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MEMORANDUM

October 31, 2016

TO: Forest Practices Board

FROM: Hans Berge, Adaptive Management Program Administrator

SUBJECT: Water Typing Technical Reports: Protocol Survey Electrofishing, Off-Channel Habitat, and Type F Habitat Guidance.

The purpose of this memo is to provide a summary of three technical documents for your consideration of a Type F rule and guidance (attached). These reports were created as part of the Type F Matrix adopted at your August 2015 meeting and focused on electrofishing, off-channel habitat, and determination of the regulatory break between Type F and Type N waters. The purpose of these reports was to provide TFW Policy with information to better understand technical issues surrounding water typing and identify areas where consensus recommendations could be brought to the Board.

Recommendations of Best Practices Regarding Protocol Survey Electrofishing

This report summarizes the findings of the electrofishing technical group (ETG) in evaluating the use and efficiency of current protocol survey electrofishing to detect fish. The ETG was tasked with developing a set of recommendations around areas of contention identified by TFW Policy where protocol survey electrofishing is regularly applied. The participants in the ETG were experienced in applying and/or reviewing protocol survey electrofishing data and were stakeholders in the Adaptive Management Program. The recommendations in this report focus on a range of issues, but they can be summarized into probability of detecting the last fish, adequacy of single site visits in determining absence, seasonality of fish occupancy of habitats, and harm to individuals or their populations.

Probability of detection—Electrofishing is the most common method used to capture fish in streams given its simplicity and providing immediate results (if fish are present). There are many important factors that influence the quality of data collected in electrofishing surveys including skills of the operator and crew, water chemistry (e.g., temperature, conductivity, and clarity), and channel complexity (substrate, presence of wood, undercut banks, etc.).

Adequacy of single site visits—Single site visits can be sufficient to establish fish presence, given they occur when the species are present and conditions are appropriate for its use (e.g., conductivity, water clarity, temperature).

Seasonality—Current guidelines for the survey seasons may be sufficient based on assumptions about the movement of fish in headwater streams with current population abundances and distribution.

Harm—When proper protection measures are taken, harm can be greatly reduced to individuals or populations. Where a population contains less than 25 breeding pairs, electrofishing may have a detrimental effect on a population.

Review of off-channel habitat protection under the current Washington Forest Practices Rules

This report was authored by four independent experts in fisheries, aquatic ecology, fluvial geomorphology, and ecosystem processes. This group used available literature to identify the importance of off-channel habitat (OCH) to fish, the role of OCH in regulating productivity, and literature to support using bankfull width and depth to define the extent of OCH.

Importance—OCH occurs across the landscape and is most frequently observed in riverine floodplains that often have channel migration zones but also occurs in confined or unconfined channels without a channel migration zone. The importance of OCH has been well documented for fishes and amphibians. In the Pacific Northwest these habitats have been shown to be particularly important to juvenile salmonids. The report includes a summary of key papers in the appendix for further reading.

Productivity of OCH—In large rivers, the productivity of OCH has been well documented. The smaller channels outside of channel migration zones have OCH that has important value for thermoregulation, predator avoidance, production of macroinvertebrates, refugia during high flows, and storage of organic matter. As identified in the Forests and Fish Report (1999) OCH is an important component to functioning fish habitat.

Use of bankfull benchmarks to identify OCH—Bankfull flow is a benchmark used commonly to describe the datum where channels are connected to floodplains and represents the common flow where the most sediment is transported through time. The bankfull flow sets the long-term average morphology of a stream, within which aquatic habitat is embedded. It also represents the flow at which habitat maintenance and creation is initiated, thus its reference as the “maintenance” flow. Since it represents a frequent more typical flood, aquatic organisms have adapted to this disturbance regime. In combination, these factors support the use of bankfull to define channels, but the direct connection between flow has not been explicitly explored in the literature and the authors suggest additional research in the Adaptive Management Program to better understand this areas of uncertainty.

Recommendations—Additional work is necessary to evaluate several important areas of uncertainty related to OCH and the Type F rule. First, further evaluation of the five percent gradient connection does not seem to be supported by science. Second, a study to understand how common OCH occurs in forest practices and whether or not it is excluded. Third, a follow up study to determine what is being omitted (if anything) and developing a protocol to capture any ommissions.

Technical working group recommendations to assist in the development of Type F abitat guidance

The report of the technical working group (TWG) was focused on identifying areas of improvement in Board Manual 13 to go from a "fish presence" to a "fish habitat" system for water typing. The TWG was given direction to use the current definition of fish habitat in WAC 222-16-010 and to consider current water typing goals (accuracy, error, and balancing uncertainty). The group identified recommendations for changes in the Board Manual and included some areas where further work would be necessary. Most of the document was reached in consensus and areas where there was not consensus have been highlighted in **bold** font. At the conclusion of the report, there are three proposals: water type model, physicals, and a habitat assessment method. All three of these proposals meet the direction to adopt a "fish habitat" system and each have their own strengths and weaknesses.

RECOMMENDATIONS OF BEST PRACTICES REGARDING PROTOCOL SURVEY ELECTROFISHING

Results of the Electrofishing Technical Group for TFW Policy Committee

Prepared by: Howard Haemmerle, Pete Bisson, and Hans Berge

JUNE 27, 2016

FOREST PRACTICES ADAPTIVE MANAGEMENT PROGRAM

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The participation of the above persons does not imply wholesale endorsement of the document by them or their caucuses for each recommendation contained within this document.

EXECUTIVE SUMMARY

This report summarizes the findings of the Electrofishing Technical Group (ETG) regarding the use and effectiveness of protocol electrofishing surveys in detecting fish. The ETG was asked to consider a number of questions related to the efficacy of backpack protocol survey electrofishing and this report addresses each of those questions with a concluding statement followed by a discussion of the evidence supporting the conclusion. This evidence includes published scientific papers as well as the collective experience of members of the ETG who have strong backgrounds in sampling small streams. Where appropriate, specific recommendations are also given.

It is important to note that this document is the authors' attempt to represent a wide range of experience and perspectives, and it does not claim consensus from all technical group participants on every conclusion and recommendation. An attempt was made during every meeting to reach consensus on each question, but it was not always possible. Individual caucuses are expected to bring any unresolved issues related to protocol survey electrofishing to be considered by the entire TFW Policy Committee for inclusion in the Type F discussions subsequent to the release of this report.

Electrofishing is part of implementing a protocol survey that informs the process of stream typing. While this report presents the group's findings about modern electrofishing techniques and survey protocols, it is important to note that it does not address the question of how electrofishing survey results inform where the F/N boundary (division between fish bearing and non-fish bearing segments of the stream) should be located. Electrofishing is an important tool for informing the process of establishing the F/N boundary but it is not the only tool. Our report is restricted to questions about the protocol electrofishing survey technique itself.

A large number of questions were put to the ETG and there was considerable subject overlap among some of them. Rather than repeat each of the questions in the executive summary, we summarize our findings relative to four general topics: (1) probability of detection, (2) adequacy of single site visits, (3) seasonality of fish occupancy, and (4) harm to individual fish or their populations. More detailed answers to specific questions are found in the body of the report.

1. *Probability of detection*

Electrofishing remains the method of choice for detecting fish in streams. Such sites are typically characterized by channels that do not easily lend themselves to other types of fish sampling. Other survey technologies such as environmental DNA (eDNA) are under development and refinement and show great promise, but electrofishing is still the most widely used, effective and efficient method at this time. Site characteristics including water chemistry and clarity, stream size, and the presence of structures in the water that provide escape cover (e.g., undercut banks and log jams) affect capture efficiency, making it impossible to confirm with absolute certainty that fish are absent from a site. However, in the majority of cases electrofishing is the preferred method of detecting fish presence in headwater streams and is the technique most likely to provide accurate information.

2. *Adequacy of single site visits*

Single site visits are believed to be sufficient to establish fish presence, particularly when surveys extend at least one quarter mile above the location of the last sampled fish. The consensus of the ETG was that multiple site visits are not necessary provided the survey protocols are followed and conditions for electrofishing are favorable. This includes sites above natural and man-made barriers to fish passage.

3. *Seasonality of sampling*

The current protocol electrofishing survey guidelines provide a sufficient time window for electrofishing when flows are typically low or declining, but not at the lowest point in the hydrologic year. The ETG acknowledges that seasonal fish movements occur, but based on current evidence the occupied length of perennial headwater streams does not change much over a year in the absence of significant channel altering events such as debris flows. Therefore, surveys carried out according to the existing timelines have a high likelihood of detecting fish if they are present at a site.

4. *Harm to fish or fish populations*

In most situations, protocol electrofishing surveys are unlikely to result in harmful demographic effects on headwater fish populations as long as appropriate precautions are taken to avoid damage to active redds, damage to instream and riparian habitats, or to cause extensive downstream movement of population members. Special cautions or postponement of electrofishing surveys should be exercised if the population is suspected to contain very few breeding individuals (scientific literature suggests 25 breeding pairs as a lower threshold). The electrofishing technique itself does have the potential to harm individuals and eggs exposed to electrical fields. Spinal injuries are most common. The risk of injury can be minimized by employing modern equipment and using settings that are least harmful to fish. The ETG suggests that training and possible certification of electrofishing crews can also reduce risk, as well as ensuring that protocol surveys are conducted in a consistent manner.

INTRODUCTION

The Type F Permanent Water Typing Rule has been a Forest Practices Board (Board) and Policy priority for the past several years. The issue went through Stages 1 and 2 of the dispute resolution process, ending in the submittal of majority/minority reports to the Board in February 2014. At that time the Board directed Policy to work on two specific issues that are necessary for development of a permanent rule (electrofishing and off-channel habitat). By directing the issue back to Policy with more specific guidance, the Board continued following the adaptive management process for resolving formal dispute according with the adaptive management board manual (Section 22) on those two components.

At its February 2014 meeting, the Board approved a motion associated with development of a permanent water typing rule, and both the Board and Policy work plans were amended to reflect the motion. The identified steps are essential for the Board to consider when making a final determination of the appropriate approach to take in the development of a permanent water typing rule. Policy was directed to complete recommendations for options on a permanent water typing rule, beginning with two tasks: (1) development of "best practices" recommendations regarding protocol survey electrofishing, including an evaluation of published relevant literature, minimizing potential site-specific impacts to Incidental Take Permits covered species, and options for reducing the overall extent of the surveys' use, and (2) an evaluation of the current rule process to identify off-channel habitat under the interim water typing rule, including recommended clarifications in field implementation guidance, or rule language. The evaluation must be based, in part, on field review of approved Forest Practices Applications and water type modification forms.

The motion adopted by the Board directed Policy to evaluate electrofishing best practices in the context of protocol surveys, not electrofishing as a general practice. The Board motion also asked that Policy convene a technical group to help evaluate these best practices. The AMPA convened a technical group that included practitioners and other caucus representatives to identify best practices regarding electrofishing within the context of protocol surveys, including how to reduce site-specific impacts of practices of protocol survey electrofishing and how to reduce the overall extent of the surveys' use. This document is produced by the technical group to meet the intent of a "best practices recommendation".

Policy reviewed a draft work plan for what the technical group would do to meet the Forest Practices Board motion, which included a list of items that the technical group would review/consider. Policy specifically asked the technical group: "What can the technical group identify to inform Policy's recommendations on how to reduce site-specific impacts of electrofishing and the overall extent of the protocol surveys' use?" To assist the technical work group, Policy generated a list of questions and concerns the technical group should consider (including implementation issues and other relevant documents and questions previously raised by Policy including – memo from UCUT to AMPA (Dec 2013), Tech/Op memo, FFR sections, draft water typing Charter documents (2013), comments to the draft electrofishing literature review (May/June 2015), comments to the electrofishing workshop summary (Feb 2015), etc.). The AMPA convened the technical group (ETG) in October 2015.

The technical group was tasked with identifying technical and scientific issues related to the application and use of electrofishing associated with the protocol surveys to determine how it may be possible to maximize the efficient and effective application of all available information including electrofishing to minimize both site specific impacts to Incidental Take Permit relative to Endangered Species Act-listed fishes and the overall use of electrofishing. Members of the technical group were in complete agreement that the final product of their work must be grounded in science. With this in mind their first action was to draft a purpose statement to guide the development of a final product. The resulting purpose statement of this report is:

"Use science and data to develop "best practices" recommendations regarding protocol survey electrofishing, including an evaluation of relevant literature, to minimize potential

site-specific impacts to all fishes including Incidental Take Permit covered species, and identify options for optimizing the overall extent of the surveys' use."

The technical group was initially tasked with a set of questions regarding the use of protocol surveys in water typing consistent with their purpose statement, identifying which questions/concerns from the items provided by Policy they considered relevant to the electrofishing topic and which issues they would not address as part of the electrofishing review process. The technical group identified those questions and concerns outside their purview so Policy would be able to address them through other venues.

This report summarizes the issues identified, topics addressed, and proposed recommendations that resulted from the technical group's work. The ETG notes that there was overlap among some of the questions we were asked to address; therefore, there is some duplication of content in several of the answers.

RESPONSES TO POLICY'S QUESTIONS

Responses were developed to assist members of Policy in responding to the Board's February 2014 Motion. Questions have been separated into five categories: site specific impacts of electrofishing on fish, optimization of the overall extent of survey use, seasonal distribution of fish and timing of surveys, alternatives to electrofishing, and training and/or certification.

SITE SPECIFIC IMPACTS OF ELECTROFISHING ON FISH

1. Do single visit surveys affect fish populations?

Conclusion:

Under most survey conditions, population-scale damages from a single visit protocol electrofishing survey seem improbable. Exceptions can occur where surveys affect very small breeding populations of fish that are isolated above natural or man-made barriers to fish passage.

