REVIEW OF RESEARCH ON THE EFFECTIVENESS OF WASHINGTON'S FOREST PRACTICES ACT RULES TO PROTECT BENEFICIAL USES AND WATER QUALITY

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REVIEW OF RESEARCH ON THE EFFECTIVENESS OF WASHINGTON'S FOREST PRACTICES ACT RULES TO PROTECT BENEFICIAL USES AND WATER QUALITY – SEDIMENT –

Since adoption of the State of Washington's Forest Practices Act in 1974, its forest practice rules have been assessed and tested and have evolved in response to new information. Washington is unique among states in developing cooperative research programs such as Timber/Fish/Wildlife (TFW) and the Cooperative Monitoring Evaluation and Research (CMER). Perhaps the most comprehensive changes in the rules since 1974 were adopted as part of the Forests and Fish Agreement (F&F). The rules adopted under F&F represent a major commitment by landowners to meet water quality and aquatic habitat objectives. It is important to recognize that many of those changes were designed not to keep material out of streams, but to provide sources of future wood inputs. Major commitments were also made to identify and upgrade roads to reduce sediment delivery to streams. Forestry, like all other land uses, has legacy conditions that benefit from active restoration and remediation efforts, which are part of road maintenance and abandonment plans. Here we review recent findings on mitigating forest management activities to reduce sediment loads resulting from forest management.

SEDIMENT IS NATURAL AND ESSENTIAL TO AQUATIC SYSTEMS

Any discussion about sediment in forest systems needs to recognize that it is a natural component and is essential for aquatic functions. Perhaps the most succinct synthesis of our understanding of sediment in forest streams prior to the 21st Century was provided by Everest et al. (1985):

> Undisturbed streams in forests have stored abundant sediment in their channels and maintained an equilibrium between sediment input and sediment routing. An abundance of large organic debris and other roughness elements played an important role in the storage and routing of sediments. Forest management has broadly changed sediment storage and equilibrium in streams throughout much of the western United States. The general result has been a concurrent loss of roughness elements and accelerated routing of sediment through fluvial systems. There is evidence that stable channels containing stored sediment and large organic debris are far more productive at every trophic level than either degraded channels mainly devoid of sediment or channels that are aggraded and unstable. Thus there seems to be a broad middle ground between too much and too little sediment in salmonid habitats.

One important recent change in this "equilibrium" view of sediment is recognition that sediment in streams is shaped by disturbance events, with pulses of sediment or wood or both, and that aggradation and degradation occur simultaneously in the same watershed. Harvey et al. (1987) found that:

> In the current cycle of aggradation and degradation, the spatial and temporal variability of sediment deposition and erosion can be illustrated by reference to 3 locations along the study reach where the cycle is now complete…The downstream time-lag can be

> explained by 3 factors; (1) degradation of upstream reaches increases sediment delivery to the lower reaches, (2) baselevel is [now] lower for the tributaries which causes them to degrade and supply sediment, and (3) the width of the valley increases downstream which allows more sediment storage.

Miller and Benda (2000) observed important habitat benefits to streams in response to a sediment wave moving through a stream reach:

> Transient channel changes similar to those inferred at Gate Creek have been observed in many rivers following sediment influxes and sediment-wave passage. These include (1) aggradation followed by incision… (2) increase in channel width followed by incision… (3) fining of the channel-bed-surface sediment grain size followed by coarsening… (4) transformation of single channels to braided channels… (5) decrease in the number of pools in conjunction with an increase in riffles followed by an increase in pool frequency and depth…

One surprising observation by Kirchner et al. (2001) was that, "…long-term sediment yields are, on average, 17 times higher than stream sediment fluxes measured …[over the last] 10-84 yr[s]." This unexpected result may have been a consequence of extreme events (e.g., floods following severe wildfires) not being captured in recent monitoring, and may also have been an artifact of the recent period of fire suppression. Consistent with other studies (e.g., Beschta and Jackson 2008), McBroom et al. (2003) observed that most sediment comes out of watersheds during extreme events.

Sediment is a natural component in forest streams; channels can degrade and aggrade in the same watershed; pulses of sediment are essential to create favorable habitat features; and sediment patterns are strongly tied to extreme runoff events.

