrain with gentle side slopes, a 100-foot forest buffer retains about 80% of the N and P passing through in surface and subsurface flow (Nieber 2011). That is, at 100 feet, about 20 percent of the N mobilized from upslope disturbance filters through and reaches the receiving water. A 50-foot buffer allows about 35% of mobilized N and P to pass through. Although few studies are available for wider buffers, by extrapolation it appears that forest buffers of between 150 and 250 feet width are likely necessary to ensure that *ca.* 90 to 95 percent of nutrient load is scrubbed from the water before it reaches the adjacent stream, wetland, or lake. The effective distances might in fact be greater (i.e., retention efficiencies lower) for most coastal Oregon forest lands because side slopes are generally higher and soil porosity is likely greater than those in most available field studies.

63. In other words, reducing riparian forest buffers from 150 feet to 50 feet likely results in almost doubling the nutrient loading to streams resulting from upslope logging disturbance. Expanding riparian buffers to *ca.* 250 feet width from the edges of stream channels would likely be needed to attain nutrient retention efficiency above 90 percent. Research also shows that buffers must be continuous in order to effectively protect receiving waters from nutrient pollution; once nutrients reach surface waters in segments by penetrating areas with narrow or no forest buffers, they generally remain in the aquatic system (Wenger 1999).

64. Thinning or other logging within the riparian buffer creates pockets of disturbance and sources of nutrients within the buffer. Because nutrients originating at these points can reach streams without passing through the full buffer width, their retention efficiency is greatly reduced. To put it more simply, logging within 150 of stream channels substantially increases the loading of nutrients to surface waters because it simultaneously creates near-stream nutrient sources at the same time it "punches holes" in the riparian forest functional nutrient filter.

65. In my professional opinion nonpoint source nutrient pollution generated by logging is contributing to widespread water quality impairment in Oregon's coastal areas. Specifically, increased nitrogen and phosphorus from upland logging is delivered to streams and wetlands by surface and subsurface flows that are not adequately filtered through unlogged riparian forest buffers. Elevated nutrient levels drive biological processes that cause violations of water quality standards for dissolved oxygen, nutrients, and water clarity and chlorophyll concentration in lakes, rivers, and estuaries in the coastal zone. Oregon Forest Practices Rules for all stream types are grossly inadequate

in width and management prescription to effectively filter N and P mobilized from upland logging, roads, and fertilization of tree plantations. Conversely, implementation of suitably wide no-cut forest buffers could be by far the most effective practice for bringing nutrient-impaired water bodies into compliance with water quality standards; beyond being effective at limiting nutrient loads, it could prove to be absolutely necessary to prevent nutrient loading from forest practices, depending in part on the rate of logging and nutrient mobilization from in the watershed. When nutrient impacts and the need for nutrient control measures are fully accounted for in Oregon (they have barely been considered to date), in my estimation the nutrient retention functional requirements will become the limiting functional design criterion for riparian buffers, far more critically limiting than stream temperature, sediment, woody debris, headwater habitat, and other specific functional considerations that drive current forest management policymaking. Of course all of those other functions and resource values would also greatly benefit from expanded no-cut stream buffers for nutrient protection.

Headwater Stream Protection: On-site and Downstream Effects.

66. Headwater streams by definition contribute water and sediment to downstream areas, hence are critical in determining water quality and habitat conditions for aquatic resources in downstream receiving waters across the landscape (Gomi et al. 2002, Lowe and Likens 2005, Freeman et al. 2007). But headwater streams themselves are also by linear extent the most widespread freshwater habitat in Pacific Northwest landscapes. Small streams, whether permanent or ephemeral in flow, constitute important water resources and habitats for many animal and plant species. Olson et al. (2007) and Welsh (2011) reviewed the importance of sediment and erosion and

deposition processes in affecting stream-associated amphibians and determining sedimentation, water quality, and habitat features in downstream, fish-bearing waters. While the effects of logging, including increased sediment delivery to headwater streams, can be at least partly mitigated by riparian buffers (within which logging operations, including ground disturbance and tree removal, are excluded), some larger-scale effects of logging across catchments tend to be pervasive and not fully mitigated by narrow forest buffers (Beschta et al. 1995, IMST 1999) . Moreover, current Oregon state rules governing forest practices on private lands do not require forest buffers on many--perhaps most--headwater streams that are not fish-bearing, especially those that lack permanent or continuous flow (Olson et al. 2007).

67. Headwater streams lie at the erosional interface of the stream network and hillslopes. Not only are steep headwater streams the recipients of erosion and sediment generated by hillslope processes, they are themselves formed and maintained by erosional and sediment transport processes. Changes in the dynamics of erosion and sediment delivery, then, are dramatically and rapidly expressed as changes in channel stability, morphology, and turbidity in headwater streams. Gomi et. al. (2005) reviewed the variety of processes and conditions that initiate and mediate the consequences of suspended and fine sediment in headwater streams in the Pacific Northwest. While the roles of forest roads and landslides in delivering sediment to streams have received much scientific and some policy attention in recent decades in the Pacific Northwest, we have long known that forest practices also introduce sediment to streams via direct ground disturbance, and by way of alteration of catchment-wide hydrology following vegetation removal. Recent scientific information points to a need to re-examine current forest

practices in light of increasing understanding of these "dispersed" erosion and sediment sources (Reid et al. 2010, Klein et al. 2012).

68. Headwater streams in coastal Oregon—in particular non-fish-bearing streams with perennial or intermittent flow--are known to support populations of species of amphibians that are highly sensitive to temperature changes (increases in summer or possible decreases in winter), sedimentation, loss of wood that provides habitat structure, and changes in microclimate that can be caused by logging of near-stream forests (Olson et al. 2007), Welsh (2011). While these species can often persist after logging impacts to their habitats, though often at greatly reduced numbers, short-term response to logging is not an adequate measure of their population response to logging. Logging-caused stresses on their habitat may not be expressed immediately, but may require, for example, the coincidence of a large flood or sustained drought within 5-20 years of logging before their full effects are triggered. Therefore, some sensitive species such as salamanders could persist after extensive logging of their habitat during a cycle of wet years, but could be extirpated if a cycle of dry years follows logging disturbance. Both sustained population declines and more seriously, extirpations of headwater-dependent aquatic or stream-dependent species, violate the narrative criteria to ensure full protection of aquatic life as a beneficial use of Oregon's coastal area waters.

FORESTRY ROADS

69. The federal agencies (Dec. 2012 Finding p. 9) determined that "Oregon has not provided a sufficient description of this voluntary effort to enable the State to demonstrate that the Oregon Plan satisfies the forest roads element of this condition.....

Also, the State has not provided the federal agencies with specific data to document the effectiveness of voluntary efforts to determine the extent of forestry road miles not meeting current road standards within the coastal nonpoint management area. This information could enable the federal agencies to determine if the voluntary improvements through the Oregon Plan have significantly addressed legacy road issues." I agree with these conclusions, and wish to provide additional observations pertinent to forest roads.

70. In reviewing Oregon's proposed approach to Additional Management Measures for forest roads, I rely on Mills et al. (2005) as the primary reference describing the intent, scope, and accomplishments of Oregon's programmatic approach to this challenge. In my discussion I have been asked to concentrate on that portion of impacts to streams that result from roads other than the delivery of polluted runoff from pipes or ditches directly to surface waters, which has been legally determined to be regulated as a point source discharge. While a large portion of polluted road runoff that reaches surface waters is conveyed through culverts or constructed ditches, a good deal is delivered through dispersed runoff from road surfaces, from piped or ditched flows that are secondarily diverted by soil plugs, debris or snow and ice, and subsequently disperse across the roadway and are delivered to streams and wetlands via fluvially excavated rills and gullies (i.e, directly delivered to streams not by way of an engineered conveyance). Such channel-incising runoff can initiate during intense rainstorms or rapid snowmelt events anywhere there is a dip or graded irregularity in the road surface.

71. Once they attain a channel-forming condition, I have observed the resulting rill or gulley incising slopes to penetrate downslope 150-350 feet or more through fully vegetated streamside forests, carving across floodplains and entering

natural surface streams and wetlands as sediment-laden flows. Essentially these constitute newly formed first-order stream channels that exist solely as a function of distortion of slope drainage by the road surface. These features are particularly problematic and common on stream-parallel timber hauling routes, and I have observed them commonly in the Oregon Coastal Zone after high rainfall and rapid snowmelt events. These non-point source rill and gulley features most commonly develop on roads that are rutted or have their grades and surface drainage distorted by soil slumping, as well as on roads that lack drainage relief structures or where such structures have failed because improper design or maintenance. However, they also occur with frequency along wider, surfaced main haul routes where the expansive, low permeability rocked or paved road surface can generate a high volume of both runoff and sediment during flashy storm events. Even a slight distortion or dip on a major haul road can draw enough runoff to initiate gulley incision and fluvial erosion in most Coast Range soils, especially in the North Coast and Siskiyou regions where rainfall intensities can be particularly high. While less commonly associated with properly outsloped roads, they can occur when the outsloped road contours are disrupted by heavy traffic or deep-seated failure of soils underlying the road prism, or occasionally, when outsloped roads are improperly graded leaving an outboard berm that collects runoff.

72. The Oregon Plan as currently formulated (Mills et al. 2005) suffers acutely from a lack of benchmarks, performance standards, and other measurable objectives that could define what an environmentally acceptable road network looks like. There also appears to be no workable comprehensive inventory, survey sample, or self-reporting protocol that could support tracking of activities and road conditions on an ongoing basis.

The highly ambiguous status of "vacated" and "legacy" roads (legacy roads are those not used since 1972, or that were abandoned and improperly vacated since 1972, or whose history relative to the 1972 date is ambiguous) —both from the policy point of view and the biophysical status and impact point of view—further complicates this situation.

73. Mills et al. (2005) presents a plan that may support an incremental but unquantified rate of improvement of actively managed forest roads on private industrial forest lands and state forest lands; however, it's crucial to recognize that reductions in sediment delivery from improvements in the condition of existing roads can easily be offset by the construction of additional roads in the watershed, increasing overall road density. But Mills et al. at best describes an ill-defined plan that has been mostly not implemented on the some-15 percent of the coastal region that is in small woodlot or nonindustrial ownership (Mills et al. 2005, p.18). It provides no visible assessment or plan at all for the extensive federal-state-private "Co-op" (cooperatively managed under federal authority) road network that extends broadly through coastal lands of "checkerboard" or other mixed ownership pattern, which is managed differently from landowner-controlled road networks on private forest lands. (It is unclear how improvements to "Co-op" roads might have been reported in Mills et al [2005] Tables 3-5.) The Plan also appears to provide no mechanism of reporting or improvement for roads not actively in use for forest management or that have never been in use since the 1972 passage of the Oregon Forest Practices Act. It is unclear how the plan tracks and leverages improvements on roads that were abandoned or improperly vacated but are not in current use. It is clear (Mills et al. 2005, p. 11) that as implemented, Oregon requires older roads to be upgraded, or else properly vacated, only when they show signs of

immediate failure that would cause visible damage or when the particular road segment becomes needed for forestry operations. In the absence of immediate use to trigger the upgrade, many older roads are left to erode and fester on the landscape; because they are for the most part not drivable or not driven on, such roads often have serious ongoing erosion and future erosion hazards that are not observed and therefore not repaired.

74. Importantly the regulatory measures (i.e., Best Management Practices) adopted under the Oregon Forest Practices Rules, as outlined in Mills et al. (2005, p.8), offer no specific management requirements or recommended practices to address the specific source and mechanism of sediment from roads that are not delivered through engineered cross drains, as described above, but delivered by way of rills and gullies. However some benefit in this regard may be obtained from the restriction on wet season road use (Mills 2005, p.10) implemented in 2002, which requires operators to cease heavy truck traffic on certain roads where road surfaces are subject to breakdown when saturated. My own observations in the field are that the wet season road use rules are often not implemented or not enforced, and that even heavy recreational traffic by on-road or off-road recreational vehicles, the operators of which are often unaware of wet weather road use rules, contribute to road surface distortion that can result in runoff diversion, rilling and gullying.

75. I also note the regulatory measures and practices outlined in Mills et al. (2005) do not very specifically address the issue of damage to culvert inlets, reported to be a widespread problem by Skaugset and Miller (1998; 28 percent of road-crossing culverts in the Siskiyou georegion had inlet capacities reduced by at least half). Culvert inlets are often damaged when heavy equipment is used to remove sediment or debris

blockages from areas surrounding the end of a culvert. That is, careless implementation of the BMP to clear culvert inlets results in physical damage to those pipes and further constricts culvert inlets. This is relevant here, because if the culvert inlet is plugged, runoff overtops the road, fails to enter the road's designed drainage system, and diverts downslope, often excavating large gullies, triggering fill and slope failures, and transporting sediment before eventually joining a stream. This diverted discharge enters a gray area of point versus nonpoint pollution.

