

## MEMORANDUM

**To: Interested Parties**

**Fr: Chris Frissell, Mary Scurlock and Bronwen Wright**

**Re: The Western Oregon Paired Watershed Studies: Initial Results, Limitations and Policy Implications**

**Dt: 25 August 2014**

This memorandum expands on material presented to the Oregon Board of Forestry at its June 23, 2014 Riparian Rulemaking Workshop.

### **I. Overview and Current Status**

Oregon's Watershed Research Cooperative (WRC) is involved in three paired watershed studies in Western Oregon, one in which data collection is complete and two that are ongoing. These studies are located in the Alsea river basin in the mid-Coast Range, Hinkle Creek of the Umpqua river basin in the Cascade Mountain Range, and the Trask river basin in the northern Coast Range. The purpose of these studies is to learn more about the effects of current timber harvest practices upon aquatic ecosystems, as well as to provide an opportunity for public outreach. The studies use similar designs and methods to analyze forest practices rules. Participants in the WRC include Oregon State University, private timber companies, and state and federal agencies.

Each study has been or will be carried out for a period of ten years. Post-harvest data were or will be collected for 4 years. Scientists have collected data related to stream temperature, fish abundance, amphibian abundance, aquatic invertebrates, sediment, hydrology, and many other variables that help us understand how timber harvest under current forest practices rules impact watershed health. The three study sites collectively cover more than 12,000 acres.

- *Alsea*

The Alsea Paired Watershed Study began in 2006. The study site is one that was also used before for a study conducted between 1959 and 1973. The original study evaluated the effects of clearcuts with no stream buffers, followed by slash-burn. Data collection for the revisited Alsea Study will continue until 2016. A control site in this study has not been little disturbed by forest management since the 1800's.

- *Hinkle Creek*

WRC began the Hinkle Creek study in 2001. After pre-treatment data were collected, timber harvest treatments were conducted in 2005 and 2008. Post-treatment data collection

was completed in 2011. The Hinkle Creek study was conducted exclusively on land that is privately owned by Roseburg Forest Products.

- **Trask**

The Trask Paired Watershed Study began in 2006. In 2012 was the first year of post-harvest data collection, and collection will continue until 2016. The Trask study focuses on small, non-fishbearing, headwater streams. Data are being collected both adjacent to the non-fish-bearing streams, and downstream from harvest treatments to evaluate the effects of upstream harvest on fish downstream. The study site includes state, federal, and private lands, and timber harvest on the treatment sites was conducted according the timber harvest regulations for each of those respective land managers. Some initial results of data collection and analysis have already been presented to interested parties.

## **II. Summary of study findings and publications to date**

Data have been compiled and analyzed for all three studies. However, data collection is still underway in the Alsea and Trask watersheds, so results are still in preliminary stages for these studies. Most of the study findings and publications to date have related to the Hinkle Creek study.

Findings to date in the Hinkle Creek study address many variables, including streamflow, summer low flows, amphibians, sediment yield, nutrients, coastal cutthroat trout, stream temperature, and aquatic macroinvertebrates. In brief, scientists have noted many changes that result from current forest practices in Oregon. Specifically, timber harvest resulted in significant increases in streamflow,<sup>1</sup> August summer low flows,<sup>2</sup> sediment yield,<sup>3</sup> water yield, peak flows, storm flows,<sup>4</sup> and concentrations of nitrogen.<sup>5</sup> Significant increases and decreases to maximum daily stream temperatures, as well as significant decreases in minimum daily temperatures, were observed after logging in fish-bearing and non-fish-bearing streams.<sup>6</sup> On a watershed scale, timber harvest resulted in a net decrease in

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<sup>1</sup> Zégre, N., A.E. Skaugset, N.A. Som, J.J. McDonnell, and L.M. Ganio. In Lieu of the Paired Catchment Approach: Hydrologic Model Change Detection at the Catchment Scale. *Water Resour. Res.*, 46, W11544, doi:10.1029/2009WR008601, at p. 14.

<sup>2</sup> Surfleet, C.G. and A.E. Skaugset. The Effect of Timber Harvest on Summer Low Flows, Hinkle Creek, Oregon. *West. J. Appl. For.* 28(1) 2013.

<sup>3</sup> Local and downstream impacts of contemporary forest practices on sediment yield. Abstract from 2013 WRC conference. [http://watershedsresearch.org/assets/reports/WRC\\_Conference%20Abstracts\\_2013.pdf](http://watershedsresearch.org/assets/reports/WRC_Conference%20Abstracts_2013.pdf)

<sup>4</sup> A synthesis of the impacts of contemporary forest practices on aquatic ecosystems at a watershed scale: A Case Study From Hinkle Creek. Abstract. Note above.

<sup>5</sup> The Influence of Contemporary Forest Management on Stream Nutrient Concentrations in an Industrialized Forest in the Oregon Cascades. Abstracts, as note above.

<sup>6</sup> Kibler, K. M., A. Skaugset, A., L.M. Ganio, and M.M. Huso. Effect of contemporary forest harvesting practices on headwater stream temperatures: Initial response of the Hinkle Creek catchment, Pacific Northwest, USA. *Forest Ecology and Management* 310:680-691. 2013. OFRI, however, in its fact sheet regarding the studies says about the Hinkle Creek study: “One surprising result to date is that stream temperatures did not rise significantly after clearcutting.” Expansive Watershed Studies Take a Look At Contemporary Forest Practices. Page 3. Watersheds Cooperative Fact Sheet.