SEDIMENT LOADS VARY WIDELY FOR DIFFERENT GEOLOGIES AND OVER TIME

More than two decades ago concerns were raised about fine sediment in Washington streams and an observed correlation with forest management. Responding to these observations, Duncan and Ward (1985) found that, "The amount of fine sediment (<2 mm in size) was more closely correlated to the lithology and soils of the watershed than to forest management practices, specifically forest roads." Geology and soils, as well as geomorphic position and characteristics, influence observed sediment characteristics. In an evaluation of proposed Total Maximum Daily Load (TMDL) assessment methodology, Ellis-Sugai (2009) cautioned that "geologic and geographic variability needs to be taken into account when selecting reference sites and comparing them to the watershed in question." Not only do sediment loads and conditions vary with geology, but they also vary in response to storm patterns, disturbance history, and legacy conditions. Beschta and Jackson (2008) reported that Flynn Creek, the control watershed in the Alsea Watershed Study (1959-1973), had annual sediment yields ranging from 58 to 1270 tons/mile^2. Wildfires (Ice et al. 2004), severe storm events (McBroom et al. 2003; Robison et al. 1999), and other watershed disturbances can result in widely different sediment fluxes and loads in streams.

Sediment conditions depend on geology and disturbance patterns, and can vary one or two orders of magnitude between years even without forest management activities.

FOREST PRACTICE RULES OR BEST MANAGEMENT PRACTICES CAN REDUCE SEDIMENT LOADS

There has long been concern in Washington and elsewhere that unrestricted forest operations can result in elevated sediment loads (Brown 2008). This historic potential is represented by data from numerous paired watershed studies in this region, including the Alsea (Beschta and Jackson 2008) and H.J. Andrews Experimental Watersheds in Oregon (Fredricksen 1970) and Caspar Creek in northern California (Lewis 1998). There is strong evidence nationally and regionally that forest practice rules used in Washington dramatically reduce sediment loads to streams.

Washington has a comprehensive set of forest practice rules and programs designed to minimize negative impacts from sediment. Key elements include:

- riparian management zones and wetland management zones designed to minimize near-stream disturbance and sediment delivery
- road construction rules to minimize erosion and sediment delivery
- road maintenance and abandonment plans to upgrade existing roads
- harvesting rules designed to minimize erosion and sediment delivery
- unstable slope rules designed to minimize acceleration of landslides
- site preparation rules designed to minimize erosion and sediment delivery

Forest practice rules are designed to be redundant in protecting of water quality. For sediment, they are first designed to reduce accelerated erosion and, if erosion does occur, to reduce transport of sediment to streams. An example of this redundancy can be found in the harvesting rules addressing ground-based operations. WAC 222-30-070 (9) states that "Ground-based systems shall not be used on slopes where in the opinion of the department this method of operation would cause actual or potential material damage to public resources" [limits erosion generation on steep slopes]. Where ground-based systems are appropriate, skid trails must be kept to the minimum width (WAC-222-30-070 (7)(a)). In addition, WAC-222-30-070 (8)(b) requires that "Skid trails located within 200 feet horizontal distance of any typed water that directly delivers to the stream network shall use water bars, grade breaks, and/or slash to minimize gullying and soil erosion. In addition to water barring, skid trails with exposed soils that is erodible and may be reasonably expected to cause damage to a public resource shall be seeded…" Each of these specific actions is generally supported by extensive research results demonstrating effectiveness. For example, McGreer (1981) showed that slash on skid trails significantly reduced sediment losses from sites in Idaho. Castelle and Johnson (2000) reviewed the literature on sediment delivery and found that most sediment deposits within 200 feet. One exception is where "breakthrough" sites with concentrated flow may be located (Rivenbark and Jackson 2004), but dispersing flow with water bars and other diversion practices helps to address this concern (Bilby et al. 1989; Furniss et al. 2000).