76. A compliance rate of more than 95 percent was reported by Mills et al. (2005, p. 22) for BMPs applied to treat road surface drainage to reduce sediment delivery to streams. Presumably compliance was surveyed across all forest ownership categories, but this was not specified in the report. I believe there are at least two shortcomings to this basis for reporting BMP outcomes. First, if these assessments are accurate, then it conversely means that in five percent of cases inventoried management of roads was distinctly out of compliance with BMPs. Given very high road densities in many watersheds in the Coastal Oregon region, this represents many road miles, and many, many sites, that are delivering sediment to streams as a result of noncompliance with practicable BMPs. Moreover, it is very important to recognize that "full implementation" of BMPs on the mainline portion of the road network does not equate to zero sediment delivery. The actual rate of sediment delivery from roads deemed in full compliance has not been reported, and is undoubtedly quite variable, but based on my field observations it is with certainly always greater than zero. More information is needed to better quantify this source.

77. Second, in my opinion the state's determination of BMP compliance appears to be inflated compared to my personal field observations on several occasions in the coastal zone of Oregon over the past 15 years. While I agree that both design and maintenance considerations on many large industrial forest ownerships in Oregon have improved during that time period, on any typical day in the field in the past decade I have found far more examples of noncompliance, that is, examples of direct sediment delivery from roads surfaces to streams during recent rainstorms or snowmelt events, based on causal events that could be avoided with improved road design or maintenance practices, than these data and conclusions would appear to indicate. They are not at all hard to find. This is the case in particular on certain industrial forest land ownerships (not all) and on state forest lands where road traffic is generally higher than on nonindustrial ownerships.

78. I have also been in the field when Oregon Department of Forestry staff were describing their protocol for determining hydrologic connectivity of road drainage ditches to other geomorphologists and hydrologists. In these professional interactions I noted a high level of disagreement among parties about how road connectivity was determined. Based on this experience and based on visiting some roads described by the state in survey reports (e.g., Skaugset and Miller 1998), it is my professional opinion that the state's surveys of forestry roads in Oregon tend to underestimate hydrologic connectivity as it is generally defined and evaluated in the literature (e.g., Wemple et al. 1996, Jones et al. 2000, Wemple and Jones 2003). I believe the reliability of the Oregon's survey protocol and practices could and should be greatly improved with formal third party review. I also advise the federal agencies to be wary of accepting

Oregon's information on hydrologic connectivity of roads until such a third party review has been accomplished.

79. In its Forest report, the IMST (1999) made 19 specific recommendations for improving road management on Oregon forest lands. These are extracted on p. 7 of Mills et al. (2005). While it appears that Oregon's revision of road rules has been responsive to the IMST's recommendations 8 through 14 on roads, it remains unclear whether the rule changes address the others. For example, in Recommendation 16 the IMST suggested the Oregon Department of Fish and Wildlife and Oregon Department of Forestry "should develop a collaborative program of monitoring to quantify the linkages between parameters of ecosystem condition and wild salmonid recovery." But there is no evidence those agencies have implemented that recommendation. If that collaborative research has been undertaken, there is little hint of it in Mills et al. (2005) and other documents I reviewed in preparing these comments. One obvious objective of such a project would be to develop measurable standards of road condition that could be used to measure the degree of harm that roads cause to salmonids, and in turn provide target conditions for environmentally "safe" forest road systems that could be considered. In the absence of that monitoring, one must assume based on the best available science that forest roads on state and private lands in Oregon are polluting streams and impairing water quality.

80. Another example is Recommendation 19, in which the IMST suggested that the same two agencies "collaborate to develop forest road stream crossing strategies that facilitate the passage of large wood." Here again there is no evidence the agencies have completed the recommended work, at least not to any productive end. This is

unfortunate because "hard crossings" and other structures that replace the function of enclosed culverts could go a long way to improving not just the passage of wood and sediment downstream, but also reducing the vulnerability of roads to stream blockage and drainage diversions that cause both physical and biological damage.

81. Additionally, while upgrading culvert capacity to accommodate an estimate Q50 peak flow (Mills et al. 2005, p.12) is a step forward from past practices, I question whether it is a large enough step. The Q25 design capacity was deemed insufficient because of a high frequency of failure under past hydrologic regimes. While a statistically-derived Q50 capacity might be better suited to past hydrologic regimes, it could well be inadequate to accommodate future hydrologic regimes, given that most regional step-down models of future climate change project flashier and seasonally earlier snowmelt conditions, more rain-on-snow events, and higher rainfall intensity for much of the Coastal Zone (Mote et al. 2005, Dalton et al. 2013).

82. Oregon has adopted no watershed-scale measures of road system condition to establish a benchmark for acceptable conditions for salmon persistence and survival, water quality, and other water resources. This curtails the state's ability to measure progress toward water quality compliance and maintaining beneficial uses, and contributing to salmon recovery. Mills et al. (2005, p. 3) summarily dismiss road density-based metrics as an index of road effects on water quality and fish, with the simple argument that not all road segments have equivalent impact on streams. While this is certainly true, it does not necessarily follow that road density metrics are biophysically irrelevant. Numerous studies have established watershed-scale statistical relationships between road density, stream habitat conditions, and fish populations

(Trombulak and Frissell 2000, Carnefix and Frissell 2009) and road density often rises to the top of the list of landscape physical variables that correlate with fish population status in landscape-scale studies (Baxter et al. 1999, Bradford and Irvine 2000, Sharma and Hilborn 2001, Carnefix and Frissell 2009). Among fish and riparian wildlife species in the coastal region, to my knowledge only the Oregon coast coho has seen formal consideration of the role of road density in contributing to its conservation, in NOAA's report on scientific underpinnings of the species status review (Stout e t al. 2012). Stout et al. pointed out that prior studies of coho production compared across watersheds in British Columbia (Bradford and Irvine 2000) and western Washington (Sharma and Hilborn 2001) found moderate to strong associations of declining coho abundance with road density in the contributing watershed. A close look at Sharma and Hilborn (2001) suggest most of the effect is accounted for by greatly reduced coho production at road densities exceeding about 4 miles per square mile road density in western Washington. While inventory and map data for roads on private forest lands in coastal Oregon are notoriously poor, even a cursory examination of aerial photos with reference to available road maps clearly reveal that many private industrial and some State Forest lands exceed this road density. Harms are likely expressed at much lower road densities in some watersheds, but in this range fish response may be muted by variation such as road condition and locations relative to sensitive habitats, time since road construction, and other factors (Carnefix and Frissell 2009). The most comprehensive analysis for the Oregon coastal zone to date was published by Firman et al. (2011), who found road density of contributing watersheds to be one of the landscape and watershed condition factors that most consistently explained variation in Oregon coast coho salmon

population abundance. Roads segments at high road densities have redundant effects, and the first increments of road construction may impose the largest effects on aquatic ecosystems (Carnefix and Frissell 2009); that is, most ecological harm may be expressed at moderate road densities (relative to contemporary landscape road conditions), and with only marginal further harm at higher road densities. Moreover, while sediment delivery is of undoubted importance, it is not the only mechanism by which roads harm fish and other biota in streams; roads also affect peak and potentially low flows and may increase water temperature fluctuation by intercepting and diverting shallow groundwater, and roads are both sources and vectors for the delivery of nutrients and traffic-borne chemical contaminants to streams and rivers (Trombulak and Frissell 2000, McCarthy et al. 2008). In my professional opinion no watershed or regional standard or metric of environmental acceptability of road network condition is going to be successful at explaining biological conditions and responses if it does not incorporate some measure of road density that accurately reflects the impact of all extant roads on the ground—including abandoned roads.

83. In my opinion the inherent contribution of forest roads to nonpoint source pollution, in particular sediment but also nutrients, to streams, coupled with the extensive occurrence of forest roads directly adjacent to streams through large portions of the coastal Oregon area, adversely affects water quality in streams to a degree that is directly harmful to fish and other aquatic life. In my opinion this impairment occurs on a widespread and sustained basis; runoff from roads may be episodic and associated with annual high rainfall or snowmelt events, but once delivered to streams, sediment and associated pollutants deposited on the streambed cause sustained impairment of habitat

for salmon and other sensitive aquatic and amphibian species. Current road design, management of road use and conditions, the locations of roads relative to slopes and water bodies, and the overall density of roads throughout most of the coastal area all contribute materially to this impairment. This effect is apart from, but contributes additively in effect to, the point source pollution associated with road runoff that is entrained by culverts or ditches before being discharged to natural waters.

LANDSLIDES

84. The Federal agencies in the Finding (2012) point out that Oregon Forest Practices impose constraints on logging and roadbuilding on unstable slopes and other high-risk landslide prone areas, but only where landslides pose risks to life and property. The Finding calls for the State to adopt similar harvest and road construction restrictions for all high-risk landslide prone areas with the potential to impact water quality and designated uses. I concur, and would add that this will require not just identification and implementation of effective management measures to mitigate landsliding and its harms to water, fish and wildlife, but Oregon will have to decide on a framework for determining risk allocation in applying mitigation measures. For example, the federal agencies under the Northwest Forest Plan ostensibly aim for a target of no increase in landslide rates, or no departure of landslide regime from natural-historical conditions. Of course with existing infrastructure of roads and clearcuts on the landscape, this is difficult or impossible to actually achieve. But it does provide a rational management goal—that is, human-caused landslides in all circumstances are to be avoided. Oregon completely lacks overarching guidance on controlling mass erosion from land

management practices for environmental resource protection and this is a very significant deficiency in its forest practices program.

85. Oregon appears to be extremely slow to embrace scientific advances in the understanding of the mechanisms and causes of landslide initiation and factors that affect their behavior and influence on the landscape once initiated. For example, Schmidt et al. (2001) presented persuasive physical evidence that variability in root cohesion is a major component of landslide initiation, and they provided empirical evidence that lateral root cohesion diminishes by an order of magnitude from mature, conifer-dominated forests to clearcuts. Moreover, root cohesion in second-growth industrial forest, while variable, is in many cases more similar to clearcuts than to mature conifer forests, and this comports with incidence and volume of mass of landsliding observed in many careful, ground-validated empirical studies. (Sources reviewed in Beschta et al. 1995, Robison et al. 1999, Sidle 2006). The work of Schmidt et al. (2001) shows that short-rotation industrial forestry on state, county, and private forest lands in the coastal Oregon region has elevated hillslope vulnerability to landsliding over very large areas compared to pre-management conditions, and that only marginal recovery of slope stability is seen in second-growth forests that today dominate the Coastal landscape. Schmidt et al. (2001) further showed that the practice of herbicide spraying further decreased root cohesion, extending the time window of elevated landslide hazard. Roering et al. (2003) extended that framework to show that landslide incidence in the Mapleton area could be predicted readily by careful mapping of forest vegetation that corresponded with lateral root cohesion. In other words, root strength can be predicted by mapping the distribution and characteristics of trees on potentially unstable slopes—and root strength changes rapidly

if those trees in vulnerable locations are logged.

Debris flows

86. In the Oregon coastal zone, debris flows originating from roads and clearcuts are, on average, larger and travel longer distances than landslides originating in mature forest cover (May 2002, May and Gresswell 2003, Lancaster et al. 2003). They commonly contain less wood than debris flows originating from and passing through mature and old growth forests. The result of this consistent pattern is larger and more frequently scoured areas impacted by larger debris flows than would occur under natural forested conditions with smaller and less frequent debris flows on the landscape (Lancaster et al. 2003). Miller and Burnett (2008), building on earlier work by Benda and Cundy (1990), offer a comprehensive mapping scheme using existing data and established geophysical physical relationships to digitally identify run-out zones and potential initial sites of debris flows. This approach can be used to develop high-resolution risk maps of Coast Range forests to identify zones where logging could be restricted to maintain root strength and moisture balance, and where roads should be avoided. Presumably because some significantly large areas of private and state would be justifiably classified as hazardous for logging, Oregon has resisted putting available science to work to develop a credible mitigation scheme to protect water, fish and wildlife from harmful landslides under a human-accelerated regime.

87. The lack of best practices to reduce harm to stream resources from landslides in the Coastal zone is not a result of any lack of scientific tools. However, it is clear that potentially large adjustments of practices and current expectations of timber harvest from landslide-prone industrial and state forest lands will be needed for effective

practices to be implemented. In my opinion, the transformation of coastal stream habitats by extensive scour in some locations and sediment deposition in others associated with accelerated rates of landsliding and increased frequency and runout distance of debris flows--both caused by logging on private and state forest lands-- contributes causally to widespread impairment of habitat essential for sustaining fish and aquatic life, and fishing in streams of the Oregon coastal zone. Those impairments, of course, violate Oregon's numeric, narrative, and antidegradation water quality standards where they occur. Under current management of private forest lands in Oregon, and factoring in both road and logging-related contributions to risk, it appears the overall incidence of landslides and debris flows that impair water resources is increased by roughly an order of magnitude in the coastal Oregon area (the measured magnitude varies widely by road conditions, recent extent of logging, slope conditions, stream network geography, and the timing of triggering storm events).