[http://oregonforests.org/sites/default/files/publications/pdf/WRC\\_Overview.pdf](http://oregonforests.org/sites/default/files/publications/pdf/WRC_Overview.pdf). OFRI also states:

average daily temperature after the first entry and a net increase in average daily stream temperature after the second entry.<sup>7</sup> Clearcuts also resulted in decreases in macroinvertebrate taxa richness.<sup>8</sup>

On the other hand, some putatively expected impacts from timber harvest under current Oregon forest practices rules were not detected in the Hinkle Creek study. For example, significant short-term decreases in the density of aquatic larvae of Coastal Giant Salamander, *Dicamptodon tenoborusus*, were not observed. However, potential long-term impacts on this species have not been determined.<sup>9</sup> Likewise, scientists found very few detectable or consistent changes in habitat and biological parameters for coastal cutthroat trout, *Oncorhynchus clarki lewisi*. Increases in biomass, length, and growth of cutthroat trout were observed as a result of logging along fish-bearing streams.<sup>10</sup> Regarding stream temperature, scientists did not find the expected increases in maximum daily temperature for non-fish bearing streams,<sup>11</sup> and no evidence was found that changes in stream temperatures in upstream reaches caused stream temperature changes downstream.<sup>12</sup>

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“Preliminary findings suggest that modern harvest practices in small streams without fish have little effect on stream temperature[.]” Hinkle Creek Paired Watershed Study. Fact Sheet at Page 1. Watersheds Research Cooperative. [http://oregonforests.org/sites/default/files/publications/pdf/WRC\\_Hinkle.pdf](http://oregonforests.org/sites/default/files/publications/pdf/WRC_Hinkle.pdf) and characterizes the changes to stream temperatures as minimal. Id at p. 3.

<sup>7</sup>The Impact of timber harvest on stream temperature at a watershed scale: A case study from Hinkle Creek. Abstract, note above. Scientists have suggested that “(f)or all stream reaches, the changes in stream temperature could reasonably be explained by the changes in the energy budget associated with that stream reach.” A synthesis of the impacts of contemporary forest practices on aquatic ecosystems at a watershed scale: A Case Study From Hinkle Creek. Abstract. Note above.

<sup>8</sup> Long-term Studies of Macroinvertebrate Responses to Harvest in Hinkle, Alsea and Trask Watersheds. Abstract, note above.

<sup>9</sup> Leuthold, N., Adams, M. J., & Hayes, J. P. Short-Term Response of *Dicamptodon tenebrosus* Larvae to Timber Management in Southwestern Oregon. *Journal of Wildlife Management* 76(1), 28-37. Online at <http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/31762/LeutholdNielsForestryShortTermResponse.pdf?sequence=1>

<sup>10</sup> The effects of stream adjacent logging on downstream populations of coastal cutthroat trout. [http://watershedsresearch.org/assets/reports/WRC\\_Bateman\\_Hinkl%20Fish\\_2013\\_S3.pdf](http://watershedsresearch.org/assets/reports/WRC_Bateman_Hinkl%20Fish_2013_S3.pdf). A synthesis of the impacts of contemporary forest practices on aquatic ecosystems at a watershed scale: A Case Study From Hinkle Creek. Abstract. Note above.

<sup>11</sup> A synthesis of the impacts of contemporary forest practices on aquatic ecosystems at a watershed scale: A Case Study From Hinkle Creek. Abstract. Note above. The lack of expected rise in water temperature may be explained by the slash that was placed on stream after harvest, which kept the streams cool. Id. “The true impact of the harvesting treatment on summer stream temperatures in Hinkle Creek has likely yet to be observed. Over the next several years the protective layer of logging slash covering the harvested streams will decompose and as these watersheds are intensively managed with post-harvest herbicide treatments, it is probable that the streams will be exposed to high levels of solar radiation before the riparian canopy recovers.” The Influence of Contemporary Forest Harvesting on Summer Stream Temperatures in Headwater Streams of Hinkle Creek, Oregon by Kelly Maren Kibler. Master’s Thesis. [http://watershedsresearch.org/assets/reports/WRC\\_Kibler,Kelly\\_2007\\_Thesis.pdf](http://watershedsresearch.org/assets/reports/WRC_Kibler,Kelly_2007_Thesis.pdf)

<sup>12</sup>The Impact of timber harvest on stream temperature at a watershed scale: A case study from Hinkle Creek. Abstract, note above. Increased water temperature upstream may not persist downstream “due to groundwater influx and the celerity and residence time of the water in the streams.: A synthesis of the impacts of contemporary forest practices on aquatic ecosystems at a watershed scale: A Case Study From Hinkle Creek. Abstract. Note above

Temperature results at these sites were likely dominated by localized complexity and logging-related changes in groundwater dynamics, rather than shade-mediated effects.

In the Alsea study, scientists found that timber harvest resulted in increased nitrate concentrations,<sup>13</sup> slightly increased stream temperatures,<sup>14</sup> and pulses of glyphosate herbicide in the water column.<sup>15</sup> After harvest, scientists observed an increase in cutthroat trout biomass and abundance for age 1+, but did not find any change in relative growth rate.<sup>16</sup> Researchers have only just begun collecting data postharvest in the Trask study, so results are preliminary. Initial results indicate that construction or reconstruction of road to support logging (but prior to logging and hauling) was associated with a pattern of increases in turbidity and suspended sediment concentration in streams below road crossing locations.<sup>17</sup>

### **III. Limitations of the Paired Watershed Studies as Bases to Change Forest Management Rules and caveats**

#### ***A. The “controls” are previously managed forest ecosystems, not fully recovered from past logging disturbance, greatly limiting inference.***

To the extent that “control” watersheds in these studies are not natural, unmanaged areas, but are previously logged watersheds lacking late successional forest conditions and affected by existing logging roads and landings, these studies can only evaluate whether additional harvest will cause additional incremental adverse impacts to an altered landscape. They cannot tell us what the overall adverse cumulative impacts of intensive timber harvest have been and will continue to be.