Discussion:

It is important to recognize the difference between the effects of electrofishing on individual fish and the effects of electrofishing surveys on fish populations. Potential physiological impacts of electrofishing on individual fish and fish eggs are discussed below. Population-level impacts caused by electrofishing can occur if surveys cause significant alterations of Viable Salmonid Population (VSP) parameters – population abundance, population growth rate, population spatial structure, or population diversity – such that the long-term viability of a fish population is compromised (McElhany et al. 2000). To determine potential electrofishing impacts on VSP parameters it is necessary to know the effective population size (number of breeding individuals) in a local population and the possibility for immigration into or emigration from local breeding populations to occur, both of which can influence the true effective population size. Large populations are less vulnerable to harm from single visit surveys than small populations in cases where a site visit affects a relatively small fraction of the overall breeding group. Small, closed populations on the other hand are at greater risk of harm if electrofishing results in impairment of the reproductive success, survival, or distribution of a significant fraction of breeding adults. Nielsen (1998) suggested that an effective population size of 25 or fewer breeding pairs of trout could be vulnerable to potential electrofishing damage. In practice it is very difficult to know the number of potentially breeding adults in a population without sampling the population's entire distribution and being aware of the distribution of natural and man-made barriers to migration.

Most fisheries managers seek to obtain data on the total abundance of fish inhabiting a particular stream system. However, for smaller, high-order, streams, such abundance data may not exist. In the absence of data for the total abundance of a population, effective population size may serve as a surrogate for abundance. Since effective population size focuses solely on the relative genetic contributions of adults, the concept does not account for abundance of egg to fry, and fry to smolt, life stages, nor does effective population size necessarily reflect the carrying capacity of a particular habitat. For ESA-listed populations, VSP criteria may matter more than simple estimates of abundance. This becomes critical where sensitive populations that are important to recovery of ESA-listed stocks inhabit headwaters that do not support large numbers of adults.
In most cases, trout will occur higher in a drainage network than non-salmonid species. The following tables give the species identified in last fish surveys conducted in western (Fransen et al. 2006) and eastern (Cole and Lemke, unpublished) Washington CMER investigations.

Table 1. Species present within the stream reaches immediately below the terminal upper limits of occurrence among streams in western Washington State. More than one species was identified at some sites.

	Sites where present	
Species	Percent	Number
Cutthroat Trout *Oncorhynchus clarkii*	88.9	256
Sculpin *Cottus spp.*	10.4	30
Coho salmon *Oncorhynchus kisutch*	5.2	15
Rainbow trout *Oncorhynchus mykiss*	2.8	8
Brook trout *Salvelinus fontinallis*	2.1	6
Threespine stickleback *Gasterosteus aculeatus*	0.3	1

Previously, trout inhabiting small headwater streams were believed to reside in fresh water throughout their life histories and to undertake limited, if any, migrations. Evidence supporting this assumption came largely from marking studies in the UK where the same fish was captured on successive years from the same small stream, often from the same pool (Elliot 1989). If it is assumed that headwater resident fishes do not move, one consequence is that riverine drainage systems contain a mosaic of breeding populations substantially isolated from each other as a result of restricted or absent gene flow. In theory, this can lead to very small effective population sizes in tributaries where trout have access to short segments of the channel and where interbreeding among adjacent tributary populations is absent or minimized.

Table 2. Fish species observed in each watershed during 2002 last fish resurveys in eastern Washington (Cole and Lemke, unpublished data).

Watershed	Cutthroat Trout	Brook Trout	Bull Trout	Redband/Rainbow Trout	Sculpin spp.
Big Sheep		X			
Cabin	X				
Cooper	X	X			
Deer	X	X			
Le Clerc	X	X			
Naneum	X				X
NF Deep	X				
NF Touchet			X	X	
Rattlesnake	X				
Taneum	X	X			

More recent evidence suggests that movement of adult trout among headwater streams does occur where no natural or unnatural fish passage barriers are present, even though the same fish can occasionally be found at the same place at certain times of the year. Fausch and Young (1995) documented the movement of adult Cutthroat Trout among headwater tributaries in the northern Rocky Mountains and suggested that the ability to move around was an important adaptive mechanism for surviving in seasonally variable and often unpredictable environments. Walter et al. (unpublished CMER study) found that nearly 100% of the fish sampled and tagged immediately below the F/N break in western Washington were absent from the same reach a year later, yet densities often were similar year to year. The development and refinement of PIT-tag (passive integrated transponder) technology has facilitated a better understanding of fish movements in small Pacific Northwest streams, and since PIT-tags have been widely employed most monitoring studies have concluded that movement is widespread and is an important attribute in resident fish life histories. However, large-scale PIT tagging of juvenile fish creates its own set of risks, primarily due to tag burden, sub-lethal tag effects, and delayed mortality.

It is possible that single site visit surveys could directly affect small headwater fish populations, but damaging effects would only occur under specific circumstances. The population inhabiting the stream segment of interest would have to be truly isolated by an impassable barrier from the recruitment of new adults moving up into the stream. That is, fish could leave the segment by moving downstream but new recruits would not be able to enter the population by moving upstream. The location of such specific circumstances in Washington's watersheds has not been fully mapped, but isolated Cutthroat Trout populations upstream from natural and/or anthropogenic barriers are common in the Pacific Northwest (Guy et al. 2008). In these watersheds, a single debris flow or other large disturbance can cause an immediate decrease in intra-population genetic diversity that persists in locations where no subsequent immigration to the population occurs (Guy et al. 2008). Based on available evidence, headwater fish populations upstream from natural and man-made migration barriers are vulnerable to genetic and demographic harm if surveys cause a loss of adult fish that reduce the breeding population size to a level that impairs one or more VSP parameters. In102 protocol site visits in 2015, Weyerhaeuser scientists usually encountered fewer than 4 fish in a population survey, but in approximately 45 percent of surveys more than one fish was encountered (graph below, unpublished data of B. Fransen). Therefore, the breeding population would have to be very small and the site visit would have to result in displacement, reproductive impairment, or mortality of adults in order to cause population level impacts.

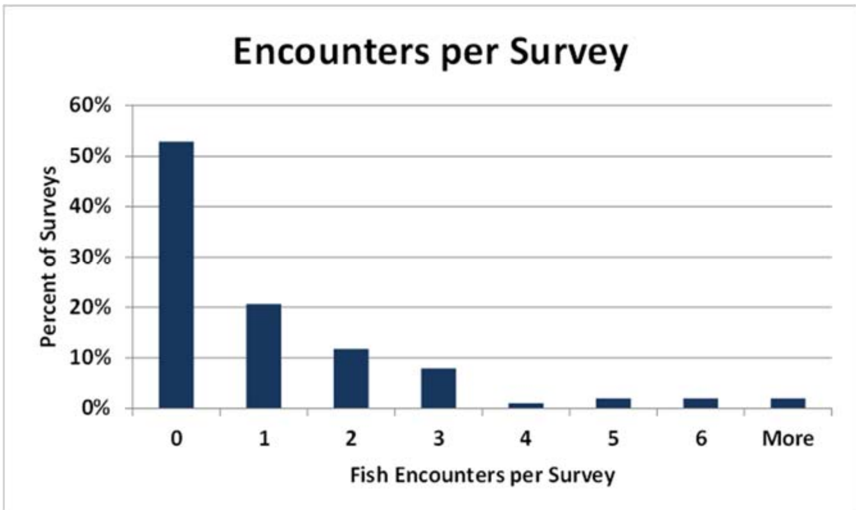


Figure 1. Number of fish encountered per survey at 102 protocol survey sites (B. Fransen, unpublished data).

Based on DNR's RMAP (Road Maintenance and Abandonment Plans) reports, the vast majority of impassible culverts that have been removed and/or replaced are located in the lower portions of watersheds as a result of RMAP's prioritization of anadromous fish passage (DNR annual RMAP reports, DNR / WDFW fish passage database). Impassible culverts historically installed in steep headwater areas are often located underneath deep road fills making them very costly to replace with fish passable culverts. Impassable headwater culverts yet to be replaced can isolate fish populations and form boundaries for areas within watersheds where negative impacts from electrofishing could occur if isolated breeding populations upstream of the barriers are very small.

The barrier effect could be exacerbated if there was significant downstream movement of fish from the sampled reach as a result of volitional avoidance of the electrical field or disturbances related to wading in the stream, or alternatively, if there was drift of stunned fish downstream during the electrofishing procedure itself. To have a significant effect on the population, fish moving downstream out of the sampled reach would need to pass over the barrier that would prevent them from moving back into the site. Finally, a fish population could be negatively impacted if single visit electrofishing led to immediate or delayed mortality of enough shocked individuals or eggs to cause a significant reduction in one or more VSP parameters.

As outlined above, the potential to reduce the number of breeding adults depends on the geomorphic setting of the stream segment in question and the ability of new colonists to move into the site, thus expanding the effective population size. It is important to note that even in intensively monitored watershed studies where headwater populations (not isolated) have been repeatedly electrofished for a decade or more (Hall et al. 1987; Hartman et al. 1987) there is no direct evidence that long-term harm to salmon and trout populations related to electrofishing has occurred. Given the importance of understanding the effects of protocol single site visits on headwater fishes, additional studies focusing on the demographic and genetic impacts of electrofishing on small populations would be helpful.

Recommendations:

Careful attention to electrofishing technique minimizes risks to individual fish, prevents both adults and juveniles from being driven downstream out of the site, and blocks egress from shocked areas by stunned fish, thus reducing the likelihood of long-term demographic impacts. Environmental conditions that may compromise the effectiveness of an electrofishing survey include extremes in flow (low or high), turbidity, extremes in conductivity and water temperature (low or high, see NOAA and e-fishing equipment manufacturers guidelines), and dense or impenetrable riparian vegetation. Carrying out effective surveys using techniques that result in low risk to fish populations will require careful adherence to protocols and board manual guidance, particularly NOAA electrofishing guidelines for ESA-listed fish and WDFW Scientific Collection Permit conditions, and training that provides both proper instruction to electrofisher operation as well as hands-on field experience. It may be helpful to conduct repeat surveys in a small subset of sites for quality control purposes.

Specific recommendations include:

- Use electrofisher settings appropriate for a stream’s conductivity.
- Ensure environmental conditions at time of survey are appropriate and within limits of protocols.
- Follow manufacturer recommendation on when and how to use equipment.
- Avoid electrofishing over active redds.
- Minimize walking in the stream.
- Use procedures to minimize egress of fish.
- Ensure adequate training of survey leads and crews.

2. Is there evidence of direct harm from electrofishing on incubating eggs and gravid females (especially in headwaters where cutthroat spawn)?

Conclusion:

With proper training, experience, and equipment, direct harm from electrofishing can be minimized. However, the procedure itself has the potential to harm all fish life history stages through lethal and sub-lethal injury and stress.

Discussion:

Electrofishing has been used as a survey tool for more than a half century. Over that time there have been many advances in sampling technology as well as a number of studies on the specific effects of electrofishing on physiological performance. Nielson (1998) provides a useful synthesis of electrofishing impacts on trout populations in the Sierra Nevada Mountains of California. Relative to Question 12, potential harm from protocol surveys goes beyond harm associated directly with electricity effects. A two-person survey team walking carelessly through wadeable channels during a spring survey window can impact eggs and alevins in active redds. Cutthroat Trout typically spawn from late winter to early summer, depending largely on a stream's thermal and discharge regimes, with eggs potentially incubating at spawning locations from March to July. Steelhead or resident Rainbow Trout typically spawn between December and June, with eggs incubating at spawning locations throughout that period or longer. Physical damage to incubating eggs can take place if redds are disrupted by wading when eggs and alevins are crushed or washed from the egg pocket. Owing to their small size, resident Cutthroat or Rainbow Trout inhabiting headwater streams do not excavate deep redds and the substrates selected for spawning are composed of smaller gravel than those selected by larger, anadromous salmonids. Eggs may be deposited only a few centimeters below the substrate surface where they may be vulnerable to wading; therefore, it is important for surveyors where possible to avoid wading in stream habitats likely to be used for spawning such as pool tail-outs and low gradient riffles with small to medium diameter gravels. In most cases spawning, gravel incubation, and fry emergence have been completed by early August, and surveys after that time have reduced likelihood of impacting reproductive success.

Evaluating the direct physiological harm from electrofishing to eggs and gravid females is more difficult because electrofishing equipment has been increasingly refined over the years and the published literature on the effects of electrofishing on developmental physiology, based on older technology that is no longer be used, can be outdated. Nevertheless, what literature does exist points to the possibility of some electrofishing-related injury (Sharbor and Carothers 1988; Thompson et al. 1997), although the injury rates have been found by some investigators to be low if proper techniques are followed (Ainslie et al. 1998; McMichael et al. 1998). Spinal injuries, by far, are the most commonly cited injury type and such injuries occur when rapid contraction of muscles during electric shock causes vertebrae to deform or fracture. This can happen at any life history stage.

Visible evidence of electrofishing-related injury does not always reveal the extent of spinal damage. In one study, 40% of fish held in aquaria for a year after exposure to electrofishing showed X-ray evidence of some spinal injury, whereas only 2% exhibited external signs of injury immediately after being shocked (Dalbey et al. 1996). Voltage, wave form, and pulse rate can affect egg development, although some authors believe that the potentially harmful effects of increased voltage are more important than either wave form or pulse rate (Dwyer and Erdahl 1995; Roach 1999). Sharbor and Carothers (1988) found that exponential and square wave pulse patterns were less harmful than quarter-sine waves, and virtually all investigators recommend that surveyors utilize the lowest possible voltage with a wave form that causes the least injury to eggs, juveniles, or adults. However, the ability of electrical currents to effectively stun fish is size-dependent; voltages and wave forms optimized for capturing adult trout are not the most effective for fry, and vice-versa.

The best equipment settings will likely involve a compromise between shocking effectiveness and the potential for injury, a compromise best gained through experience and by adherence to NOAA electrofishing guidelines (http://www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/section4d/electro2000.pdf), as well as any state permit requirements. The NOAA guidelines state "Electrofishing in the vicinity of adult salmonids in spawning condition and electrofishing near redds are not discussed as there is no justifiable basis for permitting these activities except in very limited situations (e.g., collecting brood stock, fish rescue, etc.)". In addition, because of temperature-related physiological stress associated with warm summer conditions, the greatest risk to ESA-listed fish during surveys may consist of failing to follow stream temperature restrictions on electrofishing during warm survey periods.