FOREST CHEMICAL APPLICATIONS

88. Pesticides in most common use by aerial spraying in coastal Oregon watersheds include herbicides (Hexazinone and 2,4-D, Atrazine, and Glyphosate, Clopyraild and others,) insecticides (Carbaryl and Diflubenzuron) and fungicides (Chlorothalonil). (Dent and Robben 2000, Table 4). Ammonium and nitrate fertilizers are also commonly sprayed over plantations. Aerial spraying is of greatest concern because on forest lands it involves the largest quantities of chemical application over the largest areas, with more potential for advective spread of chemicals from target areas to adjacent riparian areas and water bodies (Dent and Robben 2000).

89. NOAA/NMFS has issued final biological opinions on the use of many pesticides on salmon listed Pacific salmon species in the U.S. (http://www.nmfs.noaa.gov/pr/consultation/pesticides.htm). These opinions are based on exhaustive review of available studies on toxicity, fate and effects, and exposure of fish in the wild to these pesticides under label-conformant applications. To date NMFS has determined that some of these chemicals (e.g., 2.4-D, Carbaryl) are likely to jeopardize salmon under prevailing use, and Chlorothalonil is likely to adversely modify aquatic habitats in ways that harm salmon.

90. In this section I specifically focus on whether Oregon's regulatory requirements for forest chemical applications (pesticides, herbicides, etc.) are sufficient to protect water quality in all streams. Beyond label application requirements, Oregon's Forest Practices Rules (Dent and Robben 2000) preclude direct aerial herbicide application within 60 feet of significant wetlands, Type F or D streams, large lakes, other lakes with fish use, and other areas of open water larger than one-quarter acre at the time of application. No herbicide application buffer is specified in the chemical rules for streams which are neither Type F nor D—that is Type N streams, including those with perennial flow and those with seasonal flow. Under Oregon rules, all herbicide applications must ensure retention of the riparian vegetation components required by the forest practices water protection rules.

91. It is a simple matter to conclude that Oregon's forest chemical application rules are not protective of all streams and wetlands. First, many water bodies are afforded no mandatory application buffer whatsoever, so chemicals may be sprayed to the water's edge, and some level of overspray, indirect drift, and delivery by surface

runoff or by groundwater transport through soil macropores (Armstrong et al. 2000) into adjacent water bodies is inevitable (even when direct application to waters is forbidden) (Harris and Forster 1997, Battaglin et al. 2008). These vulnerable waters in the coastal Oregon zone forest area include headwater streams above fish barriers and small wetlands and ponds, all of which are important for a wide variety of amphibians and invertebrates that may be vulnerable to pesticide toxicity (Howe et al. 2004, Relyea 2005). Moreover, drift into non-fish perennial streams can be expected to result in direct aqueous delivery of entrained chemicals to fish-bearing streams immediately downstream. "Intermittent" or "patch" retention requirements for Type N perennial streams only partially buffer them from chemical drift. Second, riparian retention rules that allow extensive thinning of riparian stands to within 20 feet of the water's edge result in a riparian vegetative buffer that may be highly porous to aerial drift, much more so than dense, unlogged riparian forest; when coupled with application rules that allow aerial spraying within 60 feet of fish-bearing streams, some penetration to streams is highly likely to occur under all but the most ideal circumstances. A third concern is that because Oregon's riparian rules do not adequately buffer streams from slope erosion and sediment delivery, and because Oregon's forest road rules leave hydrologic connectivity of many roads entirely untreated, pesticide residues and toxic breakdown products may be delivered to streams indirectly in runoff or bound to sediment or organic particles mobilized by erosion processes. Where the latter process is prevalent, concentrations of chemicals may briefly spike with the season's first higher flows before they fall to dilute concentrations with sustained higher flow levels in winter (Chiovarou and Siewicki 2008). This exposure may reflect a mix of breakdown products that are not always

measured with tests for the originally applied product (Kolpin et al. 2006, for example showed that the Glyphosate degrade AMPA was detected much more frequently in stream water than Glyphosate itself).

92. In a limited field investigation by the Oregon Department of Forestry, Dent and Robben (2000) concluded that aerially sprayed herbicide and fungicide did not reach known toxic concentrations in the water of adjacent, buffered Type F and D streams. Retained riparian vegetation was not killed by herbicide application in this study. However, some delivery of chemical residues to stream water was measured at low concentrations. The study did not assess the effectiveness of water quality protection with typical application practices on streams without overstory riparian buffers such as Type N streams. Given the design limitations and limited sample, including the fact that herbicide application occurred six to eighteen months prior to the field evaluation, and the problem that applicators were aware that the study was proceeding, which may have biased them to conservative application methods, in my opinion the Oregon Department of Forestry was and remains greatly overly optimistic in concluding that its rules are protective of surface water resources. The frequent, if not near-ubiquitous detection of pesticide residues in water quality monitoring samples in Oregon (e.g. the USGS Clackamas Study, http://pubs.usgs.gov/sir/2008/5027/section6.html, Carpenter et al. 2008) suggest that the problem is more widespread and systematic, and less controlled by existing rules and practices, than Oregon admits.

93. My professional opinion is that Oregon forest practices rules are insufficiently formulated to directly or indirectly prevent forest pesticides from entering surface waters at sufficient concentration to cause deleterious impacts to aquatic life;

harms are likely greatest in headwater streams and small wetland where vegetative buffers are not required, where application may occur to the water's edge, and where concentrations are likely highest because water flows are low. Depending on their specific effects, pesticides may pose risk of direct toxicity, or may injure aquatic animals by impacting their food supply, or by way of other ecological impacts. (See http://www.nmfs.noaa.gov/pr/consultation/pesticides.htm).

HYPOTHETICAL 85-FOOT NO-CUT STREAM BUFFER

94. I have been told that Oregon might consider adopting an 85-foot no-cut buffer rule for fish-bearing (Type F) streams. In the event such an alternative practice is adopted for Oregon private and state forest lands, I have included a brief analysis here of its likely effects with regard to compliance with water quality standards.

95. Eighty-five foot no-cut buffers, if implemented, would result in temperature increases of less than 0.3 degrees C at some sites, while others would likely see measurable increases exceeding 0.3 degrees C. Based on RipStream data made available to date, no-cut buffers of 90 to100 feet would appear to be necessary to ensure shade loss is not driving temperature increases at all sites. I note that in Oregon where waters have been deemed temperature impaired and TMDLs developed that apply to all perennial streams in a basin or watershed, the load allocation to those waters is zero or close to zero; this argues for application of a conservative buffer rule that ensures against adverse warming of all streams, not just a portion of them.

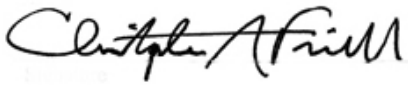
96. If an 85-foot no-cut buffer were to be adopted for small, medium and large fish-bearing streams, and if this prescription also specifically prohibited operations that

result in ground disturbance within the 85-foot buffer, this would largely mitigate on-site, nonpoint source sediment delivery associated with ground disturbance from logging activities. However, logging operations within 30 feet any stream will still result in contributions of sediment that will violate water quality standards. And if headwater Type N streams were not protected with a no-disturbance, no vegetation removal buffer of 30 feet width or greater, sediment delivery to more widespread Type N streams that are generally on sleeper slopes where sediment mobilization add delivery are higher overall) would continue to impair water quality conditions in type N streams, as well as impairing water quality in Type F streams immediate downstream, through inexorable sediment transport processes.

97. If 85-foot no-cut buffers were applied across all type F streams, woody debris recruitment rates would likely increase substantially over present practices but would still be insufficient compared to debris recruitment rates expected to occur with wider buffers of 150+ feet, or under natural forest conditions. Eighty-five foot no-cut buffers on Type F streams would not be sufficient to eliminate water quality impairment from nonpoint sources associated with roads; while it would somewhat attenuate sediment pollution from stream parallel roads along type F streams, it would do nothing to protect more numerous Type N streams from sediment pollution, and sediment pollution in headwater Type N streams will in most cases be transported downstream to impair Type F streams as well. No cut buffers of 85-foot width would also attenuate pesticide drift to a more effective degree than present narrower or thinned-put buffers, but again, the lack of protection for Type N headwater means Type F streams would be impaired through inevitable transport of contaminants downstream.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Signed this _14th_ day of March, 2014, in Polson, Montana.



_____

CHRISTOPHER A. FRISSELL

Literature Cited

Armstrong, A. C., Matthews, A. M., Portwood, A. M., Leeds-Harrison, P. B., & Jarvis, N. J. 2000. CRACK-NP: a pesticide leaching model for cracking clay soils. *Agricultural Water Management* 44(1):183-199.

Bahuguna, D., Mitchell, S. J., & Miquelajauregui, Y. 2010. Windthrow and recruitment of large woody debris in riparian stands. *Forest ecology and Management* 259(10):2048-2055. http://cef-cfr.ca/uploads/Membres/Windthrow.pdf

Battaglin, W. A., Rice, K. C., Focazio, M. J., Salmons, S., & Barry, R. X. 2009. The occurrence of glyphosate, atrazine, and other pesticides in vernal pools and adjacent streams in Washington, DC, Maryland, Iowa, and Wyoming, 2005–2006. *Environmental Monitoring and Assessment* 155(1-4):281-307.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads and the distribution of bull trout *(Salvelinus confluentus)* spawning in a forested river basin: implications for management and conservation. *Transactions of the American Fisheries Society,* 128:854-867.

Benda, L.E., and T.W. Cundy.1990. Predicting deposition of debris flows in mountain channels. *Can. Geotech. Journal* 27: 409-41.7

Beschta, R.L., and 12 others. 1995. Cumulative effects of forest practices in Oregon. Report prepared for Oregon Department of Forestry, Salem, OR. 705 pp. http://ferm.forestry.oregonstate.edu/sites/default/files/pdf/CumulativeEffectsofForestPractices.pdf

Blair, M.S. 1994. Oregon Coastal Lake Study: Phosphorus Loading and Water Quality Implications. M.S. Thesis, Oregon State University, Corvallis, OR. 114

Bourque, C.P.A., and J.H. Pomeroy. 2001. Effects of forest harvesting on summer stream temperatures in New Brunswick, Canada: An inter-catchment, multiple-year comparison. *Hydrology and Earth System Sciences* 5(4):599-613.

Michael J Bradford, M.J., and J. R Irvine. 2000. Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. C*anadian Journal of Fisheries and Aquatic Sciences*, 2000, 57(1): 13-16, 10.1139/f99-283.

Brummer, C.J., T.B. Abbe, J.R. Sampson, and D. Montgomery. 2006.
Influence of vertical channel change associated with wood accumulations on delineating channel migration zones, Washington, USA. Geomorphology 80 (2006) 295–309. http://www.capr.us/PDFs/workshop_2011/References/Fluvial%20Geomorphology/brummer_etal_2006_geomorph80.pdf

Burnett, K.M. and D.J. Miller. 2007. Streamside policies for headwater channels: An example considering debris flows in the Oregon Coastal Province. *Forest Science* 53: 239-253. [online] URL: http://www.fs.fed.us/pnw/lwm/aem/docs/burnett/2007_burnett_miller_forsci_streamsidepol.pdf

Carnefix, G., and C. A. Frissell. 2009. Aquatic and Other Environmental Impacts of Roads: The Case for Road Density as Indicator of Human Disturbance and Road-Density Reduction as Restoration Target; A Concise Review. Pacific Rivers Council Science Publication 09-001. Pacific Rivers Council, Portland, OR and Polson, MT. [online] URL: http://pacificrivers.org/science-research/resources-publications/road-density-as-indicator/download

Carpenter, K.D., S. Sobieszczyk, A.J. Arnsberg, and F.A. Rinella. 2008. Pesticide Occurrence and Distribution in the Lower Clackamas River Basin, Oregon, 2000–2005. U.S. GEOLOGICAL SURVEY Scientific Investigations Report 2008–5027. Prepared in cooperation with the Clackamas Watershed Management Group (Clackamas River Water Providers and Clackamas County Water Environment Services) and the National Water-Quality Assessment Program. http://pubs.usgs.gov/sir/2008/5027/section6.html

Chiovarou, E. D., & Siewicki, T. C. 2008. Comparison of storm intensity and application timing on modeled transport and fate of six contaminants. *Science of the Total Environment* 389(1):87-100.

Cloern, J.E. 2003. Our evolving conceptual model of the coastal eutrophication problem. *Marine Ecology Progress Series* 210:223-253.

Committee on Environment and Natural Resources. 2010. Scientific Assessment of Hypoxia in U.S. Coastal Waters. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC. http://www.whitehouse.gov/sites/default/files/microsites/ostp/hypoxia-report.pdf

Compton, J.E., M. R. Church, S.T. Larned, and W.E. Hogsett. 2003. Nitrogen Export from Forested Watersheds in the Oregon Coast Range: The Role of N2-fixing Red Alder. *Ecosystems* 6:773–785. DOI: 10.1007/s10021-002-0207-4. [online] URL: http://andrewsforest.oregonstate.edu/pubs/pdf/pub4402.pdf

Cordone, A. J., & Kelley, D. W. 1961. *The influences of inorganic sediment on the aquatic life of streams*. California Department of Fish and Game. http://www.nativefishlab.net/library/textpdf/17590.pdf

Daggett, S.G., A. H. Vogel, and R. R. Petersen. 1996. Eutrophication of Mercer, Munsel, and Woahink Lakes, Oregon. *Northwest Science* 70 (Special Issue 2):28-38.