A study specifically addressing how timber harvest practices in Washington affected sediment-related water quality impacts during the pre-F&F era was reported by Rashin et al. (2006). In assessing the effectiveness of pre-F&F buffers they found that 19 of 22 sites studied "…showed zero delivery from harvest erosion features by the second year following timber harvest. This finding illustrates the overall effectiveness of stream buffers as a BMP to prevent chronic sediment delivery to streams." They further found that "stream buffers practices were most effective where timber falling and yarding activities were kept at a least 10 m from streams and outside of steep inner gorge areas. The overall effectiveness of streamside buffers was diminished by cable yarding routes or skid trails that crossed the buffers and streams." Rashin et al. also found that the pre-F&F BMPs along nonfish bearing streams without buffers were generally ineffective except for some special conditions (e.g., winter harvests over snow). As a result of these findings, equipment exclusion zone rules (e.g., WAC 222-30-021-(2)) were adopted and the rules for crossing streams with ground or cable equipment were tightened (WAC 222-30-060, WAC 222-30-070).

Because of the redundancy in protection and because of the high natural variability in sediment parameters (see later discussion), it is often best to use a paired watershed or replicated control-reach approach to assess the effectiveness of the "package" of forest practice rules. Two remarkable studies from outside this region show how effective sediment-minimizing forest practices can be compared to past practices. Dr. John Hewlett, considered by many to be the father of forest hydrology, studied the impacts of logger's-choice forest harvesting on the Grant Forest, Georgia, in the mid-1970s (Hewlett 1979). He found that "…sediment pollution of streams by forestry operations appears from this study to be far less than annual levels of export deemed tolerable under agriculture." However, he also concluded that if the operations had employed just three additional control practices (well designed and maintained roads, adequate streamside management zones, exclusion of machine planting near abandoned gullies) the sediment produced from forest harvesting could have been reduced by about 90%. Williams et al. (2000) and Jackson (personal communication) repeated watershed studies in the Piedmont, the first in South Carolina and the second back at Grant Forest. In both cases they confirmed Hewlett's prediction: when BMPs were used sediment losses due to management were reduced by about 90%. A similar return to a historic watershed study was undertaken at the Alto Watershed Study in Texas. McBroom et al. (2008) found sediment losses associated with contemporary forest practices with Best Management Practices (BMPs) reduced to one-fifth the impact observed with clearcutting, shearing and windrowing, and burning without BMPs. During the pre-treatment period of the recycled study Tropical Storm Alison caused sediment fluxes that greatly exceeded those observed following the second forest harvest. These types of results are not limited to watersheds outside the Northwest.

Lewis (1998) compared suspended sediment losses in two studies conducted at Caspar Creek in northern California. One study was conducted prior to adoption of modern forest practice rules and the second was after the rules were adopted. Using different models, Lewis (1998) and Rice et al. (1979) came to similar estimates of the increases in suspended sediment for the study without state forest practice rules and with poor road locations. The two assessments estimated increases of approximately 1400 to 1500 kg $ha^{-1}yr^{-1}$ for the year after road construction and 2900 to 3250 kg $ha^{-1}yr^{-1}$ for the five year period after harvesting. "Reversing the roles of the two watersheds for the later North Fork logging with forest practice rules, the same analysis was unable to detect an effect" (Lewis 1998). Using different assessment methods, Lewis estimated that this second treatment with forest practice rules implemented resulted in an increase of 188 kg $ha^{-1}yr^{-1}$. This compares to annual sediment loads that can vary from 50 to more than 5000 kg $ha^{-1}yr^{-1}$. Further analysis by Lewis, accounting for a potential flow effect, suggested that pre-forest practice rule treatment resulted in 2.4 to 3.7 times the effect that post-forest practice rule treatment caused. Some of this increase in suspended sediment was probably a result of increased storm flow volumes. Cafferata and Splitter (1998), looking at the same watershed, found a difference in landslide frequency for these two studies. "Numerous landslides were document after road construction and logging in the South Fork [pre-forest practice rules] owing to inadequate road, skid trail, and landing design, placement, and construction. In contrast, the size and number of landslides after timber operations in the North Fork to date have been similar in logged and unlogged units." While various statistical models can be used to confirm or reject that a sediment change has occurred from management, it is clear that the forest practice rules in California greatly reduce sediment load increases, especially compared to natural inter-annual variability.