The use of the term “control” can be misleading in that it implies that “control” watersheds have recovered from past logging impacts, physically and biologically. However, recovery can require a great deal of time, such as re-establishing the large woody debris accumulations that are anchored by very large trees and snags and play vital roles in

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<sup>13</sup> WRC conference abstracts

[http://watershedsresearch.org/assets/reports/WRC\\_Conference%20Abstracts\\_2013.pdf](http://watershedsresearch.org/assets/reports/WRC_Conference%20Abstracts_2013.pdf)

<sup>14</sup> Presentation:

[http://watershedsresearch.org/assets/reports/WRC\\_Light\\_Alsea%20stream%20temps\\_2013\\_S2.pdf](http://watershedsresearch.org/assets/reports/WRC_Light_Alsea%20stream%20temps_2013_S2.pdf)

<sup>15</sup> Id, Herbicides in Needle Branch stream water. Louch J.G., G. Allen, G. Ice, T. Garland, and J. McDonnell. Abstract, presentation online at

[http://watershedsresearch.org/assets/reports/WRC\\_Louch\\_Herbicides\\_2013\\_S2.pdf](http://watershedsresearch.org/assets/reports/WRC_Louch_Herbicides_2013_S2.pdf)

<sup>16</sup> Presentation abstract for “Fish Population Response to Harvesting with Contemporary Forest Practice Regulations: The Alsea Watershed Study Revisited.” Bateman, D, R. Gresswell, D. Hockman-Wert, D. Leer, and J. Light. April 2013. <http://watersheds.org/results/#alsea>,

[http://watershedsresearch.org/assets/reports/WRC\\_Conference%20Abstracts\\_2013.pdf](http://watershedsresearch.org/assets/reports/WRC_Conference%20Abstracts_2013.pdf).

<sup>17</sup> “Suspended sediment concentrations and turbidity responses from contemporary road crossings in the Trask river watershed” Ivan Arismendi, Jeremiah Groom, Sherri Johnson, Maryanne Reiter, Liz Dent, Alba Argerich and Arne Skaugset. Presentation, online at

[http://watershedsresearch.org/assets/reports/WRC\\_Arismendi\\_Trask%20road\\_2013\\_S1.pdf](http://watershedsresearch.org/assets/reports/WRC_Arismendi_Trask%20road_2013_S1.pdf).

shaping watershed and stream dynamic processes and the habitat critical for fish and wildlife. Full recovery is expected to take centuries.<sup>18</sup>

Demonstrating true ecological recovery can be elusive, and recovery has often been misrepresented or ill defined in past research. Our ability to scientifically resolve ecological recovery is complicated in a number of ways. Here are a few examples of such complications:

- *Incipient recovery* is marked by return of an ecosystem toward an apparent stable or median state, but without regaining resilience, such that each subsequent disturbance results in reset, exaggerated or protracted response compared to original state. In a static sense, some structural feature may resemble the natural forested condition, but the watershed and stream may respond in a more volatile manner to subsequent natural or man-made disturbances.
- *Arrested recovery*, in which the post-disturbance ecosystem stabilizes for a long period at a new state that is quantitatively and qualitatively different from original state; for example it may be marked by sustained depletion of large wood, the persistent accumulation of instream sediments, or increased background sedimentation rates associated with a road system. These departures may require time periods of centuries, or very infrequent events (such as a very large storm with few new slope erosion sources) before full recovery to a more nearly natural-historical condition is realized.
- *False recovery* is an inferred return to pre-disturbance state that in fact represents a transient crossover point or qualitative transition from one post-disturbance state to yet another post-disturbance response state. For example, elevated summer low stream flows in the initial years following logging may be followed by a few years of flows similar to pre-disturbance conditions, but in subsequent decades low flows transition to a substantially depleted state in response to evapotranspiration demand from vigorously re-growing vegetation in second-growth forest riparian areas.<sup>19</sup>

Each of the states described above would predictably contribute in some way to a pattern of exaggerated spatial and temporal variability among the putative benchmark or "control"

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<sup>18</sup> Pollock, M.M. and T.J. Beechie.(2014) Does riparian forest thinning enhance biodiversity? The ecological importance of large wood. *Journal of the American Water Resources Association* 50(3):543-559. DOI: 10.1111/jawr.12206; Sedell, J.R., P.A. Bisson, , F.J. Swanson, , and S.V. Gregory. (1988) What we know about large trees that fall into streams and rivers. Pp. 83-112 In *From the forest to the sea, a story of fallen trees*, Maser, C., Tarrant, R.F., Trappe, J.M., and Franklin, J.F., tech eds. USDA Forest Service General Technical Report GTR-PNW-229, Pacific Northwest Res. Sta., Portland, OR.  
<http://andrewsforest.oregonstate.edu/pubs/pdf/pub871.pdf>

<sup>19</sup> Hicks B.J., R.L. Beschta, and R.D. Harr. (1991) Long-term changes in streamflow following logging in western Oregon and associated fisheries implications. *Water Resources Bulletin* 27(2): 217- 226; Moore, R.D. and S.M. Wondzell. 2005. Physical hydrology and the effects of forest harvesting in the Pacific Northwest: A review. *Journal of the American Water Resources Association* 41(4):763-784. DOI: 10.1111/j.1752-1688.2005.tb03770.x

streams within second growth forests. Some investigators might then conclude that a high level of supposed “natural variability” obscures the significance of observed responses to subsequent management disturbances, *when in fact these responses might be seen as more significant when compared to the range of conditions more characteristic of natural, pre-logging ecosystems (e.g., wherein very few streams would be depleted of large wood, regardless of the successional state of surrounding forests)*. This points out that the selection of so-called “controls” is crucial for limiting or broadening the inferences that can be drawn from paired watershed studies.