Recommendations:

Minimizing harm to individual fish and eggs will require that:

- Surveyors be properly trained and experienced.
- The proportion of the stream exposed to electrofishing be limited.
- Modern equipment and machine settings that cause the least amount of damage while still effectively detecting fish.
- Available knowledge of potential fish use in and/or upstream of reaches being surveyed (species, size, spawn-timing, etc.) be utilized.
- The amount of physical disruption to the channel be minimized.

3. What is currently being done to reduce site-specific impacts *of protocol electrofishing surveys*?

Conclusions:

Landowners currently have several options to reduce site-specific impacts of single visit surveys. While some of these options are described in Board manual guidance, they are not rules and therefore the extent to which these options are used is currently unknown.

Discussion:

Several options exist to minimize site-specific impacts of single visit surveys, including:

(a) Follow protocol electrofishing survey guidelines using the best available equipment and careful survey procedures. Careful attention to the setting of the stream reach in question (appropriateness of an electrofishing survey, flow regime, presence of passage barriers, suitable fish habitat upstream and downstream), employing fish shocker settings that result in the least injury while providing for effective capture, avoiding excessive wading in the channel (especially in potential spawning habitats), and taking care to prevent the downstream displacement of fish when performing the survey all contribute to reducing site-specific impacts.

    Ambient conductivity is used to measure the concentration of dissolved solids ionized in water and is an important consideration in reducing site specific impacts. The unit of measurement commonly used is one millionth of a Siemen per centimeter (micro-Siemens per centimeter or µS/cm). Charges (electrons) transfer along these ions between the two electrodes of the electrofisher and are delivered to the fish. Higher conductivity allows for easier transfer of electrons and lower conductivity causes reduced transfer of electrons. The key to successful electrofishing is to minimize the difference between the internal conductivity of a fish and the ambient conductivity of the surrounding water. Fish are generally accepted to have a conductivity of 115 microSiemens/cm (Miranda 2009).

(b) Use visual observation prior to electrofishing. Visually spotting fish from the stream bank does not injure fish or eggs, and in most cases it is possible to identify fish to the species level based on known distributions of species in the drainage. However, relying solely on visual observations to determine fish presence is more prone to false negative errors than electrofishing, i.e., concluding that fish are not present when in fact they are. Visually observing fish in very small streams can be especially difficult when the channel is small, the fish species present are cryptic, the fish populations are small, water is turbulent, and cover is abundant. For bottom-dwelling species that are occasionally the uppermost stream residents such as sculpins or lampreys, visual observations are virtually impossible. While visual observation is an acceptable method to document fish presence, it is not an acceptable tool for documenting fish absence.

(c) When appropriate, use an alternative technique for determining presence such as environmental DNA (eDNA). This technique is very benign compared to electrofishing because it simply involves filtering several liters of stream water and assaying it for DNA from species of interest. While this technique is currently gaining traction many investigators still feel that it risks false negative errors when target species are rare and thus contribute a very small fraction of detectable DNA in the sample. The difficulty is compounded when the library of reference DNA sequences for species of interest is incomplete. Nevertheless, a recent study demonstrated that improvements in the technique have the potential to make it a more reliable tool for headwater fish detection (Wilcox et al. 2015), and continued technique refinement and development of reference genetic libraries may make eDNA a viable alternative to electrofishing in the future.

(d) Survey coordination. Contact WDFW, local Tribes, private landowners, DNR, and/or NGOs to determine what surveys have already been performed in the watershed of interest.

Recommendation:

- Training and/or demonstration of requisite experience is needed for all field crew leaders. Electrofishing can have direct impacts on fish and under specific circumstances can have population-level impacts. Electrofishing protocol surveys are performed by individuals and organizations representing a wide range of backgrounds and experience. To ensure the proper level of consistency, effectiveness, optimization, and accountability, survey leader proficiency should be demonstrated periodically and survey crew members should be instructed in correct techniques, such as: Training as it relates to issue of impacts.
- Type of equipment – proper use including equipment settings.
- Prior investigation of fish presence (pre-mission planning).
- Create a widely available database of known fish distributions. If changes to stream location or water types are proposed and accepted for a FPA those changes should be reflected in a centralized GIS database to prevent unnecessary surveys.
- Reduce impact by limiting length of stream surveyed.
- Assess use alternative methods for documenting fish presence.
- Personnel guidelines (number of staff).
- Avoid multiple site visits during appropriate season once fish presence determined.
- Environmental conditions at time of survey – ensure that conditions are appropriate and within limits of protocols.
- Be aware of isolated habitats and existing stressors.

4. What is the availability of state and/or federal agencies to provide electrofishing and protocol survey assistance to landowners?

State and federal agencies do not currently provide this service. Private consulting firms, NGOs, and tribes have offered electrofishing assistance to landowners.

OPTIMIZATION OF THE OVERALL EXTENT OF SURVEY USE

1. Are surveys ineffective at low flow?

Conclusion:

Based on practitioner experience protocol electrofishing surveys are generally effective at detecting fish during low flow conditions when those flows fall within the normal long-term range for a given stream and time of year. Whether or not fish occupy a specific site during low-flow conditions is a question of distribution, rather than protocol survey effectiveness.

Discussion:

The ETG interpreted ‘low flow’ to represent average flows that fall within the normal long-term range for a given stream and time of year. There was general agreement that:

- Protocol electrofishing surveys are generally effective at low flow.
- Periods of low flow may, in fact, represent the most effective time to survey due to there being more fish per unit channel area, clear water conditions, etc.
- In cases of extreme low flow conditions, electrofishing effectiveness may be compromised when stream depth is too shallow for electrode submersion. The most acute example is when a stream reach dries up completely. In these cases, the loss or lack of flow can reduce or eliminate the opportunity to detect fish and thereby impair survey effectiveness.

With regard to isolated habitats and existing stressors, there are no published environmental thresholds for determining when habitats are too physically isolated (presumably, this means situations where flows are intermittent and fish are concentrated in a few pools) or water quality conditions are such that stress on fish associated with electrofishing would be likely to cause injury or death. However, when surveying ESA-listed fish, NOAA electrofishing guidelines contain specific temperature thresholds above which electrofishing is not permitted. Fish that remained stunned for extended periods of time may become easy prey for predators. Protocol experience and training sessions should discourage surveyors from electrofishing in residual pools where inhabitants are likely to be temperature- or food-stressed, and/or exceedingly susceptible to predation. Experience and professional judgment on the part of the surveyors will be needed when deciding whether or not electrofishing is appropriate.

2. Are surveys ineffective at high flow?

Conclusion:

Based on practitioner experience, protocol electrofishing surveys can be effective at detecting fish during high flow conditions when those flows fall within the normal long-term range for a given stream and time of year. Whether or not fish occupy a specific site during high-flow conditions is a question of distribution, rather than protocol survey effectiveness.

Discussion:

The ETG interpreted ‘high flow’ to represent average flows that fall within the normal long-term range for a given stream and time of year. There was general agreement that:

- Protocol electrofishing surveys are not “ineffective” at high flow, but may be “less effective” than at normal or low flow.

- High flow conditions may not represent the optimal time to conduct protocol electrofishing surveys. Furthermore, there is a high flow threshold where surveys should not be conducted due to potentially difficult (and unsafe) sampling conditions resulting from increased water volume and depth, higher stream velocity, higher stream turbidity and/or reduced fish response to the electrical field. These conditions may result in reduced likelihood of detecting fish which could result in “false negatives”.
- Surveyors tend to avoid sampling in high flow conditions so this may be a non-issue in practice.

3. Are protocol surveys ineffective in streams over 5 feet wide?

Conclusion:

Based on practitioner experience, protocol electrofishing surveys are generally effective at detecting fish in streams greater than 5 feet bankfull width.

Discussion:

For the purposes of this discussion the ETG interprets the “5 feet wide” criteria to mean channel bankfull width (BFW) because that is the stream metric referenced in Board Manual 13. Some research investigating the relationship between stream channel size and overall electrofisher effectiveness/efficiency has been done, however, results are highly variable. Kruse et al (1998) found that stream width was the most important measured stream variable that influenced capture probability and catch efficiency. Weyerhaeuser Company (unpublished data for CMER) shows a catch efficiency of 84% (16% probability of not capturing fish) for streams that are 1 meter wide, 82% (18% probability of not capturing fish) for streams that are 2 meters wide, and 79% (21% probability of not capturing fish) for streams that are 3 meters wide. This report states: “Stream width appears to be a poor predictor of likely catch efficiency within the ranges of stream widths typically encountered during (protocol) electrofishing surveys.”

Protocol electrofishing surveys are not generally ineffective in streams over 5 feet wide, but electrofishing effectiveness can be negatively correlated with stream size. Larger streams may have a higher expectation or presumption of fish use. These larger streams also have a wider cross-sectional area and deeper water column that may require more electrofishing effort (e.g. multiple electrofishers, multiple surveys) in order to increase the probability of detection.

Recommendation:

The metric of “5 feet wide” (BFW) should be revisited, as this does not necessarily represent what practitioners would consider a “larger stream” in the context of protocol electrofishing surveys.

4. Is ¼ mile sufficient to demonstrate fish absence?

Conclusion:

Protocol electrofishing surveys conducted over a distance of ¼ mile upstream from the last detected fish are generally sufficient to indicate fish absence with a high probability.

Discussion:

For the purposes of this discussion the "¼ mile" criterion is in reference to the surveyed stream length upstream of the last detected fish. Published data supports the assertion that the ¼ mile survey criteria is generally sufficient to indicate fish absence. Bliesner and Robison (2007) report that: "In streams with low gradient a minimum of 300 m should be surveyed… In streams where a gradient break of a minimum of 8-12% exists this study has indicated that 60 m is sufficient to indicate the Class I (fish bearing), Class II (aquatic life) break." There was general agreement among the ETG that if fish have not been detected within ¼ mile survey and there is no potential habitat upstream (including above permanent, temporary or gradient barriers), then absence is implied. However, the need to survey additional distance upstream from the last detected fish may depend on habitat type, stream size, water level, and other stream properties.

5. Are multiple surveys necessary to demonstrate absence?

Conclusion:

Multiple protocol electrofishing surveys conducted on a single stream segment are not generally needed to indicate fish absence. However, there may be exceptions where stream size, atypical flows, seasonal or annual fish distribution patterns, recent restoration of fish passage, or recent channel disturbances suggest that multiple surveys would be worthwhile. It is important to note that absence cannot be demonstrated, but they probability associated with presence can be evaluated to see when it is improbable that fish are present (e.g., >95% probability that fish do not occur).

Discussion:

The single survey criterion is usually sufficient depending on habitat type, stream size, water level, etc. For the purposes of this discussion the term "multiple surveys" means surveys conducted at a single site over multiple days, seasons, and/or years, not multiple survey passes conducted on a single day. Some published data (Cole et al. 2006) supports the assertion that a single protocol electrofishing survey is generally sufficient to indicate fish absence. The authors, however, do acknowledge the fact that: "Longer term studies that include sampling over a wider range of stream flows and that occur after catastrophic environmental events may further characterize variability in the upper limits of fish distribution". There was general agreement within the ETG that in specific instances where seasonality in fish distribution may be expected, where flow conditions at the time of an initial survey are not "normal", or when a survey is conducted in very wide streams channels, additional survey effort may be necessary. In addition, stream segments that have been subject to recent channel disturbance events such as debris flows may require additional survey effort (even in subsequent years), particularly if stream conditions have been significantly altered.

6. Are surveys effective above man-made barriers where fish occur above the barrier?

Conclusion:

Based on practitioner experience, protocol electrofishing surveys are generally effective in stream reaches above man-made barriers where viable fish populations exist, and where the abundance and/or species composition of fish within that reach does not appear to be influenced by the presence of the man-made barrier and appropriate environmental factors exist (e.g., conductivity, temperature, turbitity, etc.).

Discussion:

There is no evidence to suggest that electrofishing would be less effective above man-made barriers than below them for the purpose of determining fish presence, particularly when habitat conditions and fish composition and abundance are similar between reaches. The appropriateness of using protocol electrofishing surveys for determining fish presence above man-made barriers may be influenced by the characteristics of the fish population in the reach upstream from the barrier relative to the population downstream. In situations where the presence of a man-made barrier influences the abundance and/or species composition of fish above the barrier and that this influence could impact the upstream distribution of fish, protocol electrofishing surveys may not be appropriate. Board Manual 13 addresses this situation and recommends using physical criteria unless otherwise approved by DNR through consultation with WDFW, Department of Ecology, and affected Tribes in these cases.

7. Is detection poor in small headwater streams?

Conclusion:

The probability of detecting fish in headwater streams using protocol electrofishing surveys can be influenced by population density and numerous other factors previously mentioned above, but is generally not poor.

Discussion:

Headwater streams may support low densities of fish, which can result in reduced electrofishing efficiency and detection probability. The probability of detecting fish is directly related to the population size (Weyerhaeuser Company, unpublished CMER data). The draft CMER Preliminary Assessment of Variable Catch Efficiency states, "Likelihood of detection was lower in sites where fish abundance was low and estimated reduced catch efficiency in response to smaller population size". Some research has shown that electrofishing efficiency is negatively correlated with increasing stream size (Kruse et al. 1998, Rosenberger and Dunham 2005), while others have found no significant difference when testing this population abundance and capture efficiency (Foley et al. 2015). However, the ETG felt that in the majority of cases electrofishing is the preferred method of detecting fish presence in headwater streams and is the technique most likely to provide accurate information.

8. Are two shockers [electrofishers] required in larger streams?

Conclusion:

Based on practitioner experience, multiple electrofishers are not generally required when conducting protocol electrofishing surveys in streams larger than 5 foot bankfull width.

Discussion:

The ETG found no specific documentation or data to support the need for two electrofishers in headwater streams wider than 5 ft. BFW. The use of multiple electrofishers should be approached with caution as two shockers may increase the potential risk of site-specific survey impacts on fish. There likely is an upper channel width threshold above which two (or more) electrofishers would result in greater probabilities of detection, but these conditions are generally not encountered during protocol electrofishing stream surveys.