The Hinkle Creek Watershed Study in Oregon is the first paired watershed study to test the effectiveness of the Oregon Forest Practices Act rules since the Act was adopted in 1971. This is a nested paired watershed study with control basins at multiple scales and multiple treatment subbasins (http://www.watershedsresearch.org/HinkleCreek/HinkleCreek.html). One of the main focuses of the study is how harvesting affects the water quality of fishless headwater streams and how those impacts transport downstream. Pre-treatment monitoring was conducted from 2001 to 2005, and harvesting occurred in winter 2005/2006. A second harvest along fish-bearing reaches was recently completed. First results showed increases in sediment due to harvesting along the non-fish headwater reaches (Zégre 2008), largely as a result of increased flow (the vast majority during the first fall after harvest). Intensive biological monitoring is being conducted in conjunction with water quality monitoring. While sediment loads were found to be significantly increased, fish have shown almost no response except a possible slight bump in movement and an increase in productivity associated with the first harvesting in the headwater reaches (Doug Bateman, Oregon State University, personal communication).

Another nearby test of state forest practice rules is found at Mica Creek in northern Idaho. In a nested paired watershed design, the Idaho Forest Practices rules for road building, selective harvesting and clearcutting, and site preparation using prescribed burning have been tested. Karwan et al. (2007) recently published a paper summarizing the suspended sediment results from that study. They found that:

> Road construction, including improvement of the existing roads, did not produce a significant difference in monthly suspended sediment load relative to a control watershed. Clearcut harvesting did produce a significantly higher suspended sediment load immediately following the harvest. However, within one year following the harvest, sediment load became statistically indistinguishable from that of the pretreatment calibration period. Monthly sediment loads did not differ between the partial cut watershed and its control, nor did the loads further downstream differ from their control. Overall, the 14 years of data used in this study showed variability in suspended load, tracking precipitation and discharge, and the effectiveness of best management practices to maintain suspended sediment load within the range of natural variability. The difference seen from clearcut harvesting could be attributed to the increase in discharge and water yield associated with the clearcut, thereby carrying more sediment to the monitoring flume.

Reiter et al. (2009) recently published the results of 30 years of monitoring flow and water quality in the Deschutes River Watershed of western Washington. Adjusting for flow, they found a declining trend in turbidity even as active forest management continues in the watershed. This decline is believed to be a result of improvements in erosion and sediment runoff coming from forest roads.

Washington has a comprehensive package of Forest Practice Rules designed to minimize sediment increases related to forest management activities. Paired watershed tests in adjacent states showed that similar rule packages have been effective in reducing sediment increases to minor changes. There is preliminary evidence that minor and temporary changes in sediment such as those observed with these studies can be tolerated by aquatic communities. A recent trends analysis of turbidity carried out in western Washington showed that turbidity is declining while active forest management continues.

ONGOING TESTING OF THE EFFECTIVENESS OF THE RULES

Another unique element in the history of forest practices in Washington is the legacy of the Watershed Analysis program and cooperative research. This legacy provides additional confidence that current forest practices are effective. It also provides assurance that changes will be made in the future if the rules are found to be deficient in some capacity.

Watershed Analysis (WA) was conducted on numerous watersheds across Washington to allow watershed and site-specific conditions to be recognized and effective local rules developed. This rich legacy of WA in multiple watersheds resulted in some common themes that were adopted as part of F&F (Ice and Reiter 2003). No other state or federal agency has the number and quality of WA found in Washington.

Washington is also pre-eminent in developing cooperative research to assess the effectiveness of forest practice rules. The motto of the TFW Program was "We will go where the truth takes us." This remains the philosophy of current cooperative research efforts. Several sediment assessments by TFW can be found at http://tinyurl.com/rxqfw8. Results from ongoing studies, including those looking at roads, harvesting in headwater streams (Riparian Ecosystem and Management Studies; http://www.dnr.wa.gov/Publications/lm_hcp_p_bigley2005b.pdf), and the performance of F&F rules to moderate landslides (http://www.crcwater.org/masswasting.html), were presented at a recent CMER conference (http://www.ruraltech.org/video/2009/CMER_Conference/).

Washington has a rich history of testing its Forest Practices Act rules and modifying them where necessary to meet environmental objectives. That legacy was used to develop the F&F rules and continues today with ongoing assessments.