Dalton, M.M., P.W. Mote, and A.K. Snover. 2013. *Climate Change in the Northwest Implications for Our Landscapes, Waters, and Communities*. Island Press, Washington DC. 271 pp.

Dent. L. and J. Robben. 2000. Oregon Department of Forestry: Aerial pesticide application monitoring. Oregon Department of Forestry Forest Practices Monitoring Program Technical Report 7. Salem, OR. 35 pp.

Dent, L., D. Vick, K. Abraham, S. Shoenholtz, and S. Johnson. 2008. Summer temperature patterns in headwater streams of the Oregon Coast Range. *Journal of the American Water Resources Associatio*n 44: 803-813.

Firman, J. C., E.A. Steel, D.W. Jensen, K.M. Burnett, K. Christiansen, B.E. Feist, Blake E., D.P. Larsen, and K. Anlauf. 2011. Landscape Models of adult coho salmon density examined at four spatial extents. *Trans. Am. Fisheries So.c* 140:440-455. DOI: 10.1080/00028487.2011.567854.

Freeman, M.C., C.M. Pringle, and C.R. Jackson. 2007. Hydrologic connectivity and the contribution of stream headwaters to ecological integrity and regional scales. *Journal of the American Water Resources Association* 43(1):5-14. DOI: 10.1111/j.1752-1688.2007.00002.x. http://www.researchgate.net/publication/227601517_Hydrologic_Connectivity_and_the_Contribution_of_Stream_Headwaters_to_Ecological_Integrity_at_Regional_Scales1/file/9c960524a16d6690a6.pdf

Frissell, C.A. 1992. Cumulative effects of land use on salmon habitat in southwest Oregon coastal streams. Doctoral dissertation, Oregon State University, Corvallis, OR.

Glazik, R. 1987. Dynamics of shallow groundwater temperaure in the Vistula abandoned valley, the Plock Basin. *Geographica Polonica* 53:115-128. http://rcin.org.pl/igipz/Content/4204/WA51_13403_r1988-t53_Geogr-Polonica.pdf#page=121

Gomi, T., R. C. Sidle, and J. S. Richardson. 2002. Understanding processes and downstream linkages of headwater streams. *BioScience* 52:905-916.

Gomi, T., R. D. Moore, and M. A. Hassan. 2005. Suspended sediment dynamics in small forest streams of the Pacific Northwest. *Journal of the American Water Resources Association* 41(4):877-898.

Gravelle, J.A., G. Ice, T.E. Link, and D.L. Cook. 2009. Nutrient concentration dynamics in an inland Pacific Northwest watershed before and after timber harvest. *Forest Ecology and Management* 257:1663-1675.

Groom, J.D., L. Dent, and L.J. Madsen. 2011a. Response of Western Oregon Stream

Temperatures to Contemporary Forest Management. *Forest Ecology and Managemen*, 262.8 (2011): 1618-1629.

Groom, J.D., L. Dent, and L.J. Madsen. 2011b. Stream temperature change detection for state and private forests in the Oregon Coast Range. *Water Resources Research* 47.1 Accessed November 27, 2013. doi:10.1029/2009WR009061.

Harris, G.L., and A. Forster. 1996. Pesticide contamination of surface waters: potential role of buffers zones. Pp. 62-69 in *Buffer Zones: Their Processes and Potential in Water Protection,* NE Haycock, TP Burt, KWT Goulding, and G. Pinay, Editors. Quest Environmental.Greenwood Village, CO.

Howe, C. M., Berrill, M., Pauli, B. D., Helbing, C. C., Werry, K., & Veldhoen, N. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. *Environmental Toxicology and Chemistry*, *23*(8): 1928-1938.

IMST. 1999. Recovery of Wild Salmonids in Western Oregon Forests: Oregon Forest Practices Act Rules and the Measures in the Oregon Plan for Salmon and Watersheds. Independent Multidisciplinary Science Team (IMST). Technical Report 1999-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, Oregon, 1999.

Janisch, J.E, S.M. Wondzell, and W.J. Ehninger. 2012. Headwater stream temperature: Interpreting response after logging, with and without riparian buffers, Washington, USA. *Forest Ecology and Management* 270:302-313.

Johnson, S.L., and Julia A. Jones. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Can. J. Fish. Aquat. Sci.* 57(Suppl. 2): 30–39. http://andrewsforest.oregonstate.edu/pubs/pdf/pub2640.pdf

Jones, J. A., F. J. Swanson, B. C. Wemple, and K. U. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. *Conservation Biology* 14: 76-85.

Klein, R.D., Lewis, J., Buffleben, M.S. Logging and turbidity in the coastal watersheds of northern California. *Geomorphology* 139–140 (15 February 2012):136-144. ISSN 0169-555X, 10.1016/j.geomorph.2011.10.011. [online] URL: http://www.sciencedirect.com/science/article/pii/S0169555X11005277

Kolpin, D. W., Thurman, E. M., Lee, E. A., Meyer, M. T., Furlong, E. T., & Glassmeyer, S. T. (2006). Urban contributions of glyphosate and its degradate AMPA to streams in the United States. *Science of the Total Environment* 354(2):191-197.

Kubin, E. 2006. Leaching of Nitrogen from upland forest-regeneration sites into wetland areas. Pp. 87-94 in Krecek, J. and M. Haigh (eds.) *Environmental Role of Wetlands in Headwaters*. Springer, The Netherlands.

Lancaster, S.T., S. K. Hayes, and G.E. Grant. 2003. Effects of wood on debris flow runout in small mountain watersheds. *Water Resources Research* 39(6): 1168. doi: 10.1029/2001 WR001227.

Leslie M. Reid, Thomas Dunne. 1984. Sediment Production From Forest Road Surfaces. *Water Resour. Res.* 20(11):1753-1761. DOI:10.1029/WR020i011p01753

Lowe, W.H., and G.E. Likens. 2005. Moving Headwater Streams to the Head of the Class. *BioScienc*e 55(3):196-197.

May, C.L. 2002. Debris flows through different forest age classes in the Central Oregon Coast Range. *Journal of the American Water Resources Association* 38(4): 1097-1113.

May, C. L., abd R. E. Gresswell. 2003. Large wood recruitment and redistribution in headwater streams in the southern Oregon Coast Range, U.S.A. *Can. J. For. Res.* 33: 1352–1362.

McCarthy S.G., Incardona J.P., and Scholz N.L. 2008. Coastal storms, toxic runoff, and the sustainable conservation of fish and fisheries. American Fisheries Society Symposium 64: 1-21.

McCullough, D. A., Bartholow, J. M., Jager, H. I., Beschta, R. L., Cheslak, E. F., Deas, M. L., & Wurtsbaugh, W. A. 2009. Research in thermal biology: burning questions for coldwater stream fishes. *Reviews in Fisheries Science* 17(1):90-115.

Miller, D.J., and K. M. Burnett. 2008. A probabilistic model of debris-flow delivery to stream channels, demonstrated for the Coast Range of Oregon, USA Geomorphology 94 (2008): 184–205.

Mills. K., L. Dent, J. Paul, and B. Riggers. 2005. Part 4: Reducing effects of roads on salmonids under the Oregon Plan. Oregon Plan Technical Report 1. Salem, OR. 27pp.

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: A review. *Journal of the American Water Resources Association* 41(4):813-834.

Mote, P.W., E.A. Parson, A.F. Hamlet, W.S. Keeton, D. Lettenmaier, N. Mantua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter, and A.K. Snover. 2003. Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. *Climatic Change* 61: 45–88.

Naiman, R.J., Robert J. Naiman, E.V. Balian, K.K. Bartz, R.E. Bilby, and J.J. Latterell. 2002. Dead wood dynamics in stream ecosystems. USDA Forest Service Gen. Tech.

Rep. PSW-GTR-181. Portland, OR. URL: http://grwc.info/Assets/Reports/LWD/Dead-wood-Dynamics.pdf

Newcombe, C.P., and MacDonald, D.D. 1991. Effects of Suspended Sediments on Aquatic Ecosystems. *North American Journal of Fisheries Management* 11:72-82.

Newcombe, C. P., & Jensen, J. O. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. *North American Journal of Fisheries Management* 16(4):693-727.

Nieber, J., C. Arika, C. Lenhart, M. Titov, and K., Brooks. 2011. Evaluation of Buffer Width on Hydrologic Function, Water Quality, and Ecological Integrity of Wetlands. Final Report 2011-06, Minnesota Department of Transportation, Office of Policy, Analysis, and Innovation. St. Paul, MN. 182 pp.

ODF (Oregon Department of Forestry). 2014. Oregon Department of Forestry Forest Practice Administrative Rules and Forest Practices Act . Salem, OR http://www.oregon.gov/odf/privateforests/docs/fparulebk.pdf

Olson, D.H., P.D. Anderson, C.A. Frissell, H. H. Welsh, Jr., and D. F. Bradford. 2007. Biodiversity management approaches for stream-riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management* 246(1): 81-107.

Oregon DEQ (Department of Environmental Quality). 1994. Coquille River and estuary water quality report, Total Maximum Daily Load program. Portland, OR. 48pp. http://www.deq.state.or.us/wq/tmdls/docs/southcoastbasin/coquille/CoquilleRiverTMDL.pdf

Oregon DEQ (Department of Environmental Quality). 2007. Tenmile Lakes Watershed Total Maximum Daily Load (TMDL). Portland, OR. 167 pp. http://www.deq.state.or.us/wq/tmdls/docs/southcoastbasin/tenmile/tmdl.pdf

Oregon DEQ (Department of Environmental Quality). 2010. Turbidity Technical Review: Summary of Sources, Effects, and Issues Related to Revising the Statewide Water Quality Standard for Turbidity. Report 10-WQ-022 , Portland, OR. 82 pp. + appendices. http://www.deq.state.or.us/wq/standards/docs/Turbidity/10-WQ-022.pdf

Pluhowski, E.J., and I.H. Kantrowitz. 1963. Influence of land-surface conditions on ground-water temperatures in south-western Suffolk County, Long island. USGS Professional Paper: 475-B, article 51, p. B186-B188. http://pubs.er.usgs.gov/publication/pp475B

Pollock, M. M., T. J. Beechie, M. Liermann, and R. E. Bigley. 2009. Stream temperature relationships to forest harvest in western Washington. DOI: 10.1111 / j.1752-

1688.2008.00266.x. *Journal of the American Water Resources Association* (JAWRA) 45(1):141-156.

Pollock, M. M., T. J. Beechie, and H, Imaki. 2012. Using reference conditions in ecosystem restoration: an example for riparian conifer forests in the Pacific Northwest. Ecosphere 3(11) Article 98: 1-23. URL: http://dx.doi.org/10.1890/ES12-00175.1

Pollock, M. M., and T. J. Beechie. 2012. Assessing the effect of thinning on riparian forest structure important to ESA-listed and other species in decline. In *AWRA 2012 Summer Specialty Conference: Riparian Ecosystems IV: Advancing Science, Economics and Policy.* Denver, Colorado. 27-29 June 2012. 4pp.

Poole, G.C., and C.H. Berman. 2001. An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation. *Environmental Management* 27(6):787–802. [online] URL: http://www.azwater.gov/AzDWR/SurfaceWater/Adjudications/documents/SRP13532-SRP13547.pdf

Rashin, E. B., C.J. Clishe, A.T. Loch, and J.M. Bell. 2006. Effectiveness of Timber Harvest Practices for Controlling Sediment. *Journal of the American Water Resources Association* 42:1307-1347

Reeves, G. H., K. M. Burnett, and E. V. McGarry. 2003. Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon. *Canadian Journal of Forest Research* 33:1363-1370.

Reid, L.M. and S. Hilton. 1998. Buffering the Buffer. In: Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story. U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station, Redwood Sciences Lab, Arcata, CA. [online] URL: http://www.fs.fed.us/psw/publications/documents/gtr-168/08reid.pdf

Reid, L.M., N.J. Dewey, T.E.; Lisle, and S. Hilton. 2010. The incidence and role of gullies after logging in a coastal redwood forest. *Geomorphology* 117: 155-169. [online] URL: http://naldc.nal.usda.gov/download/40745/PDF

Reid, L.M. and S. Hilton. 1998. Buffering the Buffer. In: Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story. U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station, Redwood Sciences Lab, Arcata, CA. [online] URL: http://www.fs.fed.us/psw/publications/documents/gtr-168/08reid.pdf

Relyea, R. A. (2005). The lethal impact of Roundup on aquatic and terrestrial amphibians. *Ecological Applications* 15(4):1118-1124.

Rhodes, J, J., D.A. McCullough, and F. A. Espinosa. 1994. A coarse screening process for evaluation of the effects of land management activities on salmon spawning and

rearing habitat in ESA consultations. Columbia River Inter-Tribal Fish Commission, Technical Report 94-4. Portland, OR. 245pp.