9. Use of protocol surveys during drought years (2015 and future years). Should we be making permanent calls during these years?

Conclusion:

At this time there is a lack of consensus among the ETG on this question. There is agreement, however, that the question may not necessarily be appropriate for this group. This question relates more to if/how drought conditions may impact where to establish the F/N boundary in relation to the last observed fish, and therefore when and where water type maps should be updated.

10. Effectiveness of "single-pass" electrofishing surveys to account for seasonal and long term distribution variability of fish populations within a stream system (snapshot in time).

Conclusion:

By definition a "single pass" or "snapshot in time" sample cannot address distribution variability. Multiple surveys would be needed at a given site to assess actual variability in fish use between seasons and/or years. The ETG concluded this is less a question about the effectiveness of the protocol electrofishing survey itself and more about how and where to establish the F/N break point in relation to the location of the last observed upstream fish, in order to account for potential seasonal and/or long term variability in fish distribution.

Discussion:

Studies investigating longitudinal variability in fish distribution have evolved over time. Early research by Shuck (1945) and Miller (1954 and 1957) indicated that resident trout are sedentary, while more recent research has indicated otherwise. Cole et al. (2006) and Cole and Lempke (2003) report that changes in the location of the "last upstream fish" were limited in eastern Washington streams during a two-year comparison where surveys were conducted under similar flow conditions and at the same time of year, and the changes that did take place were not believed to be biologically significant according to the authors. Changes in the location of the last upstream fish were more common, and distance of change was greater, however, when the same sites were resurveyed four years later (Cole and Lempke: Final ABR Report 2006). Cole and Lempke (2006) suggested that this increased variability in last fish locations was attributable to both inter- and intra-annual variability, and that surveys captured different flow conditions and sampling seasons. In the same report, however, Cole and Lempke (2006) also reported that: "… these data suggest that the upper limits of fish distribution are not highly variable among seasons, at least when seasonal flow conditions are similar…".

Walter et al. (in review) reported that PIT tagging and recapture data for cutthroat trout sampled at the upstream extent of fish distribution within 6 headwater catchments in western Washington suggests a high rate of mortality within and/or emigration from these small stream reaches from year to year. This, coupled with the fact that fish density in these reaches was relatively consistent through time, suggests that while individual fish in these habitats may be highly mobile, the habitat that the fish population as a whole occupied did not change significantly.

Another study to assess seasonal movement of cutthroat trout in a coastal Oregon stream using both mark-recapture and radio transmitters (Gresswell and Hendricks 2007) reported most fish moved very short distances, while a few individuals moved significant distances over the course of the 14-month study. Other research on cutthroat trout movement report similar results (Heggenes et al. 1991; Hilderbrand and Kershner 2000; Schrank and Rahel 2004).

11. What is the risk of not finding fish that are actually present (detectability) when conducting a protocol electrofishing survey?

Conclusion:

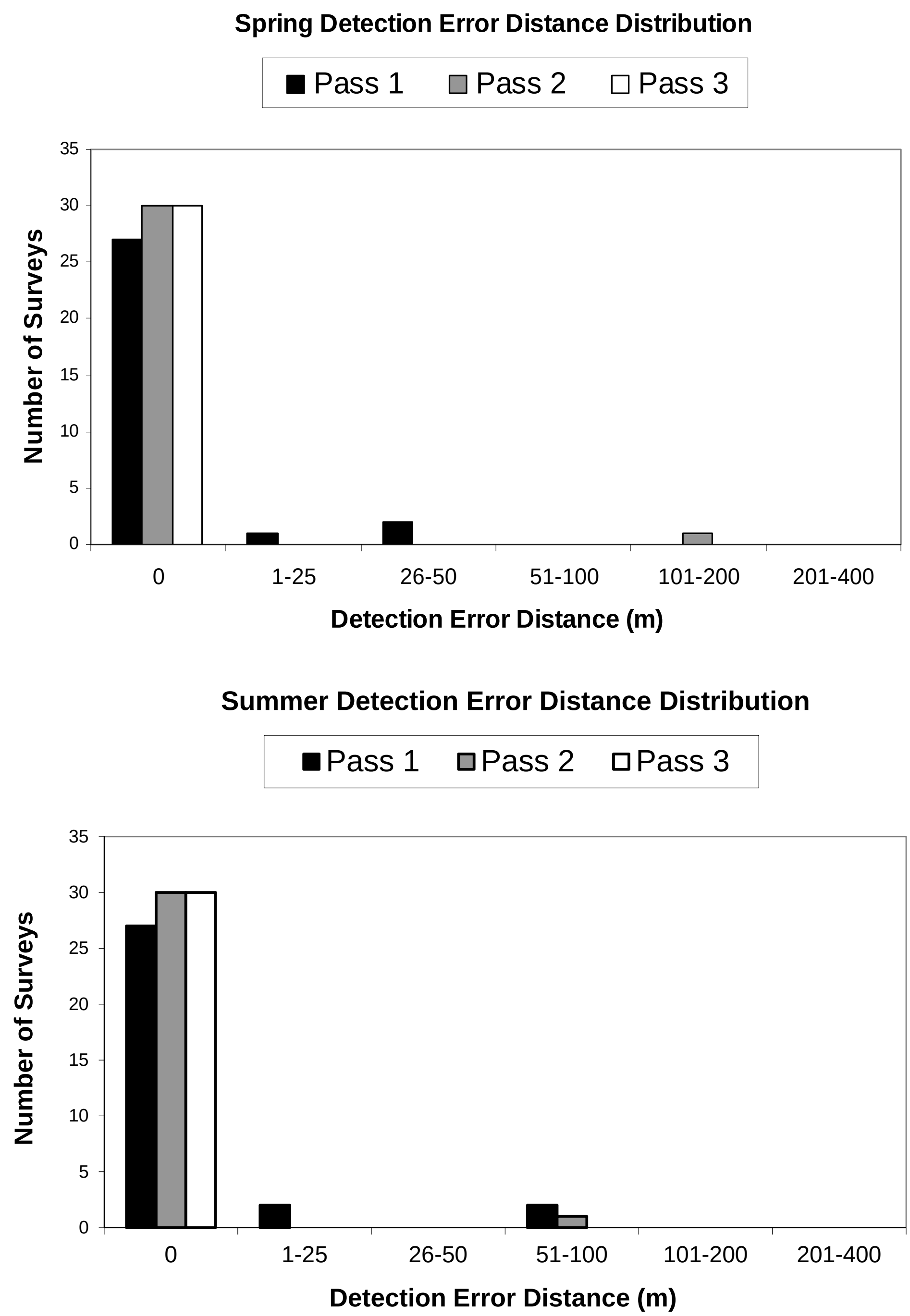
The ETG agreed that there is chance of not finding fish that are actually present. The detectability of fish is influenced by site-specific attributes.

Discussion:

Some investigations have addressed electrofishing efficiency and/or the probability of detecting fish using a backpack electrofisher, while many more examined catch efficiency. For the purposes of this discussion the term catch efficiency is used when fish had to be netted and/or brought to hand in order to be counted, where detection probability applies to situations where fish only had to be observed while electrofishing. When conducting protocol electrofishing surveys, detecting a fish is sufficient to classify a stream segment as Type-F. Fish do not necessarily have to be captured.

CMER sponsored research (Cole et al. 2002) evaluated the reliability of a single pass electro-fishing survey to detect the uppermost fish. Detection error surveys were conducted in 28 streams with terminal Type-F/N break points where no permanent natural barrier to upstream fish movement was present at or within 400 meters (m) of the break. After locating the uppermost fish by protocol electrofishing survey, additional electrofishing surveys were conducted in the reach upstream of the uppermost fish. If fish were found upstream from this point, the distance from the new uppermost fish to the original last fish location was recorded. Surveys were repeated until no fish were detected above the original location of the uppermost fish in a minimum of 4 consecutive surveys. No fish were found above the uppermost fish location identified during the initial protocol electrofishing in 27 of the 28 sites evaluated. At one site, one fish was found 0.5 m upstream on the second pass and another fish 14 m upstream in the third pass. Average error distance across all sites was 0.5 m. As part of another CMER-sponsored study (Cole and Lempke 2006), detection error was evaluated in both spring and summer. A random sample of 30 streams with fish distribution data collected during previously conducted protocol electrofishing surveys, again with terminal F/N break points where no permanent natural barrier to the upstream movement of fish was present at the break point, was selected for each season. The same resurvey protocol was followed as in the Cole et al. (2002) study mentioned above. Cole and Lempke (2006) report that fish were encountered upstream of the original uppermost fish location in only 3 of the 30 sites resurveyed in each season. Average error distance was higher than observed in the 2002 samples, and averaged 47 and 44 meters in spring and summer samples, respectively

Figure 2. Frequency distribution of spring (upper graph) and summer (lower graph) detection



error distances of last fish surveys performed in seven eastern Washington watersheds in 2005.

It is important to note that these data likely over-state survey detection error across all sites because sample sites were selected to include only those where not detecting fish that were present was more likely (e.g. terminal streams, and streams with no upstream barrier). "These data are therefore a conservative estimate of survey error across the study area" (Cole and Lemke 2003).

The reported range of catch efficiencies in the literature is somewhat variable, and can be influenced by channel characteristics such as stream width. Catch efficiencies may be lower than detection probabilities in similar habitats as it is possible to detect (observe) a fish without actually capturing it. Kruse et al. (1998) estimated a first pass survey catch efficiency of 82% (18% probability of not capturing fish that are present) in small mountain streams. Similar catch efficiencies of 84% (16% probability of not capturing fish) were reported in forested streams in Washington that are 1m wide, 82% (18% probability of not capturing fish) for streams that are 2m wide, and 79% (21% probability of not capturing fish) for streams that are 3m wide (Weyerhaeuser Company, unpublished CMER data).

SEASONAL DISTRIBUTION OF FISH AND TIMING OF SURVEYS

1. What is the appropriate period to conduct an electrofishing survey?

Conclusion:

Based on practitioner experience, no "perfect window" exists and the current window as defined by Board Manual 13 (March 1-July 15) is appropriate in most cases for western Washington.

Discussion:

The ETG is aware of no specific documentation or data to answer this question, and more research is needed on the subject. Results of research reported by Cole and Lempke (2006), however, do address the issue of changes in the upper distribution of fish between seasons and are included in the responses to other questions.

Board Manual 13 reads: "Survey information collected to determine fish use or the maximum upstream extent of habitat utilization must be collected during the time window when the fish species in question are likely to be present... In most cases, this period extends from March 1st to July 15th…". For the purposes of this discussion the term "appropriate period" would refer to the time window during which fish species are most likely to be present. The key is knowledge of target species' life histories. It is important to maintain flexibility in potential survey timing on behalf of both surveyors and reviewers. The need for this potential flexibility is supported by Board Manual 13 language (above) in stating "In most cases…". Surveys conducted outside of the Board Manual 13 window to capture potential seasonal fish use can be resolved through consultation with WDFW and affected tribes.

Additional discussion is necessary for appropriate protocol survey windows for eastern Washington.

2. **Do differences exist between headwater streams and streams lower in the watershed in relation to fish presence (seasonal use), adult spawner presence, eggs in gravel, juvenile presence, etc.?**

Conclusion:

The ETG concluded that differences do exist between headwater streams and streams lower in the watershed in relation to fish presence (seasonal use), fish abundance, adult spawner presence, eggs in gravel, and juvenile presence.

Discussion:

Fish populations in headwater streams typically occur at lower densities, have fewer spawners and eggs in the gravel, and offer less juvenile rearing habitat than downstream reaches. The impact of these differences on protocol electrofishing survey effectiveness have been addressed in a number of other responses in this document.

3. **Are there reasons to vary approach when dealing with anadromous vs resident vs all fish use – especially where resident fish are not yet spawning when e-fishing window opens?**

Conclusion:

There are reasons to vary survey approaches when encountering different species and/or life stages. Most important are consideration of timing and abundance of different life stages in the targeted survey reach. The key is knowledge of target species. If unfamiliar with the life history traits of target species, consultation with WDFW and affected tribes prior to conducting surveys is recommended.

Discussion:

For ESA-listed species, adherence to NOAA electrofishing guidelines (http://www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/section4d/electro2000.pdf), as well as any state permit requirements, should be followed. The NOAA guidelines state "Electrofishing in the vicinity of adult salmonids in spawning condition and electrofishing near redds are not discussed as there is no justifiable basis for permitting these activities except in very limited situations (e.g., collecting brood stock, fish rescue, etc.)". In addition, because of temperature-related physiological stress associated with warm summer conditions, the greatest risk to ESA-listed fish during surveys may consist of failing to follow stream temperature restrictions on electrofishing during warm survey periods.

4. **Any proposed change in the timing of e-fishing window may not fit with and may actually be in opposition to NOAA and WDFW guidelines.**

Conclusion:

This will be an important consideration when reviewing the appropriate protocol survey window for a particular site.

Discussion:

This issue should be acknowledged when considering the question, "What is the appropriate period to conduct an electrofishing survey?"

5. When should a protocol survey be used in situations such as:

a. Streams with disturbance/habitat degradation (e.g. debris flows, fires)?

Conclusion:

Consultation with DNR, Ecology, WDFW and affected tribes is the best way to ensure survey results are accepted.

Discussion:

This is very much a "site specific" question. There is a wide spectrum of disturbance influence on habitat and channel conditions that can influence both fish distribution and the ability to survey effectively. Board Manual 13 requires documentation of how disturbance or habitat degradation may have affected fish distribution. The ETG concludes that (1) natural events such as debris flows and fires are part of the natural and historic disturbance regime in headwater stream systems, (2) stream segments which have been subject to recent channel disturbance events may require additional survey effort (even in subsequent years), particularly if stream conditions have been significantly altered, (3) the need for survey flexibility is supported by data presented by Cole et al. (2006), and (4) in locations of obvious and recent disturbance events the protocol survey may document presence but is a less reliable indicator of absence.

b. Above man-made barriers (MMBs)?