Although it can be argued that “controls” selected from second growth forest are more broadly representative of existing landscape conditions -- especially on private forest lands -- it has not been established they represent adequate baseline or target conditions for recovery or restoration of water quality and habitat of listed and depressed salmon populations. In fact a great deal of information indicates the contrary.

***B. Post-harvest data for two of the three studies are still in the early stages of collection; it is premature to make any policy suggestions or inferences based upon these data.***

Although it might be tempting for some to generalize about the results across multiple paired watershed studies in Oregon, only in the Hinkle Creek study has there been enough post-logging data collected to draw reliable inferences about short-term post-logging responses in streams. But there are limited exceptions to this rule. For example, the design and treatment in the Trask study allowed data collection of the immediate response of streams to suspended sediment and turbidity at newly constructed or reconstructed road crossings. However, in subsequent years the more important sediment inputs from road crossings are likely to be realized during frequent larger storm events that have not occurred in the short time since the Trask study was initiated.

None of the current paired watershed studies has been implemented long enough—nor is any planned to be implemented long enough—to detect medium- and long-term responses to logging (see below). For example, medium-term response of stream temperature is likely to be a complex function of the rate of shade recovery balanced against possible reduction of groundwater discharge as a result of transpiration of rapidly re-growing vegetation.

***C. These studies do not reveal long-term adverse impacts of timber harvest because post-harvest data are collected for a relatively short amount of time, i.e., 4 years.***

In the Hinkle Creek Study, after the second treatment post-harvest data was collected for two years. The Alsea Study also anticipates two additional years of data collection after a second-entry treatment. Although there are ecologically and legally important impacts that can be detected in two years (such as stream temperature changes), the long-term impacts of the harvest treatments are not known, and it is unclear whether they will ever be evaluated. Short-term impact assessments are insufficient to determine the overall

adequacy of timber harvest regulations across all of Oregon's private, intensively managed forestlands to protect the full range of aquatic ecosystem processes and functions at levels necessary to meet existing legal mandates.

Dr. Arne Skauset, head of the WRC, has stated that a longer-term study than present paired watershed studies is needed to sufficiently account for temporal variability and interaction of forest management practices with natural events such as drought and floods.<sup>20</sup>

A critical take-home message from past whole-watershed research studies is that post-logging responses take many years to decades to fully unfold. In fact the principal scientific value of intensive monitoring of single watersheds is the ability to resolve the hydrologic and biological responses that take many years or decades.

For example, in the Carnation Creek studies on Vancouver Island, BC, the first several years after logging in 1976-1981 showed only a limited effect on erosion and sediment accumulation in the stream channels. However, several years of root strength attrition post-harvest coupled with a triggering storm event in 1984 caused multiple large landslides and debris flows from logged areas of the Carnation Creek watershed, dramatically impacting stream habitat conditions for an extended period of years. The resulting sedimentation and altered habitat conditions was particularly harmful to chum salmon, and contributed significantly to a collapse of the chum salmon population that initiated 6-11 years after logging, and has persisted for at least 20 years since.<sup>21</sup>

***D. Ongoing research or data collection – even if potentially probative -- is not an excuse for delay, when existing aquatic ecosystems and species are highly imperiled.***

The current status of aquatic systems on Oregon's private forests does not meet the public's expectations as expressed in state and federal law. This is demonstrated by federal Endangered Species Act listings of salmon, the persistent depression of other fish populations and stream-associated amphibians, widespread failure to meet the protecting cold water criterion under current Forest Practices Rules as demonstrated through the Riparian Function and Stream Temperature (RipStream) study<sup>22</sup>, and the prevalence of water-quality-impaired streams and rivers.

The ESA in particular requires a precautionary approach and does not condone delay in implementing more protective regulations while policymakers wait for the results of studies on the off chance that they might demonstrate that current forest management

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<sup>20</sup> "Scientist and WRC leader Arne Skauset sees the need for a very long-term project – longer than the 10-year paired watershed studies – to monitor the kinds of intensively managed private timberlands that supply most of the commercial timber in Oregon today." The Oregon Way at page 15.

<sup>21</sup> Fish-Forestry Interaction Program, Carnation Creek Project.  
[http://www.for.gov.bc.ca/hre/ffip/CarnationCrk.htm#Results\\_-\\_Forestry\\_Effects\\_on\\_Fish\\_and\\_Fish\\_Habitat](http://www.for.gov.bc.ca/hre/ffip/CarnationCrk.htm#Results_-_Forestry_Effects_on_Fish_and_Fish_Habitat)

<sup>22</sup> Oregon Forest Practices Research and Monitoring Program, Oregon Department of Forestry, Salem, OR.  
<http://www.oregon.gov/odf/privateforests/pages/monitoringripstream.aspx>

regulations are sufficiently protective. Under such circumstances, decisions about resource protection and restoration policy must be based on the weight of evidence and the *precautionary principle*.<sup>23</sup> in the face of uncertainty or conflicting information, the balance of risks in decision-making must favor conservation. Protections can be reduced at a later time, in the event they are clearly and consistently shown to be unneeded.