Robison, E. G., K. A. Mills, J. Paul , L. Dent, and A. Skaugset. 1999. Oregon Department of Forestry Storm Impacts and Landslides of 1996: Final Report. Oregon Department of Forestry, Forest Practices Monitoring Program, Salem, OR. 145 pp.

Roering, J.J., Schmidt, K.M., Stock, J.D., Dietrich, W.E., Montgomery, D.R., 2003, Shallow landsliding, root reinforcement, and the spatial distribution of trees in the Oregon Coast Range. *Canadian Geotechnical Journal* 40: 237–253.

Schmidt, K.M. , J.J. Roering, J.D. Stock, W.E. Dietrich, D.R. Montgomery, and T. Schaub. 2001. The variability of root cohesion as an influence on shallow landslide susceptibility in the Oregon Coast Range. *Can. Geotech. J.* 38:995–1024.

Schuett-Hames, D., A. Roorbach, and R. Conrad. 2011. Results of the Westside Type N Buffer Characteristics, Integrity and Function Study Final Report. Cooperative Monitoring Evaluation and Research Report, CMER 12-1201. Washington Department of Natural Resources, Olympia, WA.
http://www.dnr.wa.gov/Publications/fp_cmer_12_1201.pdf

Seavy, N. E., T. Gardali, G. H. Golet, F. T. Griggs, C. A. Howell, R. Kelsey, S. L. Small, J. H. Viers, J. F. Weigand. 2009. Why climate change makes riparian restoration more important than ever: recommendations for practice and research. *Ecological Restoration* 27(3): 330-338. URL: http://er.uwpress.org/content/27/3/330.full.pdf+html

Sharma, R. and R. Hilborn. 2001. Empirical Relationships between Watershed Characteristics and Coho Salmon (*Oncorhynchus kisutch*) Smolt Abundance in 14 Western Washington Streams. *Can J. Fish Aquat Sci.* 58:1453-1463.

Sidle, R.C. 2005. Influence of forest harvesting activities on debris avalanches and flows. In *Debris-flow hazards and related phenomena* (pp. 387-409). Springer Berlin Heidelberg. http://link.springer.com/chapter/10.1007%2F3-540-27129-5_16#page-1

Skaugset, A., and M.M. Allen. 1998. Forest Road Sediment and Drainage Monitoring Project Report for Private and State Lands in Western Oregon.
Report for Oregon Dept. of Forestry, Salem, OR, 20 Feb. 1998. Oregon State University, Forest Engineering Dept., Corvallis, OR.

Spies, T., M. Pollock, G. Reeves1 and T. Beechie. 2013. Effects of Riparian Thinning on Wood Recruitment: A Scientific Synthesis. Report of the Science Review Team, Wood Recruitment Subgroup. USDA Forest Service Forestry Sciences Laboratory, Corvallis, OR, and Northwest Fisheries Science Center, Seattle, WA. 46 pp.

Stout, H.A., P.W. Lawson, D.L. Bottom, T.D. Cooney, M.J. Ford, C.E. Jordan, R.G.

Kope, L.M. Kruzic, G.R. Pess, G.H. Reeves, M.D. Scheuerell, T.C. Wainwright, R.S. Waples, E. Ward, L.A. Weitkamp, J.G. Williams, and T.H. Williams. 2012. Scientific conclusions of the status review for Oregon coast coho salmon (*Oncorhynchus kisutch*). U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-118, 242 p.

Swanston, D.N., G.W. Lienkaemper, R.C Mersereau, and A.B. Levno. 1988. Timber harvest and progressive deformation of slopes in southwestern Oregon. *Association of Engineering Geologists Bulletin* 25(3): 371-381. http://andrewsforest.oregonstate.edu/pubs/pdf/pub867.pdf

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18-30.

Wemple, B.C., and J. A. Jones. 2003. Runoff production on forest roads in a steep, mountain catchment. *Water Resour. Res.* 39(8), 1220. doi:10.1029/2002WR001744.

Wemple B.C., J.A. Jones, and G.R. Grant. 1996. Channel network extension by logging in two basins, western Cascades, Oregon. *Water Resources Bulletin* 32:1195-1207.

Wenger, S. 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia, Athens, Georgia, USA. http://www.cc.utexas.edu/law/centers/cppdr/services/Improving%20Streams%20web/Work%20Groups/Public%20Lands/Wegner_1999_Review_of_buffer_width.pdf

Wickham, J.D., T.G. Wade, and K.H. Ritters. 2008. Detecting temporal change in watershed nutrient yields. *Environmental Management* 42:3223-231.

Wondzell, S.M. 2011. The role of the hyporheic zone across stream networks. *Hydrologic Processes* 25(22):3525-2532. DOI: 10.1002/hyp.8119.

Curriculum Vitae *9 March 2014* *18pp.*

CHRISTOPHER A. FRISSELL

Consulting Research Ecologist and
Freshwater Conservation Biologist
39625 Highland Drive
Polson, Montana 59860

Phone: 406.883.3891/Mobile 406.471.3167
e-mail: *leakinmywaders@yahoo.com*
WWWeb: https://www.researchgate.net/profile/Christopher_Frissell/

Birth: 1 December 1960, Chehalis, Washington

Education: Ph.D. in Fisheries Science, Oregon State University, 1992
M.S. in Fisheries Science, Oregon State University, 1986
B.A. with High Honors in Zoology, University of Montana, 1982

Professional Appointments:

Affiliate Research Professor, Flathead Lake Biological Station, and Systems Ecology Program (*pending*), The University of Montana, 2014-present
Self Employed, Consulting Ecologist 2012-present
Director of Science and Conservation and Senior Staff Scientist, The Pacific Rivers Council, 2000-2012
Research Associate Professor, The University of Montana, Flathead Lake Biological Station, 1998-2000
Research Assistant Professor, The University of Montana, Flathead Lake Biological Station, 1993-1998
Research Assistant Professor, Department of Fisheries and Wildlife, Oregon State University, 1994-1997
Postdoctoral Research Associate (Faculty), Department of Fisheries and Wildlife, Oregon State University, 1992-1994
Research Assistant (Faculty), Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, 1985-1992

Fields of Interest:

- Land-aquatic ecosystem linkages
- Ecology, biogeography, and conservation biology of fishes and freshwater biota in relation to landscape and hydrologic change.
- Cumulative impacts of natural processes and human activities on stream habitat
- Aquatic ecosystem conservation and restoration strategies.
- Geomorphic, hydrophysical, and landscape ecology considerations in design of integrated conservation reserves.
- Restoration and recovery planning and design for freshwater ecosystems and species.

Theses and Dissertations:

Frissell, C.A. 1992. Cumulative effects of land use on salmon habitat in southwest Oregon coastal streams. Doctoral dissertation, Oregon State University, Corvallis.

Frissell, C. A. 1986. A hierarchical stream habitat classification system: development and demonstration. M.S. thesis, Oregon State University, Corvallis.

Frissell. C. A. 1982. Colonization and development of community structure in coexisting Ephemerellid mayflies (Ephemeroptera, Ephemerellidae). Senior Thesis, Watkins Scholarship Program, The University of Montana, Missoula.

Professional Societies:

Society for Conservation Biology, 1991-present
American Fisheries Society, 1985-present
Ecological Society of America, intermittent

North American Benthological Society, intermittent

Graduate Students Mentored

Cavallo, B.J. M.S. in Organismal Biology and Ecology, The University of Montana, 1997. Thesis title: *Floodplain habitat heterogeneity and the distribution, abundance, and behavior of fishes and amphibians in the Middle Fork Flathead River Basin, Montana.*

Adams, S. B. Ph.D.in Organismal Biology and Ecology, The University of Montana, 1999. Dissertation title: *Mechanisms Limiting a Vertebrate Invasion: Brook Trout in Mountain Streams of the Northwestern USA*.

Hitt, N.P. M.S. in Organismal Biology and Ecology, The University of Montana, 2002, *Distribution and potential invasion of introduced rainbow trout in the upper Flathead River drainage.*

Carnefix, G. M.S. in Organismal Biology and Ecology, The University of Montana, 2002. Thesis title: *Movements and ecology of bull trout in Rock Creek, MT.*

Hastings, K. Ph.D.in Organismal Biology and Ecology, The University of Montana, 2005. Dissertation title: *Long-term persistence of isolated fish populations in the Alexander Archipelago.*

Reviewer for Journals and Agency Publications:

Canadian Journal of Fisheries and Aquatic Sciences, Conservation Biology, Ecological Applications, Environmental Management, Fisheries (AFS), Freshwater Biology, North American Journal of Fisheries Management, Oikos, Transactions of the American Fisheries Society, Fundamental and Applied Limnology, USDA Forest Service General Technical Reports

Member of Board of Editors for Journals:

Conservation Biology, 1996-2000

Appointments to Review Panels and Scientific Advisory Committees:

USEPA Bristol Bay Watershed Assessment Team, Subcontractor on road and pipeline impacts, through University of Alaska Anchorage and NatureServe, 2011-2012.

Independent Expert Review Panel for King County Water and Land Resources Division's Project Scoping and Implementation Practices. 2011-12. Subcontractor to MWH (Montgomery Watson Harza) for King County Dept. of Natural Resources and Parks, Seattle, WA. http://www.kingcounty.gov/environment/dnrp/publications/wlrd-expert-review-report.aspx

Umpqua Watersheds Science Advisory Council, Sponsored by Umpqua Watersheds, Inc., 16-17 November 2010, Roseburg, OR.

Wychus Creek Restoration Monitoring Plan Review Panel, sponsored by Upper Deschutes Watershed Council and Bonneville Environmental Foundation. 2 October 2009, Bend, OR.

Landscape Pattern Task Group, *State of the Nation's Ecosystems* report. 2003-2007. H. John Heinz III Center For Science, Economics and the Environment. Washington, DC. http://www.heinzctr.org/Programs/Reporting/Working%20Groups/Fragmentation/index.shtml

Science Review Team, King County Normative Flow Studies Project. 2002-2005, Seattle, WA. http://dnr.metrokc.gov/wlr/BASINS/flows/science-review-team.htm

Science Advisory Panel, Westside. Governor's Salmon Restoration Funding Board, Washington State, February 2000.

Ecological Work Group, Multi-species Framework Process and Subbasin Assessment Process, Northwest Power Planning Council 1998-2000.

Peer review panelist for U.S. Environmental Protection Agency/National Science Foundation Water and Watersheds Grants Program for 1997. 7-9 May 1997.

Scientific Group for the Governor's Bull Trout Restoration Team, State of Montana, 1994-2000

Oregon Department of Environmental Quality, 1992-95: Temperature Standards Review Subcommittee of the Technical Advisory Committee, Triennial Water Quality Standards Review

Scientific Assessment Panel for amphibian species, Eastside Oregon-Washington and Upper Columbia Basin EIS, US BLM and US Forest Service, 1994

Oregon Department of Forestry, 1990-93: Technical Advisory Group for the Forest Practices Monitoring Program; Wetlands Technical Group; Stream Protection Advisory Panel.

Peer-Reviewed Articles Published in Scientific Journals:

DellaSala, D. A., R.G. Anthony, M.L. Bond, Monica, E.S. Fernandez, C.A. Frissell, Chris, C.T. Hanson, and R. Spivak. 2014. Alternative Views of a Restoration Framework for Federal Forests in the Pacific Northwest. *Journal of Forestry* 111(6):420-429.

Williams, J. E., R. N. Williams, R. F. Thurow, L. Elwell, D. P. Philipp, F. A. Harris, J. L. Kershner, P. J. Martinez, D. Miller, G. H. Reeves, C. A. Frissell, and J. R. Sedell. 2011. Native Fish Conservation Areas: a vision for large-scale conservation of native fish communities. *Fisheries* 36:267-277. http://www.tu.org/sites/www.tu.org/files/documents/Williams%20et%20al.%202011%20Fisheries%20NFCA.pdf

Whiteley, A.R., K. Hastings, J. K. Wenburg, C. A. Frissell, J. C. Martin and F. W. Allendorf. 2010. Genetic variation and effective population size in isolated populations of coastal cutthroat trout. *Conservation Genetics* 11(5):1929-1943. DOI: 10.1007/s10592-010-0083-y

**[Forest Ecology and Management "Highly Cited Author" award for 2007-2010]*

Olson, D.H., P.D. Anderson, C.A. Frissell, H. H. Welsh, Jr., and D. F. Bradford. 2007. Biodiversity management approaches for stream-riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management* 246(1):81-107.Ebersole, J.L., W.J. Liss, and C. A. Frissell. 2007. Cold water patches in warm streams: Physico chemical characteristics and the influence of shading. *Journal of the American Water Resources Association* 39:355-368. (Published online 8 June 2007).

Poole, G.C., J.A. Stanford, S.W. Running, and C.A. Frissell. 2006. Multiscale geomorphic drivers of groundwater flow paths: subsurface hydrologic dynamics and hyporheic habitat diversity. *Journal of the North American Benthological Society*. 25(2): 288-303.