Conclusion:

Board Manual 13 addresses this situation and recommends using physical criteria unless otherwise approved by DNR in consultation with WDFW, Department of Ecology, and affected Tribes in these cases.

Discussion:

This topic has been addressed under question 6 "Are surveys effective above man-made barriers where fish occur above the barrier?" in the section on optimization of the overall extent of survey use.

c. Ponds, wetlands, and off-channel habitats?

Conclusion:

Electrofishing surveys are not the preferred tool for establishing fish presence in ponds and wetlands, especially those that are not wadeable. Protocol electrofishing surveys are not applicable to defining off-channel habitats under current rules.

Discussion:

There are two distinct questions that must be considered here. First, the appropriateness of using protocol electrofishing surveys in ponds and wetlands, and second the appropriateness of using the survey method to define off-channel habitat. Electrofishing surveys can under certain circumstances (small, shallow ponds and wetlands with good water clarity) be appropriate for documenting fish presence in ponds and wetlands, but not usually for documenting absence. The definition of off-channel habitat is currently being reviewed by a TFW Policy technical committee.

Recommendation:

Other methods (minnow trapping, seining, hook and line sampling, etc., or a combination of multiple sampling techniques) are likely to be more appropriate in ponds and wetlands.

d. How soon to shock after removal of man-made barrier or disturbance?

Conclusion:

There is no specific documentation or published data to answer this question, and more research is needed on the subject. Data (unpublished) are currently being collected by Weyerhaeuser and the Tulalip Tribe to help answer the question.

Discussion:

The ETG believes that timing will largely depend on a number of physical and biological variables including the characteristics of the fish population downstream from the blockage and the characteristics of the stream segment upstream from the blockage. We assumed that the question addresses the issue of time it takes for fish to recolonize stream habitat upstream from natural disturbance or removal of blocking anthropogenic structures.

e. No or insufficient pools meeting protocol “size” are present?

Conclusion:

Many surveys in headwater and small tributary streams simply cannot meet the qualifying pool criteria, as sufficient numbers of qualifying pools are not present in the surveyed reach. Surveyors should sample and document the pool habitat that is available.

Discussion:

This issue is not a major concern in terms of the effectiveness of protocol electrofishing surveys. For the purposes of this discussion we assume that this pool count includes the surveyed stream segment upstream of the last detected fish.

Recommendation:

Revise the survey protocols related to the number of pools of sufficient size to more accurately reflect conditions in small headwater streams.

f. Larger streams (streams that should naturally be fish habitat); is there a stream size that should automatically be considered fish habitat?

Conclusion:

There is no scientific evidence to support a single default stream size that should automatically be considered fish habitat.

Discussion:

ETG members concluded that there are some larger streams that do not contain fish, particularly those reaches upstream from permanent natural barriers.

ALTERNATIVES TO ELECTROFISHING

1. Are there alternatives that can achieve FFR/HCP precision and accuracy targets while reducing e-fishing?

Conclusion:

There are a number of alternatives to electrofishing and each has its advantages in terms of cost savings or reduction of harm to fish. However, not all have been evaluated relative to achieving FFR/HCP precision and accuracy targets.

Discussion:

a. eDNA

Environmental Deoxyribonucleic acid (eDNA) sampling is quickly becoming a useful tool in the detection of organismal DNA in water. The emerging information from eDNA researchers on fish detection indicates that legacy DNA can create false positives that still necessitates the need to validate eDNA results with tools like electrofishing. eDNA could be used to identify streams that lack fish, but the technique may be prone to false negative results when fish are rare. Whereas, streams with positive eDNA detections could be further explored with electrofishing surveys for occupancy and distribution in the drainage network.

b. Continued use of default physical criteria

TFW Policy is currently discussing the appropriateness of default physical criteria to see if they accurately reflect fish presence.

c. Model

This includes examining models, remote sensing (e.g., LiDAR), and other screening tools that could potentially target field validation efforts resulting in a reduction in the use of electrofishing.

d. Lentic sampling techniques

For areas (ponds, wetlands, other slow-flowing waters) where electrofishing is not the appropriate approach there are other alternative methods such as minnow traps, seining, and hydroacoustic surveys that can be used. If the water body is large enough and boat access is possible, a boat shocker can be used.

e. Visual Observation

Snorkeling can be used in pools to visually observe fish and can be effective where streams are too deep to be wadeable. Some fish species, because of their habitat preferences, small size, or cryptic coloration, are difficult to observe by snorkeling. Another technique utilizing visual sighting is simply to walk the banks of the stream and watch for fish, but in small channels with considerable instream and riparian cover fish are hard to observe.

f. Trapping

Trapping using wire minnow traps is a tool used to sometimes supplement electrofishing in deeper habitats/pools or where electrofishing is not appropriate for specific species. The efficacy of trapping is highly dependent on fish species. Traps in streams may be more useful for capturing invertebrates such as crayfish. Other methods, like snorkeling, are more often used for observing fish. Standardization of trapping currently has not been developed.

<u>Recommendation:</u>

There may be a need to re-examine listed alternatives to determine if they meet FFR/HCP precision and accuracy targets, and understanding advantages and disadvantages of implementing each method.

TRAINING AND/OR CERTIFICATION

Conclusion:

Protocol electrofishing surveys rely on both accuracy in establishing fish presence at a site and consistency of technique when multiple sites are surveyed over a field season. Experience can help ensure that surveys cause a minimum of harm to fish and eggs that might be present at a site, but keeping up with modern equipment and technique is important too. Additionally, leaders of survey crews need to maintain data quality control among crew members and assure that field protocols and other rules are followed. For these reasons, the ETG concluded that there would be value in having a training and/or certification program available to organizations engaging in protocol electrofishing surveys. We note that protocol electrofishing training would involve receiving instruction in both electrofishing theory and field techniques, while protocol certification would add an element of testing and (possibly) prior experience in electrofishing and stream classification. We anticipate that field crew leaders would be protocol electrofishing certified.

Discussion of alternatives:

1. Certification Process

a. Would training and/or certification be creating an issue rather than solving one?

Training needs not only to focus on electrofishing, but also on the process of water typing as a whole. This will ensure that current practices are well understood and new individuals entering the field continue with this established process. Certification can be incorporated into the training process by providing a test so that attendees can demonstrate aptitude in the material. Short term, a mandatory training and certification program would put a burden on training all practitioners. Additionally, it would create the need to identify organizations who can develop a training course and subsequently train and certify people. Further, it would require specifying how often this training/certification needs to be renewed and what costs are associated with potential training and certification. Many current practitioners are resistant to needing certification, but do understand the need for future practitioners to be properly trained and certified.

Other potential questions included:

- Would the experience of an operator be considered when establishing requirements for training/certification?
- Would the information needed to secure a Scientific Collection Permits already capture much of the requirements related to experience?
- Would training and/or certification be designed for both surveyors and water type modification (WTM) application reviewers?

The ETG discussed the idea of requiring certification for both electrofishing practitioners and WTM reviewers. If certification simply focuses on the use and operation of electrofishing equipment, then reviewers may not need to be trained and certified. But, if certification and training includes water typing methodology, then reviewers and users would both find value in training and certification. At a minimum, practitioner certification would like result in appropriate operation of electrofishing equipment and likely reduce site-specific impacts and optimize the use of electrofishing surveys as a whole. If during review it is discovered that a survey did not follow the protocol, then it should be documented that alternative methods were approved. Certification and training will only resolve this issue if the training includes instruction on how to follow the protocol and prepare a WTM that satisfies reviewers.

Certification programs are currently being offered by USFWS, Smith-Root, and NWETC that cover electrofishing safety, equipment use, and fish handling while electrofishing. There is no formal certification program for the methodology of assessing stream type modification. Therefore, it will be important to determine what information training and certification would encompass, at what point the entire training and certification process could be integrated into one course. To be clear, training involves instruction, whereas certification involves a demonstration of proficiency on the training material, often evaluated by passing a test.

Currently, training is left to practitioners training one another. This can create inconsistencies and sometimes spread misinformation. Formalized training minimizes inconsistencies and mitigates against the spread of misinformation. However, certification and maintaining certification records does create an oversight issue of who would be in charge of maintaining the database and informing those who need updated training.

Some members of the ETG expressed concern that the safety aspects of training would cover primarily safety for electrofishing crew members and that there is also a need to include proper training in fish handling, minimizing the risk of spreading invasive species, and other issues relative to protecting aquatic ecosystems. There was the suggestion that practitioners could opt out of certification and/or training if they could establish a history of professional experience, while another suggestion was that prior experience with protocol surveys and WTM forms should not necessarily be required for certification.

Typical information relative to fish presence or absence submitted with WTM forms is often not standardized. Some ETG members felt water type modifications or proposed changes to the current water type at any given site should follow one standard process. Small landowners seem to be reluctant to use the WTM form. ETG members were not sure why, but felt that incorporation of WTM instructions could be included in a training/certification program, resulting in increased use of the form.

b. Scientific Collection Permit

A Scientific Collection Permit is useful to further demonstrate electrofishing competence. The ETG felt a Collecting Permit should not be used as a surrogate for training and certification, but rather as a supplement. The suggestion was made that the WTM form could include a box where the Collection Permit number could be included. If some other survey method was used (e.g., visual observation) the form should indicate that as well.

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Review of Off-Channel Habitat Protection Under the Current Washington Forest Practices Rules

Final Report August 31, 2016

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Executive Summary

The current Washington Forest Practice Rules (FPR) (Washington Administrative Code 222-08) for fish bearing waters provide measures for protection of off-channel habitat (OCH). These rules apply to the variety of locations on the landscape where OCHs occur, from unconfined to moderately confined channels with a distinct floodplain or channel migration zone, to small confined channels with little or no channel migration zone. Concerns about whether the current water typing rule adequately protects OCH in small confined streams resulted in the formation of a science work group to review the rule to determine if it adequately defines, delineates, and protects OCH for fish in these streams. Here, we report on the findings of our work group. To assist with our review, we examined the literature and latest science in three major categories including: 1) importance of OCH to fish, 2) role of OCH in regulating aquatic productivity, and 3) literature to support using bankfull width, depth, or height to define OCH. Extensive scientific literature demonstrates the importance of OCH for fish and other biota in both large alluvial rivers and smaller more confined streams such as those covered by the rule. In addition, there is extensive literature documenting the importance of OCH in regulating productivity of small streams and production of salmonids and other fishes. Under the current FPRs, OCH is defined primarily by bankfull width (BFW) and corresponding elevation at bankfull flow, with the riparian management zone starting at the edge of the bankfull channel or the edge of the OCH, whichever is greater. Thus, whether bankfull elevation (BFE) is the appropriate flood elevation to delineate OCHs is the critical component of the OCH rule in question. Extensive scientific literature also exists to support use of BFW and BFE to delineate channels and floodplains. While the approach for defining OCH under the current rule seems logical, it is unclear if using BFE to delineate OCH leads to exclusion of some habitats or to inadequate protection of OCH under the current rule. We outlined a handful of scenarios where the current rule may be excluding OCH, though it is not clear how common OCH is in the stream channels in question. Moreover, there is little existing research for quantifying: (1) the proportion of OCH that would be excluded at BFE; (2) the flood return interval needed to capture a given percentage of the available OCH; or (3) the biological impact of not protecting all or different percentages of OCH. We conclude with recommended studies needed to address these key uncertainties.

Contents

Acronyms

AMPA	Adaptive Management Program Administrator
BFD	Bankfull depth
BFE	Bankfull elevation
BFW	Bankfull width
CMZ	Channel migration zone
DEM	Digital elevation model
FFR	Forest and Fish Report
FPR	Washington Forest Practice Rules
LiDAR	Light Detection and Ranging, a remote sensing method
LWD	Large woody debris
OCH	Off-channel habitat
PNW	Pacific Northwest
RMZ	Riparian management zone
TFW	Timber Fish and Wildlife
WAC	Washington Administrative Code

Introduction

Off-channel habitats (OCHs) such as sloughs, alcoves, groundwater-fed side channels, beaver ponds, and wetlands permanently or seasonally connected to streams are important rearing and reproductive areas for fish, amphibians, and other biota (Welcomme 1979; Ward et al. 1999; Roni et al. 2006; Meyer et al. 2007). Off-channel habitats are particularly important for juvenile Pacific salmonids (*Oncorhynchus* spp.) and there is broad literature documenting their importance particularly for juvenile coho salmon (*Oncorhynchus kisutch*) (e.g., Scarlett and Cederholm 1984; Brown and Hartman 1988; Swales and Levings 1989; Morley et al. 2005). Floodplains and off-channel areas also typically provide high species richness, refuge from predators, and complex, highly-productive habitats for different life stages of salmonids and other vertebrates (Welcomme 1979; Fausch 1984; Gregory et al. 1991; Bayley 1995; Jeffres et al. 2008; Baldock et al. 2016).

The current Washington Forest Practice Rules (FPR; Washington Administrative Code 222-08) for Type F[1] waters provide measures for protecting off-channel habitat in a variety of channel types. Under WAC 222-16-030, OCH is defined as part of Type F waters as follows:

"Type F Water" *means segments of natural waters other than Type S Waters, which are within the bankfull widths of defined channels and periodically inundated areas of their associated wetlands, or within lakes, ponds, or impoundments having a surface area of 0.5 acre or greater at seasonal low water and which in any case contain fish habitat or are described by one of the following…*

(e) Riverine ponds, wall-based channels, and other channel features that are used by fish for off-channel habitat. These areas are critical to the maintenance of optimum survival of fish. This habitat shall be identified based on the following criteria:

[1] The proposed water typing rules include Type S Water, Type F Water, Type Np Water, and Type Ns Water. Complete definitions can be found in Chapter *222-16-030. The interim water typing rules include Type 1 (S), Type 2 & 3 (F), Type 4 (Np), and Type 5 (Ns) and detailed definitions can be found in WAC *222-16-030.

(i) The site must be connected to a fish habitat stream and accessible during some period of the year; and

(ii) The off-channel water must be accessible to fish.