***E. The paired watershed design cannot demonstrate that small adverse impacts, considered to be within the range of natural variability, would not in fact cause adverse degrade aquatic ecosystems.***

A general trend toward reduced harm to water resources and fish habitat from forest management actions does not necessarily equate to either no harm or recovery. While properly implemented Best Management Practices can certainly reduce harm to water, fish and wildlife resources in many cases, whether the known reduction in harm is sufficient to reverse the cumulative impact of past management practices, thereby promoting recovery, is unknown and remains untested in most extant studies. It is the net, landscape-wide sum of disturbance effects that will determine instream and biological responses that define recovery or effective restoration. Reduced harm from individual management actions that BMPs can sometimes help achieve can be offset by two major factors: 1) an unregulated increase in management disturbances (wherein individual actions are less harmful than in the past, but the sum total of effects may be as harmful or more so), or 2) the failure of ecosystems to fully recover from past severe harms before new, albeit less incrementally severe impacts are introduced.

***F. Extensive, multiple-site studies (e.g., RipStream) have more statistical power to detect effects, and are otherwise more appropriate than paired watershed studies for informing environmental policy.***

Paired watershed studies fall into the category of so-called BACI (Before-and After Control-Impact) research designs.<sup>24</sup> This design assumes that relations between an experimental and a paired untreated control ecosystem are stationary over time. One of the advantages of this design is it allows a high degree of precision and continuity of specific measurements, and it can be framed as a nested design that is useful for detecting some limited forms of downstream effect. However, *the usefulness of BACI-type watershed study designs for informing regulatory policy is severely limited by the lack of strong replication of both treatments and untreated control ecosystems.*

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<sup>23</sup> Buhl-Mortensen, L. (1996). Type-II statistical errors in environmental science and the precautionary principle. *Marine Pollution Bulletin*, 32(7), 528-531; Noss, R. F. (1993). Some principles of conservation biology, as they apply to environmental law. *Chi.-Kent L. Rev.*, 69, 893

<sup>24</sup> Buhl-Mortensen, L. Type-II statistical errors in environmental science and the precautionary principle. *Marine Pollution Bulletin* 32(7):528-531.1996. Noss, R.F. Some principles of conservation biology, as they apply to environmental law. *Chicago-Kent Law Review* 69(4/6):893. 1993. Underwood, A.J. On beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecological applications* 4(1):3-15. 1994.



To understand this problem it is helpful to recognize that there are two main categories of error that can occur when drawing inference from such studies. *Type I error* arises when the investigator claims that evidence supports an effect when none really exists. Conventional statistical analyses are designed to minimize this probability, for example, to limit the cost of imposing a regulatory rule that may later prove to have been unnecessary. However, when dealing with ecosystems and species heavily impacted from past management practices, and where a great deal of uncertainty exists about their ability to persist under prevailing environmental conditions (i.e., in the absence of some significant recovery trend), *Type II error* assumes greater importance.<sup>25</sup> Type II error occurs when the investigator concludes there is no effect when in fact one actually exists in the field. That is, the design and measurements were inadequate to detect an effect that actually occurred; this is frequently a result of high variability in control system behavior, or of unacknowledged variability in the underlying relation between control and treatment watersheds.

The known variance structure of both physical and biological factors in montane humid forest ecosystems elevates risk of Type II error; that is, complexity and diversity in field conditions and a variety of possible responses to any single category of treatment or practice favors study designs that rest on multiple paired comparisons over time and space. Multiple replication of treatments and controls across the landscape greatly increases statistical power, or the ability to detect effects of the treatment, and reduces the likelihood of Type II error compared to BACI designs that rely on heavy instrumentation of a smaller number of watersheds.<sup>26</sup> Moreover, studies relying on multiple comparisons conducted over a far broader range of sites provide more robust environmental data domain to identify environmental conditions under which effects may be more or less likely. This can be instrumental for tailoring regulatory decisions to prevailing environmental conditions.

In effect, paired watershed studies, while they are useful for teasing out the mechanisms of cause and effect of watershed responses, are inherently limited in ways that make them unsuited as the primary scientific basis for generalizing conclusions or recommendations across basins or regions. *Multiple paired comparison designs, such as that employed in ODF's RipStream study, are far better suited for generalizing responses to management practice, hence they provide more reliable information for shaping policy and practices affecting broad areas.* In view of this, it is no surprise that while the paired watershed studies have shown only a few examples of stream warming in response to logging treatments, the RipStream study has by contrast revealed a substantial incidence of undesirable stream warming after logging under current Oregon Forest Practices Rules. RipStream results also revealed a smaller number of cases where streams did not warm after logging, consistent with some of the paired watershed study results to date. This establishes that the results of those paired watershed studies likely fall into the much smaller category of western Oregon streams that are less susceptible to stream warming stemming from riparian shade reduction—that is, they are not particularly representative of the majority of streams found throughout western Oregon, most of which have been shown

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<sup>25</sup> *Id.*

<sup>26</sup> Underwood 1994.

to be sensitive to even marginal shade reduction. It should also be noted that it appears likely that the anticipated effects of climate change in western Oregon hydrology and vegetation could make many of those streams that today are buffered by groundwater processes less so, and more sensitive in the future to the effects of riparian forest shade.

Large storms, major droughts, and windthrow events are critical triggers of many of the longest-lasting and most biologically significant responses of watersheds to forest management. Such responses occur or do not occur based on whether a triggering event, such as a large storm or rain-on-snow runoff event, strikes within a post-treatment window of years. The absence of a triggering event in the post-treatment period means the true possible range of effects was not measured. Conversely, the occurrence of such a triggering event in the pre-treatment period can obscure or mask the effects that would otherwise be observed after management treatments. In general, the patchiness of such triggering events in time and space favors more extensive study designs with multiple paired comparisons, with treatments dispersed over space and time.