Poole, G. C., J. A. Stanford, S. W. Running, C. A. Frissell, W. W. Woessner, and B. K. Ellis. 2004. A patch hierarchy approach to modeling surface and sub-surface hydrology in complex flood-plain environments. *Earth Surface Processes and Landforms* 29**:** 1259–1284.

Karr, J. R., J. J. Rhodes, G. W. Minshall, F. R. Hauer, R. L. Beschta, C. A. Frissell, and D. A. Perry. 2004. The effects of postfire salvage logging on aquatic ecosystems in the American West. *BioScience* 54:1029-1033. http://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/SalvageLoggingScience/Salvage-Karr04.pdf

Beschta, ,R.L., J. J. Rhodes, J. B. Kauffman, R. E. Gresswell, G. W. Minshall, J. R. Karr, D.A. Perry, F.R. Hauer, C. A. Frissell. 2004. Postfire Management on Forested Public Lands of the Western United States. *Conservation Biology* 18: 957–967. http://www.researchgate.net/publication/227654964_Postfire_Management_on_Forested_Public_Lands_of_the_Western_United_States?ev=prf_pub

Articles Published in Scientific Journals, continued:

Hitt, N.P., and C.A. Frissell. 2004. A case study of surrogate species in aquatic conservation planning. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 14:625–633.

Hitt, N. C., C. Muhlfeld, C.A. Frissell, and F. Allendorf. 2003. Hybridization between native westslope cutthroat trout and non-native rainbow trout. *Canadian Journal of Fisheries and Aquatic Sciences* 60:1440-1451

Poole, G. C., J. A. Stanford, C. A. Frissell and S. W. Running. 2002. *Three-dimensional mapping of geomorphic controls on flood-plain hydrology and connectivity from aerial photos*. ***Geomorphology*** 48(4):329-347.

Adams, S.B., and C.A. Frissell. 2002. Changes in distribution of nonnative brook trout in an Idaho drainage over two decades. *Transactions of the American Fisheries Society*, 131:561-568.

Adams, S.B., and C.A. Frissell. 2001. Thermal habitat use and evidence of seasonal migration by tailed frogs, *Ascaphus truei*, in Montana. *Canadian Field-Naturalist* 115: 251-256.

Adams, S.B., C.A. Frissell, and B.E. Rieman. 2001. Geography of invasion in mountain streams: consequences of headwater lake fish introductions. *Ecosystems* 296-307.

Ebersole, J.L., W.J. Liss, and C. A. Frissell. 2001. Relationship between stream temperature, thermal refugia, and rainbow trout *Oncorhynchus mykiss* abundance in arid-land streams in the northwestern United States. *Ecology of Freshwater Fish* 10:1-10.

Adams, S.A., C.A. Frissell, and B.E. Rieman. 2000. Movements of non-native brook trout in relation to stream channel slope. *Transactions of the American Fisheries Society* 129:623-638

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18-30.

Baxter, C.V., C.A. Frissell, and F.R. Hauer. 1999. Geomorphology, logging roads and the distribution of bull trout *(Salvelinus confluentus)* spawning in a forested river basin: implications for management and conservation. *Transactions of the American Fisheries Society,* 128:854-867.

Williams, R.N., P.A. Bisson, D. L. Bottom, L. D. Calvin, C. C. Coutante, M. W. Erho Jr., C. A. Frissell, J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford & R. R. Whitney. 1999. Return to the River: Scientific Issues in the Restoration of Salmonid Fishes in the Columbia River. *Fisheries* (Bethesda) 24(3):10-19.

Currens, K.P., F.W. Allendorf, D. Bayles, D.L. Bottom,. C.A. Frissell, D. Hankin, J.A. Lichatowich, P.C. Trotter, and T.A. Williams. 1998. Conservation of Pacific salmon: response to Wainwright and Waples. *Conservation Biology* 12:1148-1149.

Poole, G.C., C.A. Frissell, and S.C. Ralph. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. *Journal of the American Water Resources Association* 33:879-896.

Articles Published in Scientific Journals, continued:

Ebersole, J.L., W.J. Liss, and C.A. Frissell. 1997. Restoration of stream habitats in the western United States: restoration as re-expression of habitat capacity. *Environmental Management* 21:1-14.

Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. *Conservation Biology* 11:140-152.

Frissell, C.A., and D. Bayles. 1996. Ecosystem management and the conservation of aquatic biodiversity and ecological integrity. *Water Resources Bulletin* 32:229-240.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers: Research and Management* 12:391-413. http://tinyurl.com/c4wbcwo

Nawa, R., and C.A. Frissell. 1994. Measuring scour and fill of gravel streambeds with scour chains and sliding bead monitors. *North American Journal of Fisheries Management* 13:634-639.

Frissell, C.A. 1993. Topology of extinction and endangerment of native fishes in the Pacific Northwest and California, USA. *Conservation Biology* 7:342-354.

Frissell, C.A., R.K. Nawa, and R. Noss. 1992. Is there any conservation biology in "New Perspectives?" A response to Salwasser. *Conservation Biology* 6:461-464.

Frissell, C.A., and R.K. Nawa. 1992. Incidence and causes of failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management* 12:182-197.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management* 10:199-214. *

**[Recognized as among the ten most cited papers in benthic ecology in Resh, V.H. 2003. J. of the North American Benthological Society 22 (3): 341-35.]*

Symposium Articles Published:

Frissell, C., and G. Carnefix. 2007. The geography of freshwater habitat conservation: roadless areas and critical watersheds for native trout. Pp. 210-217 in R. F. Carline, and C. LoSapio, (eds.) *Sustaining Wild Trout in a Changing World: Proceedings of Wild Trout IX Symposium*, *October 9-12, 2007, West Yellowstone, Montana.* 308pp. http://www.wildtroutsymposium.com/proceedings-9.pdf

Symposium Articles Published, continued:

Poole, G.C., J.A. Stanford, S.W. Running, and C.A. Frissell. 2000. A Linked GIS/modeling approach to assessing the influence of flood-plain structure on surface- and ground-water routing in rivers. *Proceedings of the 4th International Conference on Integrating Geographic Information Systems (GIS) and Environmental Modeling*. Held 2-8 September 2000, Banff, Alberta. B. Parks, editor.

Stahl, R.G., J. Mille, R. Frederick, D. Courtemanch, C. Frissell, M. Kaplan, M., K. Sappington, and M. Zeeman, 1999. Managing Ecological Risks Posed by Multiple Stressors. Pages 51-66 in Foran, J.A., and S. A. Forenc (eds.) *Multiple Stressors in Ecological Risk and Impact Assessment: Proceedings from the Pellston Workshop on Multiple Stressors in Ecological Risk and Impact Assessment.* 13-18 September 1997, Pellston, Michigan. *SETAC Special Publications Series,* SETAC Press, The University of Michigan. 100pp.

Clancy, C., C. Frissell, and T. Weaver. 1998. Removal or suppression of introduced fish to aid bull trout recovery. *Proceedings of the Wild Trout XI Conference*, held August, 1997 in Bozeman, MT. http://www.wildtroutsymposium.com/proceedings-6.pdf

Li, H.W., K. Currens, D. Bottom, S. Clarke, J. Dambacher, C. Frissell, P. Harris, R.M. Hughes, D. McCullough, A. McGie, K. Moore, R. Nawa, and S. Thiele. 1995. Safe havens: refuges and evolutionarily significant units. *American Fisheries Society Symposium* 17:371-380.

Frissell, C.A., W.J. Liss, and D. Bayles. 1993. An integrated, biophysical strategy for ecological restoration of large watersheds. In D.F. Potts ed., *Changing Roles in Water Resources Management and Policy*. Proceedings of a symposium of the American Water Resources Association, held 27-30 June, 1993, Bellevue, WA.

Frissell, C.A., and R.K. Nawa. 1989. Cumulative impacts of timber harvest on fisheries: "All the King's horses and all the King's men..." In C. Toole, (ed.), *Proceedings of the Seventh California Salmon, Steelhead and Trout Restoration Conference*. February 24-26, Arcata, CA. California Sea Grant Publication UCSGEP-89-02.

Frissell, C.A., and T. Hirai. 1988. Life history patterns, habitat change, and productivity of fall chinook stocks of southwest Oregon. In B. Sheperd (ed.) *Proceedings of the Northeast Pacific Chinook and Coho Workshop*, Bellingham, Washington, 3-4 October 1988. North Pacific International Chapter, American Fisheries Society.

Books and Book Chapters Published:

Frissell, C.A., and C.W. Bean. 2009. Responding to environmental threats. In: Assessing The Conservation Value Of Fresh Waters (Boon, P.J. & Pringle, C. eds.) pp. 91-116. Cambridge University Press Books, Cambridge, UK. 293pp.

Books and Book Chapters Published, continued:

Langford T.E.L., & Frissell C.A. 2009. Evaluating restoration potential. Pp. 117-141 in P.J. Boon & C.M. Pringle (eds.) *Assessing the Conservation Value of Freshwaters. An International Perspective*. Cambridge University Press,Cambridge, UK. 293pp.

Stanford, J. A., C. A. Frissell and C. C. Coutant. 2006. Chapter 5: The Status of Freshwater Habitats. Pp. 173-248 in Williams, R. N. (ed.), Return to the River: Restoring Salmon to the Columbia River. Elsevier Academic Press, Amsterdam. 720 pp. http://www.sciencedirect.com/science/book/9780120884148

Frissell, C.A., N.L. Poff, and M.E. Jensen. 2001. Assessment of biotic patterns in freshwater ecosystems. Chapter 27 in Bourgeron, P., M. Jensen, and G. Lessard (eds.) *A Guidebook for Integrated Ecological Assessments*. Springer-Verlag, NY.

Jensen, M.E., I. Goodman, and C.A. Frissell. 2001. Design and use of aquatic biophysical classifications and maps. Chapter 26 in Bourgeron, P., M. Jensen, and G. Lessard (eds). *A Guidebook for Integrated Ecological Assessments.* Springer-Verlag, NY.

Welsh, H.H., T.D. Roelofs, and C.A. Frissell. 2000. Aquatic ecosystems of the redwood region. Pages 165-199 in R. Noss (ed.) *The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods.* Island Press, Washington, DC.

Frissell, C.A., and S.C. Ralph. 1998. Stream and watershed restoration. Pages 599-624 in R.J. Naiman and R.E. Bilby (eds.) *Ecology and Management of Streams and Rivers in the Pacific Northwest Coastal Ecoregion*. Springer-Verlag, NY.

Frissell, C.A. 1997. Ecological principles. Pages 96-115 in J.E. Williams, M.P. Dombeck, and C.A. Wood (eds.) *Watershed Restoration: Principles and Practices.* The American Fisheries Society, Bethesda, MD.

Frissell, C.A., W.J. Liss, R.K. Nawa, R.E. Gresswell, and J.L. Ebersole. 1997. Measuring the failure of salmon management. Pages 411-444 in D.J. Stouder, P.A. Bisson,and R.J. Naiman (eds.) *Pacific Salmon and their Ecosystems: Status and Future Options*. Chapman and Hall, New York, NY.

Frissell, C.A. 1996. A new strategy for watershed protection, restoration and recovery of wild native fish in the Pacific Northwest. Pages 1-24 in B. Doppelt (ed.) *Healing the Watershed: A Guide to the Restoration of Watersheds and Native Fish in the West*. The Pacific Rivers Council, Eugene, OR.

Frissell, C.A., and D.G. Lonzarich. 1996. Habitat use and competition among stream fishes. Pages 493-510 in F.R. Hauer and G.A. Lamberti (eds.) *Methods in Stream Ecology*. Academic Press, San Diego, CA.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. *Entering the Watershed: A New Aproach to Save America's River Ecosystems* . Island Press, Washington, DC.