Until formal adoption, interim waters typing rules are in effect. The interim water typing rules (WAC 222-16-031) define Type 2 (Type F) waters and off-channel habitat more specifically as follows:

"Type 2 Water" *means segments of natural waters which are not classified as Type 1 Water and have a high fish, wildlife, or human use. These are segments of natural waters and periodically inundated areas of their associated wetlands, which: ...*

(e) Are used by fish for off-channel habitat. These areas are critical to the maintenance of optimum survival of fish. This habitat shall be identified based on the following criteria:

(i) The site must be connected to a fish bearing stream and be accessible during some period of the year; and

(ii) The off-channel water must be accessible to fish through a drainage with less than a 5% gradient.

The current interim rules were meant to be used until detailed fish habitat water type maps mentioned in WAC 222-16-030 were available. The definition and delineation of OCH in the above rules are largely based on the Forest and Fish Report (FFR 1999).

Off-channel habitats occur in a variety of locations on the landscape from large floodplains to small confined channels as well as on alluvial fans. They are most frequently found in unconfined or moderately confined channels with a noticeable channel migration zone (CMZ) or floodplain. Because of the variety of landscapes over which OCH are found, they are covered by multiple FPRs. In unconfined and moderately confined channels where a channel migration zone exists, the riparian management zone (RMZ) begins at the outer edge of the CMZ. Moreover, because alluvial fans are areas where the channel moves frequently, OCH are incorporated into the CMZ. Alluvial fans are also identified as sensitive areas under WAC 222-16-010, and no timber harvest is permitted within an alluvial fan. Similarly, any waterbody such as a pond, beaver pond, wetland or lake that contains fish but is not directly connected to a stream is its own Type F water. Thus, the specific OCH habitat rule in question applies to relatively small confined or moderately confined fish-bearing channels without a clear CMZ. These are typically 3rd order or lower order streams. In the absence of a CMZ, the edge of the RMZ in a stream begins at outer edge of the bankfull channel unless OCH is present. If OCH is present, the RMZ begins at the outer edge of the OCH.

Whether the rules adequately define, delineate, and protect OCH in stream that do not have a CMZ (typically confined channels) has been identified as an area in need of additional examination. On October 1, 2015 per request of the TFW Policy Co-Chair, the Adaptive Management Program Administrator (AMPA) outlined a process to:

- Confirm the definition of off-channel habitat as it exists in the current forest practices rules;
- Confirm the manner in which OCH is delineated under the current forest practices rules; and
- Make recommendations for a permanent Water Typing rule to be presented to the Forest Practices Board.

These recommendations included five tasks for the science track:

1. Collect and review current literature and protocols used to define processes for identifying OCH.

2. Determine if OCH is being omitted from FPAs under the existing definition used to define OCH in the interim water typing system rule and, if yes, describe these habitats in a manner that would facilitate coverage.

3. Review the existing definitions of bankfull width and bankfull depth in the forest practices rules and the FFR, and determine if using bankfull elevation in the definition would be more beneficial than bankfull depth in the determination of OCH. The rule currently defines bankfull width as ‘the measurement of the lateral extent of the water surface elevation perpendicular to the channel at bankfull depth’.

4. Review the OCH description developed during Policy field site visits to determine if this description meets the definition of OCH and adequately covers off-channel

habitat as currently described in rule, WAC 222-16-031. The site visits found "*Off Channel Habitat consists of waters connected to and draining into Type S and F waters by inundation at bank full elevation of the Type S or F water and encompassed by that area of inundation at bank full width and elevation*."

5. Define the flood return interval that defines 95% of OCH and the field methods used to delineate that flood return interval.

To address these tasks, it was recommended that a formal OCH Technical Working Group with expertise in fluvial processes and aquatic ecology be contracted to complete these tasks, including development of a final report and presentation of findings to TFW Policy.

OCH Technical Working Group Approach

On February 25, 2016 a contract was issued to Dr. Philip Roni to convene and lead the OCH Technical Working Group. Based on discussions with the AMPA and the tasks that the group was charged with, it was determined that the OCH Technical Working Group (Working Group) should include leading experts with experience in stream and salmonid ecology, off-channel and floodplain habitats, fluvial geomorphology and channel classification, riparian ecology and forest practice rules. The Working Group includes four experts who have written many key papers on off-channel habitats, channel typing, and salmonid and stream ecology and each have more than 20 years of experience in the field. In addition to Dr. Roni (Principal Scientist, CFS), the team includes Dr. Peter Bisson (retired USDA Forest Service Researcher), Dr. George Pess (Research Scientist and Program Manager with NOAA Northwest Fisheries Science Center), and Dr. John Buffington (Research Geomorphologist, USDA Forest Service). All members of the working group have extensive experience working on salmon habitat and forestry issues in Washington State and the Pacific Northwest. Brief biographies of the OCH Working Group are provided in Appendix A.

The Working Group approach consisted of four steps. First, familiarize the Work Group with Washington Forest Practice Rules as they pertain to Type F (Type 2) waters and off-channel habitats, and the tasks the group has been asked to address. Second, convene in person meetings to go through each of the major tasks and provide recommendations, clarification, and discussion of science to address, support or amend the current definition of OCH under the FPR. Third, conduct a site tour to view field examples of streams where OCH rules apply. Fourth, draft the report and present the findings to Policy. As instructed, the Working Group also conducted a review of the current literature related to OCH and to specific tasks.

This report summarizes the approach and findings of the Technical Work Group, including responses to these major tasks as well as recommendations for future studies that may be needed to refine or improve the current method of delineating OCH. The five tasks outlined above focus on understanding if important OCHs are being excluded from protection. Rather than presenting the literature review in a separate section, we reviewed the literature and incorporated it into our findings and responses to key questions posed for each task.

Current Literature on Importance of OCH

The literature on off-channel habitats, which is sometimes considered synonymous with floodplain habitats, is extensive and global in nature. Rather than review all literature on off-channel and floodplain habitats, we reviewed literature that was pertinent to forested streams in the Pacific Northwest (PNW). Moreover, since the FPR addresses the protection of OCH at two scales, one being OCH or floodplain habitats in larger streams which are covered by the channel migration zone (CMZ; WAC 222-16-010), and second with the focus on relatively small more confined streams (generally 3rd order or less based on Strahler (1957) stream classification[2]), we generally focused on literature from small to medium-sized streams. We examined literature in three major categories including: 1) importance of OCH to fish; 2) role of OCH in regulating aquatic productivity; and 3) support for using bankfull width, depth, or height to define OCH.

The quality and utilization of stream channels for fish vary seasonally, and off-channel habitats are often occupied when conditions in the main stream channel become unfavorable (Peterson 1982a; Martens and Connolly 2014). As noted in the introduction, the importance of OCH to salmonids and non-salmonids fishes, amphibians, and other aquatic biota has been well documented (Welcomme 1979; Ward et al. 1999; Henning et al. 2006; Olson et al. 2006; Roni et al. 2006; Branton and Richardson 2014). In the Pacific Northwest, these habitats are seasonally

[2] Note these are approximately streams less than about 10 meters in bankfull width.

important to juvenile coho salmon and Chinook salmon (*O. tshawytscha*) (e.g., Scarlett and Cederholm 1984; Brown and Hartmann 1988; Swales and Levings 1989; Nickelson et al. 1992a; Morley et al. 2005), as well as resident (non-anadromous) salmonids such as cutthroat trout (*O. clarkii*) (Bustard and Narver 1975; Rosenfeld et al. 2000) and bull trout (*Salvelinus confluentus*) (Baxter et al. 1999; Bean et al. 2014). While they have received less attention, off-channel habitats are also important areas for non-salmonid fishes (Moyle 2002; Wydowski and Whitney 2003; Henning et al. 2006; Markle *In press*). The vast majority of research on off-channel habitats has focused on the floodplains of large to medium sized alluvial rivers (Bayley 1995; Richardson et al. 2005). We located more than 40 references that provided information on the importance of OCH to fish in the PNW in small to medium sized streams. Rather than a lengthy review of the literature, we summarize the key findings and provide a list of key references pertinent to the tasks at hand in Appendix B. While this is a relatively small body of literature compared to the research on large floodplain rivers globally, these papers consistently show the importance of off-channel habitats to production of stream-dwelling fishes (e.g., Peterson 1982b; Swales et al. 1986; Hartman and Brown 1987; Nickelson et al. 1992a, b; Richards et al. 1992; Brown 2002; Morley et al. 2005; Ogston et al. 2014). All these studies were conducted in the PNW, making the work highly relevant to the current review.

Off-channel habitats are not necessarily common in the small to medium-sized streams covered by the OCH rules. This is in part because of the location of such streams in the landscape; typically occurring at higher elevations in constrained valleys with little floodplain development. Historically, OCHs were thought to have been more common in small headwater streams prior to the reduction and removal of LWD through forestry and other land management activities (Wohl and Beckman 2014). Large woody debris is important in creating OCH in small to large rivers, and is particularly important for trapping sediment, decreasing stream gradient, and potentially creating OCHs in small streams (Wohl 2013). Streams with wider floodplains are covered by other parts of the Forest Practices Rules (i.e., riparian management zone (RMZ) and CMZ). However, OCHs in small to medium sized streams can occur in areas where such habitats are relatively scarce, and thus can be of disproportionately high importance for fish rearing and refuge during certain periods. For example, OCHs provide refuge during high flow periods when water velocities in the main channel become too great for fish to maintain energetically profitable feeding stations (Peterson 1982a; Fausch 1984). Without access to OCH, rearing salmonids and other fishes may volitionally migrate or be physically displaced downstream. Research on coho salmon in the Oregon Coast Range has demonstrated the importance of OCH to coho production, and how increasing the amount and accessibility of OCH can lead to large increases in parr and smolt production (Nickelson et al. 1992b; Solazzi et al. 2000). Furthermore, the presence of accessible, ecologically complex OCH in small and medium sized streams adds to the overall diversity of habitat types in the drainage system. This in turn facilitates the expression of freshwater life history variation (occupying multiple habitats at different times and places by different individuals in a population) – a "spreading the risk" habitat strategy believed to promote population resilience (Bisson et al. 2009).

The role of OCH in regulating aquatic productivity is well documented in alluvial streams with well-developed floodplains. Off-channel habitats are known to support increased growth and survival for juvenile coho and Chinook (Sommer et al. 2001 2005; Giannico and Hinch 2003; Jeffres et al. 2008; Ogston et al. 2014), and to support higher densities of juvenile Chinook and coho salmon than many mainstem rivers or small streams as a result of more favorable water velocities, water temperature, cover, and habitat conditions, improved water clarity, a wider variety of food resources, and absence of predatory fishes (e.g., Reeves et al. 1989; Swales and Levings 1989; Nickelson et al. 1992; Solazzi et al. 2000; Rosenfeld et al. 2008; Armstrong and Schindler 2013; Ogston et al. 2014). Off-channel habitats are also important for regulating stream productivity by acting as storage reservoirs for organic matter (Webster and Meyer 1997), for nutrient cycling and primary production (Decker 1999; Richardson et al. 2005; Wipfli and Baxter 2010), for production of macroinvertebrates for fish consumption (Gregory et al. 1991; Bellmore et al. 2013), and thermoregulation for optimal growth (Armstrong and Schindler 2013; Baldock et al. 2016). While much of the OCH literature involves floodplains adjacent to large rivers, several of the studies referenced above were conducted in relatively small streams (e.g., Reeves et al. 1989; Nickelson et al. 1992; Solazzi et al. 2000, Richardson et al. 2005; Wipfli and Baxter 2010; Baldock et al. 2016). It is important to note that some of the ecological functions provided by OCH do not require fish to actually occupy a site. Organic matter storage and processing in fishless off-channel areas, even where surface flows are absent much of the time, are nevertheless an important component of the stream's food web (Bisson and Bilby 1998). Therefore, there are some off-channel sites that are never actually occupied by fish, but that constitute part of the stream environment that supports fish productivity.

Use of Bankfull Width and Depth to Define OCH

The WAC 222-16-010 defines bankfull depth (BFD) and bankfull width (BFW) as follows:

Unless otherwise required by context, as used in these rules:

"Bankfull depth" *means the average vertical distance between the channel bed and the estimated water surface elevation required to completely fill the channel to a point above which water would enter the floodplain or intersect a terrace or hillslope. In cases where multiple channels exist, the bankfull depth is the average depth of all channels along the cross-section. (See board manual section 2.)*

"Bankfull width" *means:*

(a) For streams - the measurement of the lateral extent of the water surface elevation perpendicular to the channel at bankfull depth. In cases where multiple channels exist, bankfull width is the sum of the individual channel widths along the cross-section (see board manual section 2).

(b) For lakes, ponds, and impoundments - line of mean high water.

(c) For tidal water - line of mean high tide.

(d) For periodically inundated areas of associated wetlands - line of periodic inundation, which will be found by examining the edge of inundation to ascertain where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland.

The literature supporting the use of bankfull width (BFW), depth (BFD), and elevation (BFE) to delineate OCH can be divided into three main areas: 1) use of bankfull width and depth as a measure of stream size and floodplain extent; 2) use of bankfull depth as an indicator of flood return interval; and 3) use of bankfull elevation to determine extent of OCH.

Bankfull dimensions (width, depth) are standard measures of channel size in fluvial geomorphology and have a long history of use (e.g., Leopold et al. 1964; Leopold and Skibitzke 1967; Dunne and Leopold 1978; Harrelson et al. 1994). The bankfull flow is a frequent flood (occurring every 1-2 years on average, Williams 1978) that commonly transports the most sediment over time (Wolman and Miller 1960) and sets the long-term average morphology of floodplain rivers. The guidelines for determining bankfull dimensions outlined in the Forest Practice Board Manual (2004), which appear to be based largely on Pleus and Schuett-Hames (1998), are widely used and accepted approaches. However, determining bankfull dimensions from field observations is not without uncertainty (Johnson and Heil 1996; Buffington et al. 2009); there can, in fact, be a fair amount of variability in bankfull dimensions within a reach and from one observer to the next (e.g., Roper et al. 2010). Although training and use of standard protocols can reduce this uncertainty, it should be recognized that there is some inherent uncertainty associated with delineation of OCH using bankfull dimensions.