With low-power BACI designs, “natural variability” is less resolved, and appears to obscure the ecological significance of the apparently small changes in some factors seen in paired watershed studies. It would be an unfortunate corruption of scientific method to turn low statistical power on its head, and use unresolved variability as a rhetorical device that obscures, rather than reveals treatment effects (e.g., when observed responses are claimed to fall “within the range of natural variability”).

#### **IV. A response to various claims being made in recent public discourse about the Paired Watershed Studies**

***Claim #1: “Oregon coast coho “are holding their own”<sup>27</sup> under current practices, so change is not needed”<sup>28</sup>***

The most severely depleted species of stream and fishes in western Oregon, including the Oregon Coastal Coho Salmon, the Southern Oregon-Northern California coastal coho salmon, the Lower Columbia Coho salmon, the chum salmon, the spring Chinook salmon, summer-run steelhead, the bull trout, and lampreys, all continue to exist well below their recent historical abundance, and far below their long-term historical abundance. These forms have also been extirpated from many streams they historically occupied, and there is limited evidence to date that they can be re-established under prevailing environmental conditions. Much more systemic and sustained recovery of natural habitat conditions appears to be necessary before recovery of these species can occur.

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<sup>27</sup> OFRI, 201. The Oregon Way. Page 2.

[http://oregonforests.org/sites/default/files/publications/pdf/OregonWay\\_Fish\\_Habitat\\_singles.pdf](http://oregonforests.org/sites/default/files/publications/pdf/OregonWay_Fish_Habitat_singles.pdf)

<sup>28</sup> The Oregon Way just says that Coho are holding their own, not that that means current practices are adequate, I just wonder about that claim and how it might be used relative to the paired watershed studies. “Oregon’s unique, steady approach to preserving and improving habitat in forest streams is paying off, not only for Coho, but also for other species such as steelhead and cutthroat trout.”

***Claim #2: “The effects of forest practices are very small.”<sup>29</sup>***

It is well-established that the effects of present-day forest practices are less harmful to streams and rivers than past forest practices. What is not established is whether the incremental effects of smaller harms today further impair or retard the restoration of habitat and recovery of fish and wildlife. Because recovery from many past harms is far from complete, natural-historical ecosystem resilience has not fully re-established; hence even small incremental adverse effects can sometimes impose direct and measurable consequences on biota and habitat. Secondly, the cumulative consequences of actions that individually pose small risk of impact can, when they accrue over the larger landscape of a watershed, river basin, sum to a larger risk of harm occurring. In other words, if practices are improved, but logging (and associated impact from roads) occurs with greater frequency over larger areas affecting more streams in a given time frame, cumulative harms are likely to occur.

***Claim #3: “The effects of forest practices are the same kind of effects that would be seen anyway because of the natural variability across forested landscapes.”<sup>30</sup>***

Roads are by far the largest and most long-lasting source of impact to streams and wetlands, but roads have no natural analogue. Roads permanently affect runoff, revegetation, erosion and sedimentation, routing of leached nutrients, pesticides and other contaminants to streams. It is difficult to adequately control for and measure the long-term effects of existing and new roads, and operations that mobilize sediment from road surfaces in paired watershed studies in second growth forest areas. Existing roads, even if no longer in use, cause elevated sediment loads falsely interpreted as “background,” potentially masking additional sediment effects from logging and other sources.

Management disturbances cannot be assumed to replace or compensate for natural disturbances. Even when they occur within some perceived within natural range, of variability, human-caused disturbances are generally additive to natural disturbances, and at worst than can be multiplicative in their effects.

Finally, temperature, sediment, wood debris, and nutrients all subject to varying degrees of retention, dilution, and downstream transfer and accumulation. Paired watershed studies conducted in the headwaters, with generally low power and a limited temporal and spatial

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<sup>29</sup> A Synthesis of the Impacts of Contemporary Forest Practices on Aquatic Ecosystems at a Watershed Scale: A Case Study from Hinkle Creek; Skaugset, A., M. Adams, D. Bateman, K. Cromack, L. Ganio, and B. Gerth | 04/18/13,

[http://watershedsresearch.org/assets/reports/WRC\\_Skaugset\\_Hinkle%20Synthesis\\_2013\\_S4.pdf](http://watershedsresearch.org/assets/reports/WRC_Skaugset_Hinkle%20Synthesis_2013_S4.pdf),

“He says of current forest practices: ‘We have dramatically reduced the impact. The rules aren’t perfect, but they have made the effects very small.’” The Oregon Way, p. 8. Quoting George Ice.

“One of the exciting things about forests is they are resilient, and so if we can reduce the impacts to very small impacts, then they recover rapidly over time and downstream, and so we can protect those. We are still able to detect changes in water quality and habitat as a result of forest management activities, but those changes have become so small that they are certainly within the range of natural variability that we see in watersheds. George Ice, OFRI *The Oregon Way: Video Special Report* at 6:25, <http://oregonforests.org/content/ofri-resources?t=76&vidid=588>.

<sup>30</sup> *Id.* at slide 38. “These changes were often difficult to detect, not acute, often subtle, and the magnitude of the change existed well within the spatial variability exhibited within the watershed.”

frame to detect changes in these factors, cannot be invoked to rule out the possibility of accumulative impact downstream occurring or continuing over time. Specific studies of different design are necessary to accurately account for the interaction of natural and human-caused variability in aquatic and riparian ecosystems—and for the most part these have not been conducted.