STATE WATER QUALITY STANDARDS FOR SEDIMENT

Perhaps the most perplexing issue is how to assess the effectiveness of meeting state water quality standards that are largely unenforceable and both difficult and expensive to measure. Washington Water Quality Standards only address turbidity. Turbidity changes of 5 or 10 NTU or 10 to 20% are allowed, depending on background turbidity and the habitat being protected (WAC-173-2001A-200, Table 200 (1)(e)). Other states have developed similar turbidity standards, and problems have been identified in their application. In California the turbidity standard limits man-made increases to no more than 20% of background. Markman (1990) measured turbidity for two undisturbed streams in northern California. He found "…natural variations in turbidity and suspended sediment concentration along stream reaches of 292.6 and 110.6 meters were -.015 to 3.73 times that of the 20 percent man-induced increase tolerated by law." A study by Hall and Thomas (2002) of larger stream systems showed similar patterns. "Turbidity comparisons between adjoining sites on the two rivers were also used to assess the frequency with which 10% turbidity changes would occur in the absence of known point or nonpoint source turbidity sources. For the McKenzie River, 67% of sample dates indicated >10% differences between the selected upstream/downstream station and 53% of the dates were >10% different in turbidity on the Willamette River." This natural variability creates a difficult burden on any assessment of management impacts. Turbidity can change with discharge, storm sequence, and position in the hydrograph (rising or falling limb). Almost 30 years ago, Brown (1980) described this problem of natural variability in assessing impacts to turbidity:

> The problem of variation becomes critical when trying to assign some level of turbidity acceptable in forest streams drained by logged areas. The Oregon water quality standards prohibit any activity which increases turbidity by more than 10 percent when natural turbidities are greater than 30 JTU [Jackson Turbidity Units]. No increase in turbidity is permitted when natural turbidities are less than 30 JTU. The variation in suspended sediment concentrations described earlier makes it exceedingly difficult to establish the natural level of suspended material for any given flow condition when judging the diffuse sources of sediment typical of forest situations. And these materials are principally responsible for turbidity in streams. The natural variation is almost always greater than 10 percent about some mean value particularly at high flows. The variation in turbidity added by instrument differences or analyst error can also account for more than 10 percent. If such a rigid standard is to be enforced, each source of turbidity will have to be traced and measured. Monitoring turbidities at one or two locations in a large river system is insufficient for enforcement purposes.

Brown (1980) also cited a paper by Rice et al. (1975) that used suspended sediment concentration data from Caspar Creek and Needle Branch to determine how many grab samples would be needed to detect a 20% (Caspar Creek) or 10% (Needle Branch) change due to management with an accuracy of 90%:

> It is evident that small changes in sediment concentration are very difficult to detect in streams like these. A sampling scheme devised to detect such small changes would be nearly impossible to conduct in the field and prohibitively expensive. A more reasonable approach in circumstances of such high natural variation is to simply accept small changes in sediment as part of the natural condition and focus on detecting the large changes which are far more damaging. For example, if the 10-20 percent limit is relaxed and the sampling scheme is revised to detect a five-fold change in sediment concentration, only a few samples are required. In the 1-2 foot stage class on Caspar Creek…, the 12,327 samples required to accurately detect a 20 percent change in sediment concentration can be reduced to only 4 if the change is five times the mean.

Three recent papers are representative of concerns about the potential and limitations of turbidity as a water quality parameter to assess management impacts. Ankcorn (2003) noted that USGS is facing several key issues in interpreting continuous turbidity data. "These include: (1) different methods and technologies used to measure turbidity, (2) effects that physical properties of the solids and streamwater have on the measurement of turbidity, and (3) the best deployment strategy for measuring instream turbidity." Ziegler (2002), also with USGS, had six key monitoring method concerns about using turbidity as a surrogate for suspended sediment: "(1) methods used for measurement, (2) wavelength of light, (3) detector orientation, (4) standards for calibration, (5) grain-size and color effects, and (6) data reporting." Riedel et al. (2003) addressed concerns about development of a sediment TMDL due to high variability in organic and mineral solids in streamflow.

Detecting small changes in turbidity will be prohibitively expensive, given the tremendous natural variability exhibited by forest streams. There is a high potential for false positives when monitoring upstream/downstream turbidity. With improved measurement techniques (such as continuous turbidimeters and standardize methods), control reaches (upstream or paired), and pre-treatment data, it is possible to detect some large changes, but this intensity of measurement is mostly suitable for research-level monitoring.

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