While it is logical to use bankfull dimensions for determining the extent of OCH as described under the FPR, the Working Group was unsure of the evidence to support the use of BFE to adequately delineate OCH. Therefore, we reviewed the literature for evidence supporting this approach and to understand the most appropriate elevation (bankfull or higher) for protecting OCH.

Although considerable literature exists regarding methods for determining bankfull depth and discharge (See Appendix B), only a handful of studies have looked at using bankfull characteristics (width, elevation or depth) to define floodplain, riparian habitats, and associated flood return intervals. Verry et al. (2004) defined the riparian zone in terms of Rosgen's (1996) floodprone width — an approximation of the 50-year flood extent, which is empirically defined as the width of the valley measured at an elevation of twice the bankfull depth. Sullivan and Watzin (2009) used BFE to separate in-channel vs. floodplain habitats, and related bankfull metrics to the level of channel-floodplain connectivity and fish assemblages (diversity) in the Champlain Valley, Vermont, although this was for large-river floodplain waterbodies.

In addition, a number of GIS-based approaches have been used to predict BFE and floodplain extent from digital elevation models (DEMs) (e.g., Hall et al. 2007; Nagel et al. 2014). For example, Nagel et al. (2014) provide a freely available GIS program called the Valley

Confinement Algorithm to define the extent and shape of unconfined valley bottoms. Hall et al. (2007) used a GIS approach to predict BFE and floodplain extent from DEMs to assist with salmon habitat mapping for the entire Columbia River Basin. While GIS approaches are attractive because they allow rapid assessment of entire watersheds and regions, they should be viewed as first-order estimates that frequently have large errors and require field verification and algorithm training. Moreover, most of these approaches focus on larger floodplain rivers rather than the relatively small and confined channels covered by the OCH rule.

A recent study by Vondrasek (2015) compared use of high-resolution LiDAR data and GPS surveys for modeling channel hydraulics and delineating riparian areas and off-channel habitats under dense forest canopy in two relatively unconfined streams (Snahapish River and Goodman Creek on the Olympic Peninsula). He found that LiDAR topography coupled with a simple hydraulic model allows one to both locate riparian areas and delineate discrete off-channel wetlands, tributaries, and side channels. He also found that this LiDAR-based hydraulic model allows one to model flows in these areas to examine seasonal hydrologic connections to the main channel and to estimate the extent that OCH varies with flood recurrence interval. However, a less intensive relative-elevation model that simply used the elevation above bankfull performed similarly to the LiDAR-based hydraulic model in delineating OCH (Vondrasek 2015). While his study involved streams that are larger and have more pronounced floodplains than those typically covered by the OCH rule, it provides a useful case study for demonstrating how hydraulic models and remote sensing can be used to predict the extent of OCH that might be excluded under the interim rules based on BFE.

Although our literature review demonstrates that BFE has been used in delineating floodplain and off-channel habitats, we are not aware of any studies other than Vondrasek's (2015) that have assessed how the extent of OCH varies with discharge. Consequently, it is difficult to assess the adequacy of using BFE for delineating OCH. On the one hand, it is a logical approach because: (1) bankfull discharge controls the long-term average channel morphology in many temperate floodplain rivers, within which aquatic habitat is embedded; (2) bankfull flow is a frequent, typical flood that aquatic organisms are likely adapted to; and (3) bankfull is an easily identifiable feature (from topography, vegetation, etc.), making it a consistent and repeatable metric. As such, BFE is a convenient and relevant index of OCH extent. On the other hand, limiting delineation to the bankfull elevation could exclude additional floodplain habitat that may be available during higher flows, the extent and importance of which require further study. We speculate that results are likely basin- and species-specific, depending on hydroclimate (magnitude and duration of flooding), degree of channel confinement (floodplain geometry and hydraulics of overbank flows), type and age of riparian vegetation (roughness and floodplain complexity), and fish species/phenotype (preferred channel type and associated process domain with regard to valley geometry and flood regime, life history relative to timing of floods, and floodplain habitat requirements (depth, velocity, cover, temperature, food)). Because the OCH rules mainly apply to small and medium-sized confined to moderately confined channels with little or no floodplain development, the extent of additional OCH above the BFE may be limited. Nevertheless, a certain fraction of these small channels may offer more extensive habitat that may be important in certain river systems or to certain fish species, phenotypes, and life stages. As such, further investigation is warranted, as outlined later in this report.

Finally, while the Forest Practice Rules for delineating OCH mention bankfull depth, the key issue is determining an appropriate reference elevation (bankfull or higher) that sets the datum for defining the extent of OCH.

5% gradient OCH Rule

The Working Group was interested in how the 5% gradient rule was determined and how 5% gradient is calculated (i.e., average, maximum, etc.). There were a few scenarios where we could conceive of a channel that was more than 5% that might connect OCHs that are above the bankfull elevation. There was, however, no documentation of the 5% gradient rule in the FFR. We assume that the 5% rule is likely based on the stream gradient limit that is considered suitable for juvenile coho or Chinook salmon rearing or passage. Providing further documentation of how the 5% rule was determined and some analysis of how often this gradient rule might, in practice, lead to exclusion of important habitats would be helpful.

Define the flood return interval that defines 95% of OCH and related field methods

Determining the appropriate flood return interval that defines a particular percentage of OCH is no small task and is beyond the scope of what could be accomplished for this report. As noted previously, bankfull discharge typically has a flood return frequency of 1 to 2 years, though this varies considerably within and among streams and geographic provinces (Woodyear 1968; Williams 1978; Castro and Jackson 2001; Wilkerson 2008). Determining the flood return interval that will protect a specific percentage (i.e., 75%, 85%, or 95%) of floodplain habitat would require hydraulic modeling across a range of sites covered by the OCH rule. As discussed above, results will likely vary with hydroclimate (i.e., east vs. west side basins) and process domain (location within a basin, discharge regime, and degree of channel confinement; Montgomery 1999), nor are the biological consequences clear in terms of the ecological role of rare flood events relative to typical life cycles of a given species. Long-term monitoring or use of a fish population model would be needed to assess the potential biological effects.

Examples of areas that might be excluded from the current interim rule

The OCH Work Group identified a number of instances where the current rule could potentially exclude OCH including:

1. Wetlands, ponds, side channels or other wetted areas above BFE that do not contain fish[3] but are only connected at flood elevations higher than BFE.
2. Areas above BFE that are dry at most flows, but where fish may move into during episodic floods to rear and feed and then move back into the main channel when flows recede (i.e., Brown and Hartman 1988).
3. OCHs connected to primary channel by a channel that is steeper than 5% and does not contain fish migration barriers.
4. Areas that are currently isolated from the main channel by an obstruction, such as a logjam or natural levee (bank or berm), that may be connected in the future following

[3] If they were isolated from channel but contain fish they are Type F waters.

natural deterioration or erosion of the obstruction (i.e., habitats that might be isolated now, but could be connected in future).

In addition, the areal extent of some habitat may change from season to season, and since the RMZ would begin at the edge of the OCH, the season at which the OCH is delineated could have an impact on the starting point of the RMZ and whether the full extent of the OCH would be protected. We also note that, unlike delineation of the CMZ, temporal changes in OCH are not planned for. Rather, OCH under the current rule is assessed based on conditions observed at a given time not historic or future conditions. While OCH may not be as dynamic as other fluvial environments, such as the CMZ, OCH is expected to respond to large floods, such as those that occurred in 2006.

Key Uncertainties

What is not clear is:

- How common are these scenarios where OCH could be excluded under the current rule as implemented (WAC 222-080-031)?
- How much OCH or what percentage of OCH would be excluded?
- What is the biological impact or importance of excluding these habitat from protection?

The Working Group felt that additional information or study was needed to determine the frequency of OCH in the streams in question and the frequency with which habitats similar to those listed above might be excluded from protection by the RMZ, or used as the starting point for the RMZ.

Suggestions for Additional Study

To address the key uncertainties above, a series of studies with two phases is recommended. Phase 1 of the study would be to examine OCHs within streams covered by the current OCH rule to determine the frequency and extent of OCH across the landscape and how often OCHs are excluded or under-protected. This would likely require sampling a subset of units harvested (50 to 100) in recent years that include streams that fall in the size and gradient of streams where OCH is likely to exist. An initial office review and analysis would be conducted to determine how commonly the OCH rule is implemented. Field visits would then be conducted to: 1) assess cases of omission and commission; and 2) to confirm that OCHs were properly delineated; and 3) to assess the proportion of OCH within or outside the RMZ at sites where the rule was applied. It would also provide information on the landscape and geomorphic context where OCH is most likely to occur. Stratification and selection of sampling sites would be critical for a rigorous study and need to include geographic province (eastern vs. western Washington), ownership, channel size/stream order and other factors. The sample could potentially be drawn from unharvested units, units that will be harvested, or units that have been harvested – all of which have potential strengths and weaknesses. We recommend drawing the sample from recently harvested units (perhaps those within the last 5 years) because it would allow confirmation of how the rule is currently being applied, and would likely best address the key uncertainties about the current rule. Because of the variation in conditions among sites within and between different landscapes, it is necessary to have a relatively large, well-stratified sample. Products would include an estimate of the amount of OCH present in stream types in question, the proportion of sites where OCH was accurately delineated, and an initial list of sites for more detailed sampling and modeling in Phase 2.

Phase 2 would include more detailed research to determine whether BFE is adequate or whether a higher elevation is needed to fully protect and capture important OCH functions or what elevation above BFE would be more appropriate. This would require sampling and monitoring harvested units (presumably from Phase 1) where OCH exists to:

1) Determine seasonal extent and connectivity of OCH at different flows, in different geomorphic settings, and in different hydroclimates.

2) Conduct hydraulic modeling based on field survey data and LiDAR to examine extent of OCH at various flood recurrence intervals and elevations above bankfull.

3) Monitor fish use of OCH at various flows to determine if fish are in fact using OCH that may exist above BFE.

Ideally, sites would be taken from those sampled in Phase I; however, given that OCH in the stream channels in question may not be very common, additional units with OCH may need to be identified. Geomorphic features of those sites where OCH designation has been applied could be used to help locate other likely sites. Similar to Phase 1, a relatively robust sample (>25 sites) would be needed to provide a landscape perspective of the extent and persistence of OCH and the implications to fish and fish habitat of using BFE, or some other higher elevation to delineate OCH. Sampling multiple sites would also be required to adequately address policy questions about the benefit to fish of protecting different percentages (i.e., 75%, 85%, and 95%) of OCH sampling. Products would include proportion of OCH protected or excluded by BFE under the current rule, elevation and flood return interval that protects 100% of OCH in streams in question, fish use of OCH habitats at different flows and elevations, and impacts of using BFE or other elevations on fish habitat.

Conclusions

In response to the five tasks we draw the following conclusions.

Task 1. Collect and review current literature and protocols used to define processes for identifying OCH.

There is extensive literature documenting the importance of OCH to fish and for regulating the productivity of streams and aquatic habitats.

Task 2. Determine if OCH is being omitted from FPAs under the existing definition used to define OCH in the interim water typing system rule, and, if yes, describe these habitats in a manner that would facilitate coverage.

It is likely that some OCH is being excluded by using BFE, but additional research is needed to determine the extent and how common this is across the landscape.

Task 3. Review the existing definitions of bankfull width and bankfull depth in the forest practices rules and the FFR, and determine if using bankfull elevation in the definition would be more beneficial than bankfull depth in the determination of OCH.

The approach for defining OCH under the current rule using BFE seems logical and is at least partially supported by existing science on use of bankfull measures to delineate channels, channel morphology, and floodplains. The critical issue is whether using BFE to delineate OCH provides adequate protection. Moreover, there are no studies that have specifically examined using BFE to delineate the extent of OCH or the flood return interval that might delineate all or a specific portion of OCH. Given the uncertainty of using BFE, amending the language of the existing rule in this regard is not recommended at this time. However, further study of the issue is encouraged.

Task 4. Review the OCH description developed during Policy field site visits to determine if this description meets the definition of OCH and adequately covers off-channel habitat as currently described in rule, WAC 222-16-031. The site visits found "*Off-Channel Habitat consists of waters connected to and draining into Type S and F waters by inundation at bank full elevation of the Type S or F water and encompassed by that area of inundation at bank full width and elevation*."

The above statement would add clarity to the current rule in terms of emphasizing the importance of bankfull elevation (as opposed to bankfull depth), but uncertainty regarding the adequacy of the bankfull datum for delineating OCH is a key issue to be addressed, as discussed above.

Task 5: Define the flood return interval that defines 95% of OCH and the field methods delineate that flood return interval.

This question cannot be addressed without additional information and additional studies are needed to determine: (1) how commonly OCH occurs in the stream types in question; (2) whether application of the current rule excludes some OCH from protection and, if so, what elevation (bankfull or higher) would allow for protection of a given percentage of the available OCH; and (3) the biological impacts of not protecting the full extent of OCH at each site, particularly given that the tails of the areal distribution of habitat may correspond with large, rare floods (e.g., 50 or 100-year events). We outline the methods and studies that could address these and other key uncertainties.

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Dr. Philip Roni is a Principal Scientist with Cramer Fish Sciences (CFS) and an Affiliate Professor at the University of Washington School of Aquatic and Fishery Sciences. He has more than 25 years of experience as a fisheries research scientist and directs the CFS Northwest science team where he focuses on designing, implementing and completing, and publishing definitive studies to address pressing questions related to protection, management and restoration of aquatic systems. Prior to joining CFS, Dr. Roni led the Watershed Program at the NOAA Northwest Fisheries Science Center where he directed more than 25 scientists conducting habitat research. His research for the last 20 years has concentrated on planning, prioritization, and evaluation of various watershed restoration techniques. He regularly teaches courses and has published numerous papers on restoration science, including the comprehensive books "Stream and Watershed Restoration: a guide to restoring riverine processes and habitat" (2013 Wiley-Blackwell) and "Monitoring Stream and Watershed Restoration" (2005 AFS). Recent ongoing large research projects include estimating salmonid egg-to-fry survival, evaluating the effectiveness of large regional restoration programs, and fish response to whole watershed restoration. He received a Presidential Early Career Award (2004) from the US President and a Certificate of Achievement (2012) from the AFS for his contributions to restoration science. He has both an M.S. and a Ph.D. from the University of Washington.