***Claim #4: “Fish in general are not harmed by logging under current OFPA rules because the results in Hinkle Creek show that westslope cutthroat trout are not declining.”***

Hinkle Creek results are not likely to be representative of the biological responses occurring in streams with a variety of fish species present. Single-species systems are robust to disturbances compared to multi-species streams, or those that have been invaded by nonnative species, where biological interactions mediate complex biological response to habitat changes. Even subtle habitat shifts (e.g., slight seasonal increases in temperature, sediment, or possibly nutrients) can mediate large shifts in biotic interactions and competitive balance between fish species. Therefore, evidence of harmful effects from small-magnitude shifts in habitat condition is far more likely to be seen in streams where multiple fish species coexist, or where anadromous salmon coexist with cutthroat trout and other fishes.

Hinkle Creek results also do not span a long enough time frame to conclude that medium- and long-term harms to cutthroat trout will not occur.

***Claim #5: “Fish productivity is increased by more light from canopy removal, therefore conservation of shade is not good for fish, streamside logging is good for fish, and water quality criteria that prohibit human-caused stream temperature elevation by more than .3 degrees Celsius are bad for fish.”<sup>31</sup>***

First, the effects of removal of riparian vegetation are complex and the outcome depends on the balance of several interacting factors, including sunlight’s effects on water temperature and on algal production, nutrients, and canopy litterfall and insect production. The water quality standards, or coldwater temperature criteria, are established based on empirical evidence that temperature increases above the specified thresholds cause physiological and behavioral stress to fish that is not generally compensated or compensable by these other potential effects. In other words, the potential for increased sunlight and other factors to increase production in a way that biologically compensates for summer stream warming has already been factored into the coldwater criteria.

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<sup>31</sup> “more sunlight can boost food production and help fish feed more efficiently. This leads to more and larger fish.” The Oregon Way, page 10. “Gains for fish due to post-logging increases in sunlight substantially outweigh the challenges of increased temperatures during the warmest days of the year.” The Oregon Way, page 11, quoting Steve Cramer. However, the Oregon Way at page 11 also discusses the RipStream study and the .3 degree standard and does not make any claim that the Board of the Forestry should not make any changes to address violations of the standard. The discussion of the study and implications for forest practice rules is reasonably objective.

Second, many western Oregon streams, and most lakes and rivers are already warm enough in midsummer that temperature optima for salmonid fishes are exceeded stresses impair growth and survival. Oregon's coldwater fish fauna inhabits a warming environment; any practice that warms streams beyond their existing or natural regime is simply going to be generally harmful.

Third, climate change further exacerbates the risk of stream warming in summer and through likely reductions in summer baseflows and increased fire risk. Fourth, canopy openings from fire, windthrow, landslides, floods, and other natural disturbances are sufficient themselves to prevent western Oregon streams from being completely shaded. Logging disturbance adds additional canopy opening that compounds and adds to the effects of these natural events, rather than mimicking or replacing them. It is not uncommon that windthrow in the stream buffers left after logging results in greatly reduced shade and harmful stream warming that would not have occurred had riparian forests been left largely intact.

***Claim #6: "Amphibians are not harmed by logging under current OFPA rules."*<sup>32</sup>**

Recent studies do not provide sufficient information to draw this conclusion. Besides the general limitations of any paired watershed study discussed above, the complex life history and habitat requirements, ecological differences among species, and difficult enumeration preclude any simple and unqualified conclusions about population-level impact of logging and other forest changes on amphibians. Some species are likely to be more sensitive to long-term effects wood loss and microclimate changes in riparian areas and wetlands, others may be more sensitive to changes to near-term changes in the aquatic environment. Many studies have show that the capacity for recolonization from nearby habitat refugia across the landscape or through a stream network is a critical for survival and recovery of sensitive amphibians. Because of widespread logging and roads and the sustained loss of late successional forests, present state and private forest policies may not adequately maintain or restore such refugia on appropriate scales to support recolonization, especially where logging rotations are shorter than 50-60 years. As a result, what we perceive as baseline populations on state and private forestland are likely greatly reduced from their historic distribution and abundance. This brings a high risk of downward ratcheting of both population status and our ability to detect changes in populations over time frames that are most significant for biological recovery, especially where adjacent old-forest refugia and relatively undisturbed watersheds on federal lands are lacking.

***Claim #7: "We have time to consider forest practice rule changes."*<sup>33</sup>**

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<sup>32</sup> Short-Term Response of Dicamptodon tenebrosus Larvae to Timber Management in Southwestern Oregon, Leuthold N., M.J. Adams, J.P. Hayes | 04/17/11, Short-term Relationship of Timber Management and Pacific Giant Salamander Populations, and the Response of Larval Stream Amphibian to Predators Under Leuthold, N. | 03/02/10, <http://watershedsresearch.org/results/>

<sup>33</sup> "The fact that we've not observed short-term negative effects on fish or habitat at Hinkle Creek or Alsea suggests we have time to consider what the next set of changes in forest practice rules should be." Doug Bateman, scientist studying fish response. The Oregon Way at page 9.

When forest practices contribute to environmental changes that pose long-term consequences and are not readily reversible by management means, the notion that “we have time” to continue activities that pose risk of impact is false. Current practices affect a very large number of ongoing site-specific actions and projects annually, and these actions can individually and collectively can pose persistent, long-term consequences when they affect such processes as sediment transport and storage in streams, rivers and lakes, the abundance and functions of large wood debris, and nutrient status of rivers, wetlands, lakes, estuaries, and the nearshore marine environment. This far reach of effects in time and space is the central reason why forest practices are subject to regulation and control at all. In the case of stream temperature, we do not have the means to reverse stream warming when it occurs, as it often will, a fact firmly established in the RipStream study. In those many cases, we can only wait for riparian vegetation to become re-established, and hope that it is not further damaged and reset by post-logging windthrow, landslides or debris flows.