Final Research Reports and Miscellaneous Publications since 1993:

Frissell, C.A., with R. Shaftel. 2013. Foreseeable Environmental Impact of Potential Road and Pipeline Development on Water Quality and Freshwater Fishery Resources of Bristol Bay, Alaska. Appendix G (52pp) in *An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska, Second External Review Draft*. USEPA, Washington, DC 910-R-004a-c. 30 April 2013. Final Report for University of Alaska Anchorage Environment and Natural Resources Institute And Alaska Natural Heritage Program (NatureServe), under contract to USEP. Available online at: http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=513558

Pacific Rivers Council (Scurlock, M., and C.A.Frissell). 2012. Conservation of Freshwater Ecosystems on Sierra Nevada National Forests: Policy Analysis and Recommendations for the Future. Pacific Rivers Council, Portland Oregon, report prepared for Sierra Forest Legacy. 156pp. http://www.sierraforestlegacy.org/Resources/Conservation/Biodiversity/Conservation%20of%20Freshwater%20Ecosystems%20on%20Sierra%20Nevada%20Forests%202012%20PRC.pdf

Frissell, C.A., M. Scurlock, and R. Kattelmann. 2012. SNEP Plus 15 Years: Ecological & Conservation Science for Freshwater Resource Protection & Federal Land Management in the Sierra Nevada. Pacific Rivers Council Science Publication 12-001. Portland, Oregon, USA. 39 pp. http://www.sierraforestlegacy.org/Resources/Conservation/FireForestEcology/ThreatenedHabitats/Aquatic/RETROSNEP_PRC_Report_2012.pdf

MWH. (Montgomery Watson Harza). 2012. Independent Expert Panel Review of Water and Land Resources Division's Project Scoping and Implementation Practices. Prepared for King County Dept. of Natural Resources and Parks, Seattle, WA. 24 January 2012. 67 pp. + appendices. http://kingcounty.gov/environment/dnrp/publications/wlrd-expert-review-report.aspx

Frissell, C.A. 2011. Comment on the environmental effects on Bull Trout (*Salvelinus confluentus*) as considered in the *Supplemental Draft Environmental Impact Statement for the Montanore Project*. Report prepared for Save Our Cabinets, Heron, MT. http://www.earthworksaction.org/files/pubs-others/montanore-comments_christopher-frissell_FINAL_20111220.pdf

Pacific Rivers Council (Wright, B., and C. Frissell). 2010. Roads and Rivers II: An Assessment of National Forest Roads Analyses. Report for the Pacific Rivers Council, Portland, OR. http://pacificrivers.org/science-research/resources-publications/roads-and-rivers-ii/download

Carnefix, G. and C.A. Frissell. 2010. Science for Watershed Protection in the Forest Service Planning Rule: Supporting Scientific Literature and Rationale. Report for the Pacific Rivers Council, 6 October 2010. 22pp. http://pacificrivers.org/files/nfma/supporting-scientific-rationale-for-nfma-language

Final Research Reports and Misc. Publications since 1993, cont:

Carroll, C., D.C. Odion, C.A. Frissell, D.A. Dellasala, B.R. Noon, and R. Noss. 2009. Conservation implications of coarse-scale versus fine-scale management of forest ecosystems: are reserves still relevant? Report for Klamath Center for Conservation Research. http://www.klamathconservation.org/docs/ForestPolicyReport.pdf

Carnefix, G., and C. A. Frissell. 2009. Aquatic and Other Environmental Impacts of Roads: The Case for Road Density as Indicator of Human Disturbance and Road-Density Reduction as Restoration Target; A Concise Review. Pacific Rivers Council Science Publication 09-001. Pacific Rivers Council, Portland, OR and Polson, MT. http://pacificrivers.org/science-research/resources-publications/road-density-as-indicator/download

Duane,T.P., G. Carnefix, S.Chattopadhyay, C. Davidson, D.A. DellaSala, J.Duffield, C. Frissell, M.P. Hayes, M. Jennings, J. Kerkvliet, G. LeBuhn, P. Morton, E. Niemi, D. Spooner, and M. Weber. 2008. Economics of Critical Habitat Designation and Species Recovery: Consensus Statement of a Workshop. Report prepared for Pacific Rivers Council after a two-day workshop, October 4-5, 2007, San Francisco, CA. http://pacificrivers.org/science-research/resources-publications/economics-of-critical-habitat-designation-and-species-recovery-consensus-statement-of-a-workshop-sponsored-by-the-pacific-rivers-council-environmental-studies-program-at-san-francisco-state-university-ecotrust-and-the-national-center-for-conservati/download

Williams, J.E., D.A. DellaSala, J. F. Franklin, C.D. Williams, and C. Frissell. 2004. A new vision for wildfire preparation in the western USA. Media report presented at the Society for Conservation Biology Annual Meeting, Aug. 2, 2004, Columbia University, New York, NY.

Frissell, C. A. and G. Carnefix. 2002. Environmental correlates of spatial variation in spawning abundance of bull trout (Salvelinus confluentus) in Rock Creek Basin, Montana, USA. FLBS Report 168-02. Prepared for Rocky Mountain Research Station, USDA Forest Service, Boise, Idaho by Flathead Lake Biological Station, The University of Montana, Polson, Montana. 76 pp. + 2 appendices.

Merrill, T., D.J. Mattson, and C. Frissell. 2001. Life history, reserve design and umbrella effects: grizzly bears and aquatic systems in western Montana. Unpublished manscript, available online at http://y2y.net/files/673-merrill-reserve-design-and-umbrella-effects.pdf

Franklin, J. F., D.A. Perry, R.F. Noss, D. Montgomery, and C. Frissell. 2000. Simplified Forest Management to achieve watershed and forest health. Report for the National Wildlife Federation, Seattle, Washington. 46pp.

Frissell, C.A., P. H. Morrison, S.B. Adams, L. H. Swope, and N.P. Hitt. 2000. Conservation Priorities: an Assessment of Freshwater Habitat for Puget Sound Salmon. Trust for Public Land, Northwest Regional Office, 1011 Western Suite 605, Seattle, WA. http://www.tpl.org/tier3_cd.cfm?content_item_id=9280&folder_id=262.

Final Research Reports and Misc. Publications since 1993, cont:

Frissell, C.A. 1999. An ecosystem approach for habitat conservation for bull trout: groundwater and surface water protection. Flathead Lake Biological Station, Open File Report 156-99, The University of Montana, Polson, MT.

Hitt, N.P. and C.A. Frissell. 1999. Wilderness in a landscape context: a quantitative approach to ranking aquatic diversity areas in western Montana. Paper presented at Wilderness Science Conference, 23-27 May, Missoula, MT.

Montana Bull Trout Scientific Group. 1998. The relationship between land management activities and habitat requirements of bull trout. Report prepared for the Montana Bull Trout Restoration Team, Office of the Governor, Helena, MT.

Frissell, C.A. 1998. Landscape refugia for conservation of Pacific salmon in selected river basins of the Olympic Peninsula and Hood Canal, Washington. Flathead Lake Biological Station, Open File Report 147-98, The University of Montana, Polson, MT.

Frissell, C.A. 1997. Ecological benefits of wildland reserves: The proposed Copper Salmon Wilderness in southwest Oregon. Flathead Lake Biological Station, Open File Report 150-97, The University of Montana, Polson, MT.

Huntington, C.W., and C.A. Frissell. 1997. Aquatic conservation and salmon recovery in the North Coast Basin of Oregon: A crucial role for the Tillamook and Clatsop State Forests. Report prepared for Oregon Trout, Portland, OR.

Williams, R.N., L.D. Calvin, C.C. Coutant, M.W. Erho, Jr., J.A. Lichatowich, W.J. Liss, W. E. McConnaha, P.R. Mundy, J.A. Stanford, R.R. Whitney, D.L. Bottom, and C.A. Frissell. In press. *Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem.* Independent Scientific Group, Northwest Power Planning Council, Portland, OR.

Frissell, C.A., J.L. Ebersole, W.J. Liss, B.J. Cavallo, and G.C. Poole. 1996. Potential effects of climate change on thermal complexity and biotic integrity of streams: seasonal intrusion of non-native fishes. Final Report for USEPA Environmental Research Laboratory, Duluth, MN. Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Bottom, D.L., J.A. Lichatowich, and C.A. Frissell. 1996. Variability of marine ecosystems and relation to salmon production. Report prepared for Theme 2 of the Pacific Northwest Coastal Ecosystem Region Study Workshop, Troutdale, OR, 12-14 August.

Clancy, C., C. Frissell, and T. Weaver. 1996. Assessment of methods for removal or suppression of introduced fish to aid bull trout recovery. Report prepared by the Montana Bull Trout Scientific Group for the Montana Bull Trout Restoration Team. Montana Fish, Wildlife and Parks, Helena, MT.

Frissell, C.A., J. Doskocil, J. Gangemi, and J. Stanford. 1995. Identifying priority areas for protection and restoration of riverine biodiversity: a case study in the Swan River basin, Montana, USA. Flathead Lake Biological Station, Open File Report 136-95, The University of Montana, Polson, MT.

Final Research Reports and Misc. Publications since 1993, cont:

Beschta, R.L., C.A. Frissell, R. Gresswell, R. Hauer, J.R. Karr, G.W. Minshall, D.A. Perry, and J.J. Rhodes. 1995. Wildfire and salvage logging: recommendations for ecologically sound post-fire salvage logging and other post-fire treatments on federal lands in the West. The Pacific Rivers Council, Eugene, OR.

Frissell, C.A. 1993. The shrinking range of the Pacific Salmon. Report and status and range maps prepared for the Pacific Northwest Salmon Study, The Wilderness Society, Washington, DC.

Frissell, C.A., and W.J. Liss. 1993. Valley segment classification for the streams of Great Basin National Park, Nevada. Report prepared for the National Park Service Cooperative Park Studies Unit, College of Forestry, Oregon State University, Corvallis, OR.

Frissell, C.A. 1993. Panacea or placebo? An ecologist's view of captive breeding. *Wild Fish* July/August 1993:7-12. The Wilderness Society, Portland, OR.

Frissell, C.A. 1993. A new strategy for watershed restoration and recovery of Pacific salmon in the Pacific Northwest. Report prepared for The Pacific Rivers Council, Eugene, Oregon. Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Selected Papers and Seminars Presented Since 1993 (__=presenter):

Frissell, C.A., M. Scurlock, and K Crispen. 2011. Forest thinning in Pacific Northwest riparian areas: rationale, risks, and policy calibration. (Abstract) Annual Meeting of the American Fisheries Society, Symposium on Forest Management: Can Fish and Fiber Coexist? 4-8 September, Seattle, WA. http://pacificrivers.org/science-research/resources-publications/dr.-chris-frissells-american-fisheries-society-presentation-on-riparain-thinning/download

Frissell, C.A. 2008. Water, watersheds and forest stewardship: the shared landscape (Abstract). Paper presented at the Western Stewardship Summit: Restoring Community and the Land, Bend, OR, September 24-26 2008.

Frissell, C.A., and N.P. Hitt. 2008. Four biological quanta: a conceptual framework for conservation of stream ecosystems. (Abstract) Society for Conservation Biology Annual Meeting Symposium: Advances in Freshwater Conservation Planning. Chattanooga, TN, July 13-19, 2008.

Frissell, C.A. 2008. Ecological impacts of roads in an era of climate change (Abstract). Watershed Restoration and Forest Roads Symposium, Pacific Rivers Council, 4 April 4, Tacoma, WA. http://pacificrivers.org/conservation-priorities/land-management/roads/watershed-restoration-and-forest-roads-symposium

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A., and G, Carnefix. 2007. (Abstract) Spawning abundance of bull trout (*Salvelinus confluentus*) in relation to geomorphology, temperature and roads in tributaries of Rock Creek Basin (Missoula and Granite Counties), Montana, US. Annual Meeting of the Montana Chapter of the American Fisheries Society, 13-16 February, Missoula, MT. http://www.fisheries.org/units/AFSmontana/2007%20MCAFS%20Annual%20Meeting%20Program.pdf

Frissell, C.A. 2007. Setting regional priorities for watershed restoration. 25th Salmonid Restoration Conference, Salmonid Restoration Federation, 9-10, Santa Rosa, CA.

Frissell, C.A. 2006. Post-fire management effects on streams. NCSSF Disturbance, Management, and Biodiversity Symposium, **National Commission for Science and Sustainable Forestry,** 26-27 April, **Denver, CO.**

Frissell, C.A., and G. Carnefix. 2005. (Abstract) Indicators of landscape pattern for freshwater ecosystems. 20th Annual Symposium of the US-International Association for Landscape Ecology, 12-16 March, Syracuse, NY.

Frissell, C.A. 2004. Managing risk and uncertainty: National Forest management and freshwater conservation. Regional Centennial Forum: The Forest Service In the Pacific Southwest Region. US Forest Service, 5-6 November, Sacramento, CA.

Williams, J.E., D.A. DellaSala, J. F. Franklin, C,D.Williams, and C. Frissell. 2004. Scientific findings require a new vision for successful wildlfire preparation. News briefing at the Society for Conservation Biology Annual Meeting, Aug. 2, 2004., Columbia University, New York, NY. http://www.conbio.org/Media/Fire/

Frissell, C.A. 2001. (Abstract) What to do first with limited time, money, and staff. Watershed Restoration Workshop: Integrating Practical Approaches. Oregon Chapter of the American Fisheries Society, 13-15 November, Eugene, OR.

Ebersole, J.L., Colden V. Baxter, Hiram W. Li, and William J. Liss, and Frissell, C.A. 2001. (Extended abstract) Detecting temporal dynamics and ecological effects of smallmouth bass invasion in northeast Oregon streams. *In*: Proceedings, American Fisheries Society Special Symposium: Practical Approaches for Conserving Native Inland Fishes of the West. Montana Chapter and Western Division of the American Fisheries Society, 6-8 June, The University of Montana, Missoula, MT.