***Claim #8. “The paired watershed studies consistently show that today’s riparian protection rules have achieved a balance that is beneficial to fish within logged areas.”<sup>34</sup>***

Looking across the record of paired watershed studies old and new, *what is apparent is that in fact there is very little consistency of results.* Watershed impacts that can harm fish and water quality sometimes are not detected until many years after the logging treatments (e.g., in the case of landslides that occur after root strength decays, or summer low flows that decline below pre-logging conditions for many years, after a few initial years of increases). The complexity of outcomes, the divergence of responses from study to study and between sites within a single study where streams are replicated, and the fact that many of the most biological harmful outcomes were not unanticipated by researchers and were as a result sometimes not easily quantified given the study design, add up to a scientific record that argues strongly in favor of a precautionary approach to regulating logging activities in riparian areas, wetlands, unstable slopes, and other sensitive areas within watersheds. Once adverse effects occur, they are very often not reversible, and can remain harmful for long periods of time.

***Claim #9: Paired watershed studies “challenge scientific assumptions” that current timber harvest practices cause adverse impacts to aquatic ecosystems and that more prescriptive rules would reduce those impacts.***

Science doesn’t rely on untested “assumptions,” rather it consists of the explicit test of assumptions. The goal of research should not be to challenge supposed general conclusions that scientists make about forest practices; the goal should be objective – to find the verifiable answers and formulate more refined or better supported hypotheses about specific, repeatable associations of phenomena and mechanisms of cause and effect. The driving assumption of WRC appears to be that federal forestlands are saddled with

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<sup>34</sup> “The RipStream and paired watershed studies in Oregon, as well as logging studies in British Columbia, Washington and northern California, consistently show that today’s riparian protection rules have achieved a balance that is beneficial to fish within the logged area, and have little effect on fish more than 300 meters downstream.” Cramer Fish Sciences Review, quoted in The Oregon Way at page 11.

excessive and untested restrictions.<sup>35</sup> This posture from the very start clouds the policy implications of the research. It's not that the scientists involved aren't objective, but if subjective policy goals that drive specific studies, that must be considered in a rational consideration of the science. It is incumbent on the Board of Forestry to consider best available science, not just selectively favor a subset of studies that are purported to show forest practices are good enough or possibly too restrictive.

Conflicting research results signal that a re-examination of scientific assumptions, designs, and results is warranted. They do not provide an automatic logical license to reject older research in favor of newer research. A rational analysis must consider all of the ways that new research results may build on or alter the interpretation of older research findings; some of these may reflect complex cause and effect conditions, differences in the timing or sequence of natural and human events, and other complications that can be reconciled and explained if considered carefully. Conflict in findings is not justifiable grounds for simply throwing out older studies in favor of new studies, or cherry picking to develop policy that relies on studies in which results happen to be more favorable to the status quo of management.

***Claim #10: "Paired watershed studies like Hinkle Creek show that stream warming of headwaters does not impair downstream waters."***

The literature on the basic physics of warming and cooling of stream water shows there are no physical mechanisms that cool water fast enough to compensate for the rate and total load of warming created by opening up the canopy to solar penetration. For most streams, the potential warming is magnitudes greater than the potential for cooling when canopy vegetation is lost. That said, measurements of stream temperature at specific locations reflect the complex outcome of mixing of water from upstream with that from tributaries, and from groundwater emergence from both deep and shallow (hyporheic) sources. Water warmed in logged headwater streams does not disappear, though it may be diluted by cool water from these other sources so that downstream thermal records do not record an increase in maximum daily temperature. Warmed water mixes with surface water sources, or penetrates in to the hyporheic system, where it will subtly but surely warm these waters. This warming is more likely to be reflected in daily, weekly mean temperatures, or cumulative thermal units (degree-days) over time, and is less likely to be expressed in daily temperature maxima. Because warmed water has been allocated in the ecosystem does not mean its effects have vanished; it does make them more difficult to measure. For example, cumulative warming of hyporheic flows in alluvial aquifers can reduce their capacity to form coldwater habitat refugia and to cool surface waters when they emerge and mix. The result may be expressed most significantly well downstream of headwater sources, in larger streams and rivers where summer coldwater habitats are limiting and any thermal refugia are critical to survival and reproduction of sensitive species.

A second problem is the "drifting baseline" phenomenon referred to above. For example, the downstream "control" site in the Hinkle Creek study had seen clearcut logging in its catchment during the years just prior to monitoring for the paired watershed study. Moreover, all of the Hinkle Creek study streams were in some stage of recovery from the

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<sup>35</sup> <http://watershedsresearch.org/about/about.html>

first entry of extensive logging in the basin. The result may be that what we measure as the “control” or benchmark temperature could be well elevated above what were natural stream temperatures under historic late successional forest conditions. If so, they may be relatively insensitive to additional warming from present-day logging disturbance.

A third and related problem is that stream temperature is continuous and dynamic in space and time. While we might record that a tributary stream does not increase in temperature after logging, the stream might in fact have cooled had it not been subject to the new disturbance. *The effect of a logging treatment might be expressed not as warming after logging, but as an arrested cooling trend, which might well be discernible only with ten or more years of pre- and post-logging data.* This is another illustration of a small effect that may have a large environmental effect when it accrues across time and space. Impairing the recovery of thermal regimes is problematic for listed species like salmon when background summer temperature is presently stressful and a threat.