Carnefix, G., C. Frissell, and E. Reiland. 2001. (Extended abstract) Complexity and stability of bull trout (*Salvelinus confluentus*) movement patterns in the Rock Creek drainage, Missoula and Granite counties, Montana. *In*: Proceedings, American Fisheries Society Special Symposium: Practical Approaches for Conserving Native Inland Fishes of the West. Montana Chapter and Western Division of the American Fisheries Society, 6-8 June, The University of Montana, Missoula, MT.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A. 1999. (Abstract) Groundwater processes and stream classification in the montane West. Invited paper, Symposium #7: Aquatic Classification Schemes for Ecosystem Management: Making the Transition from Methods Development to Application and Validation. Annual Meeting of the Ecological Society of America 7-12 August, Spokane, WA.

Frissell, C.A. 1999. Fisheries and watershed processes: strategies for protection and restoration. Invited paper, Annual Meeting of the Cal-Neva Chapter of the American Fisheries Society, 24-27 March, Redding, CA.

Frissell, C.A. 1999. Surface-subsurface flow linkages in rivers and their importance for river flow conservation. Invited paper, Symposium on Water Quality and Hydropower Re-licensing, Annual Meeting of the Cal-Neva Chapter of the American Fisheries Society, 24-27 March, Redding, CA.

Frissell, C.A. 1999. Dams, uncertainty, and the salmon ecosystem. *Keynote Address*, Annual Meeting of the Idaho Chapter of the American Fisheries Society and The Wildlife Society, 4-6 March, Boise, ID.

Frissell, C.A. 1998. Climate forcing of thermal habitat in Pacific Northwest rivers: Buffering effects of floodplain forests and hyporheic processes. (Abstract) Symposium on Climate Change Impacts to Freshwater Fish Habitats, Annual Meeting of the American Fisheries Society, 23-27 August, Hartford, CT.

Frissell, C.A. 1998. Ecosystem concepts in large-scale restoration. (Abstract). Montana Chapter of the American Fisheries Society, 3-5 February, Helena, MT.

Frissell, C.A. and B.J. Cavallo 1997. Aquatic habitats used by larval western toads (*Bufo boreas*) on an intermontane river floodplain and some landscape conservation implications (Abstract). Annual Meeting of the Ecological Society of America, 10-14 August, Albuquerque, NM.

Stanford, J.A. (presented by C.A. Frissell). 1997. Conservation and enhancement of alluvial rivers: the importance of hyporheic linkages. (Abstract). Symposium on Ecological Effects of Roads, Society for Conservation Biology, 7-10 June, Victoria, British Columbia, Canada.

Frissell, C.A., and G.C. Poole . 1997 Management of Riparian Zones in Western Montana: Present Issues and Emerging Challenges. (Abstract). Annual Meeting of the American Fisheries Society, 23-28 August, Monterey, CA.

Frissell, C.A., and J.T. Gangemi. 1997. Roads and the conservation of aquatic biodiversity and ecological integrity. (Abstract). Society for Conservation Biology, Victoria, British Columbia, Canada, 7-10 June.

Frissell, C.A. 1997. Spatial assessment of biological status and biodiversity loss. Invited seminar, National Research Center for Statistics and the Environment, University of Washington, Seattle, WA, 14 January.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A., and B.J. Cavallo 1996. Thermal and hydrologic diversity of aquatic habitats mediated by floodplain complexity and hyporheic flow exchange in an alluvial segment of the Middle Fork Flathead River, Montana, USA. (Abstract). Annual Meeting of the N. Am. Benthological Society, Kalispell, MT, 3-8 June.

Frissell, C.A. 1995. Ecological principles for watershed restoration. (Abstract). Invited paper for Workshop on Watershed Restoration: Principles and Practices, Annual Meeting of the American Fisheries Society, Tampa, FL, 27-31 August.

Frissell, C.A. 1995. Managing native fish and their ecosystems: let's get (spatially) explicit! (Abstract). Invited panel presentation at Montana Chapter of the American Fisheries Society, Chico Hot Springs, MT, 6-10 February.

Frissell, C.A. 1995. Birth in the fast lane: sediment transport, human disturbance, and reproductive strategies of salmonid fishes in Pacific Northwest streams. (Abstract). Invited paper for Symposium on Influence of Geomorphic Processes on Terrestrial and Aquatic Ecosystem patterns and Processes, Annual meeting of the Ecological Society of America, Snowbird, UT, 31 July-3 August.

Frissell, C.A. 1995. Resource management impacts on bull trout populations. Invited panel presentation for Searching for Solutions: Solving the Bull Trout Puzzle Science and Policy Conference, Andrus Center for Public Policy, Boise State University, Boise, ID, 1-2 June.

Frissell, C.A. 1995. Watershed dynamics: natural pattern and process and some consequences for ecosystem management. Invited presentations at Managing Terrestrial Ecosystems Relative to Past and Present Disturbances: A Workshop Integrating Fire, Range, Fish and Wildlife Habitat and the Practice of Silviculture in the Northern Region. U.S. Forest Service, Missoula, MT, 14-16 March.

Ebersole, J.L., C.A. Frissell, and W.J. Liss (co-presenters). 1995. Invasion of non-native fishes in northeast Oregon and western Montana streams: potential impacts of climate change. (Abstract). Oregon Chapter of the American Fisheries Society, Ashland, OR, 15-17 February.

Frissell, C.A. 1994. Watershed restoration strategies. (Invited presenter and session convenor) Watersheds '94 Expo, US Environmental Protection Agency and Center for Streamside Studies, University of Washington. Bellevue, WA, 27-30 September.

Frissell, C.A. 1994. A hierarchical approach to restoration of riverine ecosystems. Invited paper at Symposium on Aquatic Habitat Restoration in Northern Ecosystems, Alaska Chapter of the American Fisheries Society, Girdwood, AK, 20-22 September.

Frissell, C.A. 1994. An integrated, biophysical strategy for ecological restoration of large watersheds (Abstract). Annual Conference of The Universities Council on Water Resources, Big Sky, MT, 3-5 August.

Selected Papers and Seminars Presented Since 1993, continued:

Frissell, C.A., and J.A. Stanford. 1994. Designing a watershed reserve network to protect and restore aquatic biodiversity in the northern Rocky Mountains (Abstract). Annual meeting of the Montana Chapter of the American Fisheries Society, Billings, Montana, Billings, MT, 9 February.

Frissell, C.A. 1994. The Endangered Species Act: principles for the protection and recovery of fishes. Invited panel presentation, annual meeting of the Idaho Chapter of the American Fisheries Society, McCall, ID, 24-26 February.

Frissell, C.A., W.J. Liss, B. Doppelt, and D. Bayles. 1993. A new, ecologically based restoration strategy for Pacific salmon in the Pacific Northwest (Abstract). Annual meeting of the American Fisheries Society, Portland, OR, 29 August-2 September.

Technical Workshops Organized (selected):

Co-organizer, with M. Scurlock and R. Kattelmann: SNEP Plus 15 Years: Ecological & Conservation Science for Freshwater Resource Protection & Federal Land Management in the Sierra Nevada. Sponsored by Pacific Rivers Council, Sierra Forest Legacy, UC Berkeley School Environmental Design, UC Davis Center for Watershed Science, and CaliforniaTrout; 12-13 December 2011, Davis, CA.

Organizer and Facilitator, Workshop on Science for River and Watershed Conservation. Sponsored by Campaign for Montana's Headwaters, 7 October 2010, Flathead Lake Biological Station, Polson, MT.

Co-convener, with M. Scurlock and Kristen Boyles: Technical Workshop on Science for Forest Planning. Sponsored by Pacific Rivers Council and Earthjustice, 29 June 2010, Seattle, WA.

Organizer and Panelist, Umpqua Independent Science Council. Sponsored by Pacific Rivers Council, 2010-2011.

Co-organizer and panelist, with Deanne Spooner and David Bayes: Workshop on Economics of ESA Critical Habitat Policy, sponsored by Pacific Rivers Council and San Francisco State University, October 4-5, 2007, San Francisco, CA.

Organizer and coordinator of Science Panel on Roads and Watersheds, sponsored by Pacific Rivers Council, 10-11 November 2006, Forest Grove, OR.

Organizer and coordinator of the Recovery Science Panel for the Western Native Trout Campaign. Sponsored by Pacific Rivers Council, meeting 2-3 March 2002, Portland, OR.

Organizer and coordinator of Biodiversity Workshop, Consortium for the Study of North Temperate Montane Ecosystems. A cooperative research venture of The University of Montana and Montana State University, supported by the NSF EPSCoR program. 4 February, 1997 Missoula, MT.

Scientific Workshop on Large Basin Restoration: Grande Ronde River (co-organizer). 21-22 March 1993, La Grande, OR. Sponsored by The Pacific Rivers Council.

Technical Workshops Organized (selected), continued:

Scientific Workshop on Large Basin Restoration: South Umpqua River. 16-18 September 1992, Roseburg, Oregon. Sponsored by The Pacific Rivers Council.

Scientific Workshop on Large Basin Restoration: Lower Rogue River. 21-23 October 1992, Gold Beach, OR. Sponsored by The Pacific Rivers Council.

Other Panels and Workshops Attended by Invitation since 1994:

Invited Review Panelist, Workshop on Linking Habitat Characteristics to Salmon Data. 29-30 September 1999, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA.

Invited participant, Yellowstone to Yukon Aquatic Conservation Science Workshop. 20-22 August 1999, Flathead Lake Biological Station, The University of Montana, Polson, MT.

Invited Panelist, Workshop on Options for Restoring Salmon Habitat in the Mainstem Snake and Columbia Rivers. Pacific Northwest National Laboratory-Battelle, 19 August 1999, Kennewick, WA

Panelist at State of Oregon/National Marine Fisheries Service Memorandum of Agreement Committee Workshop: Cumulative Effects of State and Private Forest Practices on Salmon Habitat. 21April 1998, Salem, OR.

Invited participant in a scientific workshop, Multiple Stressors in Ecological Risk Management. Sponsored by the Society for Environmental Chemistry and Toxicology and the USEPA, 13-18 September 1997, Pellston, MI.

Society for Conservation Biology Workshop: Communicating with the Media (panel member). 9 June 1997, Victoria, British Columbia, Canada.

Invited speaker for a workshop, Continuing Education in Ecosystem Management. Sponsored by the University of Idaho. Catchment scale processes and linkages between landscape and stream conditions. 31 January 1997, Moscow, ID.

The Nature Conservancy, Aquatic Classification Workshop (invited presenter). 9-11 April 1996, Cedar Creek Farm, MO.

Kenai River Community Forum (keynote speaker and panelist). The Nature Conservancy of Alaska, USEPA and USFWS, 19-21 April, Soldotna, AK.

Conservation Biology and Management of Interior Salmonids (invited presenter and session co-moderator). USDA Forest Service Intermountain Research Station and Utah State University, 4-5 October 1995, Logan, UT.

Eastside Ecosystem Planning Workshop. Sierra Club Legal Defense Fund, 16 December 1994, Portland, OR.

Co-instructor at workshop series on Watershed Restoration and the "Rapid Biotic Response Strategy" for Riverine Ecosystem Restoration, sponsored by The Pacific Rivers Council, 1993-95, California, Oregon, and Washington.

.

Other Workshops Attended since 1994, continued:

Fire/Salvage and Aquatic Ecosystems Policy Workshop. The Pacific Rivers Council, 15 December 1994, Portland, OR.

Panel on Forest Health Issues, Native Forest Network annual conference, 13 November 1994, Missoula, MTWorkshop on Watershed/Fisheries Cumulative Effects Analysis, sponsored by Headwaters, The Pacific Rivers Council, USDA Forest Service, and Bureau of Land Management. 29 September-2 October, 1994, Ruch, OR.

Boise Funders' Scoping Meeting, sponsored by Bullit, Harder, and Lazar Foundations, 30-31 August 1994, Boise, Idaho.

Workshop for a statewide process to prioritize restoration of watersheds and salmon populations, by invitation of Oregon Senate President Bill Bradbury, 18 May 1994, Salem, OR.

Other Presentations (Selected):

Scientists Briefing for U.S. Senate staff on post-fire logging and forest management and freshwater resources. Washington, D.C., 18-19 September 2006.

Invited testimony on federal land management and the future of salmon and aquatic biodiversity in the Pacific Northwest, to the U.S. House of Representatives, Subcommittee on National Parks and Public Lands, Washington, D.C., 11 March 1993.

Briefing for Congressional representatives and staff on federal lands management and conservation and recovery of salmonid fishes and riverine ecosystems, Washington, D.C., 22 January 1993.

Invited testimony to the 1991 Oregon State Legislature, on panel representing the Oregon Chapter of the American Fisheries Society, on the status of native fishes, impacts of forest practices on fish habitat, and the need or changes in environmental regulation.

Invited testimony to the Oregon Board of Forestry Forest Issues Forum, December 1990, on cumulative impacts of forest practices on native aquatic species and the need for changes in forest management.

Worked with Oregon Public Broadcasting to describe our research project and its significance in a 15-minute segment of the television program, Oregon Field Guide, first aired in June 1990.

Presented seminars, informal presentations, lectures, and discussions at research review meetings, as guest speaker in classrooms and public interest groups, at state board meetings, at workshops, and on field trips with foresters, geotechnical personnel, fishery and watershed managers, and conservationists.