Peter A. Bisson
Emeritus Scientist,
UDSA Forest Service, Pacific Northwest Research Station
Olympia, Washington

Pete Bisson is an emeritus scientist with the USDA Forest Service Pacific Northwest Research Station in Olympia, Washington. He received a B.A. in environmental biology from the University of California at Santa Barbara, and M.S. and Ph.D. degrees in fisheries from Oregon State University. From 1974 to 1995 he was an aquatic biologist for the Weyerhaeuser Company in Tacoma, Washington. In 1995 he joined the Forest Service, where his studies included fish populations, stream habitats and food webs, riparian zones, and a variety of management issues related to aquatic ecosystems. Prior to his retirement in 2012 Pete held affiliate faculty appointments at the University of Washington, Oregon State University, and the University of Idaho, and served on two National Research Council committees: one on Pacific salmon and the other on watershed management.

John M. Buffington
Research Geomorphologist
U.S. Forest Service
Rocky Mountain Research Station
Boise, Idaho.

John is a Research Geomorphologist with the U.S. Forest Service, Rocky Mountain Research Station in Boise, Idaho. He graduated from the University of California Berkeley in 1988 with a BA in geology and from the University of Washington in 1995 and 1998 with MS and PhD degrees in geomorphology. He was a National Research Council Fellow from 1998 to 2000 and a professor in the Center for Ecohydraulics Research at the University of Idaho from 2000 to 2004. He currently serves on the Science Advisory Board for the Trinity River in northern California and co-edits the Journal of Geophysical Research-Earth Surface. His research focuses on fluvial geomorphology of mountain basins, biophysical interactions, and the effects of natural and anthropogenic disturbances on salmonid habitat.

George R. Pess
Watershed Program Manager
NOAA Northwest Fisheries Science Center
Seattle, WA

George has worked in the fisheries science and management field since 1989. His primary research interest during that time has been the examination of natural and land-use effects on salmon habitat and production. George has conducted research on historic and current land use impacts on salmon habitat and production, the influence of wood in forested stream channels, the development of a wood recruitment model to determine the relative influence of forestry activities, what role watershed analysis plays in ecosystem management, and how landscape characteristics and land use affect salmon abundance and distribution. George has a B.A. in Economics and Environmental Science (Bowdoin College 1987), an M.S. in Forest Science (Yale University 1992), and a Ph.D. in Aquatic and Fishery Sciences (University of Washington, 2009).

Appendix B. Relevant Off-Channel Habitat Literature

The following provides a summary of the relevant literature we located and reviewed related to 1) importance of OCH to fish, 2) role of OCH in regulating aquatic productivity and 3) and key literature on bankfull width, depth and height. It should be noted that our focus for 1) and 2) was small streams similar to those covered by OCH rule and we excluded several references that were focused on large alluvial rivers.

1) Importance of OCH to Fish

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3) Key Literature on Bankfull width, depth and height including abstract

Abril, J. B., and D. W. Knight. 2004. Stage-discharge prediction for rivers in flood applying a depth-averaged model. Journal of Hydraulic Research 42(6): 616–629.

The prediction of the stage-discharge relationship for rivers in flood is described by a finite element model of depth-averaged turbulent flow, calibrated using (three hydraulic coefficients governing local bed friction, lateral eddy viscosity and depth-averaged secondary flow. The resulting lateral distributions of depth-averaged velocity are subsequently integrated to yield the stage-discharge relationship. The calibration of the model involves the establishment of simplifying hypotheses for certain coefficients in order to give the correct depth-mean velocity and boundary shear, both across the channel and with stage. Comparisons against some experimental data from the UK Flood Channel Facility, for channels with trapezoidal and compound cross-sections, help develop the calibration philosophy for both inbank and overbank flows. Numerical experiments with the coherence method for a hypothetical river are used to extend the model calibration to rivers with homogeneous and heterogeneous roughness. Applications of the model to simulating the flow in a number of natural valley and mountain rivers serve to test hypotheses and results obtained at a real scale.

Brummer, C. J., T. B. Abbe, J. R. Sampson, and D. R. Montgomery. 2006. Influence of vertical channel change associated with wood accumulations on delineating channel migration zones, Washington, USA. Geomorphology 80(3): 295–309.

We combine hydraulic modeling and field investigations of logjams to evaluate linkages between wood-mediated fluctuations in channel-bed-and water-surface elevations and the potential for lateral channel migration in forest rivers of Washington state. In the eleven unconfined rivers we investigated, logjams were associated with reduced channel gradient and bank height. Detailed river gauging and hydraulic modeling document significant increases in the water-surface elevation upstream of channel-spanning wood accumulations. Logjams initiated lateral channel migration by increasing bed-or water-surface elevations above adjacent banks. Because the potential for a channel to avulse and migrate across its floodplain increases with the size and volume of instream wood, the area of the valley bottom potentially occupied by a channel over a specified timeframe - the channel migration zone (CMZ) - is dependent on the state of riparian forests. The return of riparian forests afforded by current land management practices will increase the volume and caliber of wood entering Washington rivers to a degree unprecedented since widespread clearing of wood from forests and rivers nearly 150 years ago. A greater supply of wood from maturing riparian forests will increase the frequency and spatial extent of channel migration relative to observations from wood-poor channels in the period of post-European settlement. We propose conceptual guidelines for the delineation of the CMZs that include allowances for vertical fluctuations in channel elevation caused by accumulations of large woody debris.

Buffington, J. M., B. E. Roper, E. Archer, and C. Moyer. 2009. Reply to discussion by David L. Rosgen on "The role of observer variation in determining Rosgen stream types in northeastern Oregon mountain streams". Journal of the American Water Resources Association 45(5): 1298–1312.

We thank Rosgen (this issue) for his comments, which provide valuable insight regarding his channel classification and its correct application. However, we believe that many of his objections are based on misinterpretation of our analysis, which we hope to clarify through this reply. Because our measurement techniques differed from those advocated by Rosgen (1996), our study may not represent the range of variability in channel classification that would result from strict adherence to his methods. Nevertheless, this does not invalidate our analysis and the intended study goal of evaluating classification consistency and sources of observed differences. However, some of the identified shortcomings of the classification may stem from our use of methods different from Rosgen's and therefore deserve further analysis.

Castro, J.M., and P. L. Jackson. 2001. Bankfull discharge recurrence intervals and regional hydraulic geometry relationships: patterns in the Pacific Northwest, USA. Journal of American Water Resources Association 37:1249–1262.

The model bankfull discharge recurrence interval (annual series) (Ta) in streams has been approximated at a 1.5-year flow event. This study tests the linkage between regional factors (climate, physiography, and ecoregion) and the frequency of bank-full discharge events in the Pacific Northwest (PNW). Patterns of Ta were found to be significant when stratified by EPA Ecoregion. The mean value for Ta in the PNW is 1.4 years; however, when the data is stratified by ecoregion, the humid areas of western Oregon and Washington have a mean value of 1.2 years, while the dryer areas of Idaho and eastern Oregon and Washington have a mean value of 1.4 to 1.5 years. Among the four factors evaluated, vegetation association and average annual precipitation are the primary factors related to channel form and Ta. Based on the results of the

Ta analyses, regional hydraulic geometry relationships of streams were developed for the PNW, which relate variables, such as bank-full cross-sectional area, width, depth, and velocity, to bankfull discharge and drainage area. The verification of Ta values, combined with the development of regional hydraulic geometry relationships, provides geographically relevant information that will result in more accurate estimates of hydraulic geometry variables in the PNW.

Copeland, R. R., D. S. Biedenharn, and J. C. Fischenich. 2000. Channel-forming discharge. U.S. Army Corps of Engineers Technical Note ERDC/CHL CHETN-VIII-5, Vicksburg, MS.

The purpose of this Technical Note is to provide guidance and cautions to be used in approximating channel-forming discharge with bankfull, specified recurrence interval, and effective discharge methodologies. There are limitations for each of these three methods that the user must recognize.

INTRODUCTION: An alluvial river adjusts the dimensions of its channel to the wide range of flows that mobilize its boundary sediments. For many rivers and streams, it has been observed that a single representative discharge may be used to determine a stable channel geometry. The use of a single representative discharge is the foundation of regime and hydraulic geometry theories for determining morphological characteristics of alluvial channels. This representative channel-forming (dominant) discharge has been given several names by different researchers, including bankfull, specified recurrence interval, and effective discharge. This has led to confusion with both terminology and understanding of fundamental stream processes. In this Technical Note the channel-forming (dominant) discharge is defined as a theoretical discharge that if maintained indefinitely would produce the same channel geometry as the natural long-term hydrograph. Channel-forming discharge concepts are applicable to stable alluvial streams (i.e., streams that have the ability to change their shape and are neither aggrading nor degrading). For channels in arid environments where runoff is generated by localized high intensity storms and the absence of vegetation ensures that the channel will adjust to each major flood event, the channel-forming discharge concept is generally not applicable.

Faux, R., J. M. Buffington, G. Whitley, S. Lanigan, and B. Roper.2009. Use of airborne near-infrared LiDAR for determining channel cross-section characteristics and monitoring aquatic habitat in Pacific Northwest rivers: A preliminary analysis. Pages 43–60 *in* J. M. Bayer and J. L. Schei, editors. Remote Sensing Applications for Aquatic Resource Monitoring, Proceedings of the 2008 Annual Conference of the American Society of Photogrammetry and Remote Sensing, Pacific Northwest Aquatic Monitoring Partnership, Cook, WA.

Aquatic habitat monitoring is being conducted by numerous organizations in many parts of the Pacific Northwest to document physical and biological conditions of stream reaches as part of legal- and policy-mandated environmental assessments. Remote sensing using discrete-return, near-infrared, airborne LiDAR (Light Detection and Ranging) and high-resolution digital imagery may provide an alternative basis for measuring physical stream attributes that are traditionally recorded by field crews in these monitoring efforts. Here, we compare physical channel characteristics determined from airborne LiDAR versus those measured from field surveys using a total station. Study sites representing three different channel types (plane-bed, pool-riffle, and step-pool) with bankfull widths ranging from 2.5 to 18.6 m were examined in the upper John Day River basin, Oregon. LiDAR was flown on each study reach at a native pulse density of about 4 pulses/m2, with up to four returns per pulse. Channel cross sections and stream gradient were determined from LiDAR-derived digital elevation models (DEMs) and directly compared to total station measurements. The ability to remotely sense bankfull elevations and associated channel geometry was of particular interest in this study. Because bankfull mapping from LiDAR depends on topographic indicators (breaks in streambank slope), bankfull elevation was determined objectively from plots of hydraulic depth (flow area divided by width) as a function of flow height at each cross section, with bankfull defined as the maximum value of this function, or as the first plateau in the hydraulic depth function in channels with multiple terraces. The latter definition allows a blind test of remote sensing capabilities for cases where no field observations of bankfull elevation are available.

Preliminary results show that, with the exception of one outlier, the first-terrace elevations determined from LiDAR DEMs differed from those of the total station by 0–40 cm (15 cm RMSE), corresponding channel widths differed by 0.23–5.23 m, and reach-average water-surface slopes differed by 0.0–0.0018 m/m. Furthermore, the LiDAR-derived cross-sectional profiles generally corresponded with those of the total station measurements above the water-surface elevation. However, first-terrace elevations frequently differed from field observations of bankfull stage, indicating that successful remote sensing of bankfull geometry using airborne LiDAR requires field observations to train identification of bankfull topography in LiDAR DEMs. When properly applied, remote sensing using airborne LiDAR has the potential to extend the spatial coverage, speed, consistency, and precision of physical stream measurements compared to existing field based techniques, and can be used to quantify higher-order topographic metrics (e.g., areas, volumes, curvature, and topology) beyond the point and line metrics currently measured by channel monitoring programs.

Fernández, D., J. Barquín, M. Álvarez-Cabria, and F. J. Peñas. 2012. Quantifying the performance of automated GIS-based geomorphological approaches for riparian zone delineation using digital elevation models. Hydraulic and Earth System Sciences 16(10): 3851–3862.

Riparian zone delineation is a central issue for managing rivers and adjacent areas; however, criteria used to delineate them are still under debate. The area inundated by a 50-yr flood has been indicated as an optimal hydrological descriptor for riparian areas. This detailed hydrological information is usually only available for populated areas at risk of flooding. In this work we created several floodplain surfaces by means of two different GIS-based geomorphological approaches using digital elevation models (DEMs), in an attempt to find hydrologically meaningful potential riparian zones for river networks at the river basin scale.

Objective quantification of the performance of the two geomorphologic models is provided by analysing coinciding and exceeding areas with respect to the 50-yr flood surface in different river geomorphological types.

Hall, J.E., D. M. Holzer, D.M., and T. J. Beechie. 2007. Predicting river floodplain and lateral channel migration for salmon habitat conservation. Journal of Waters Resources Association 43(3):786–797.

In this article, we describe a method for predicting floodplain locations and potential lateral channel migration across 82,900 km (491 km2 by bankfull area) of streams in the Columbia River basin. Predictions are based on channel confinement, channel slope, bankfull width, and bankfull depth derived from digital elevation and precipitation data. Half of the 367 km2 (47,900 km by length) of low-gradient channels ($\leq$ 4% channel slope) were classified as floodplain channels with a high likelihood of lateral channel migration (182 km2, 50%). Classification agreement between modeled and field-measured floodplain confinement was 85% ($\kappa = 0.46$, $p < 0.001$) with the largest source of error being the misclassification of unconfined channels as confined (55% omission error). Classification agreement between predicted channel migration and lateral migration determined from aerial photographs was 76% ($\kappa = 0.53$, $p < 0.001$) with the largest source of error being the misclassification of laterally migrating channels as non-migrating (35% omission error). On average, more salmon populations were associated with laterally migrating channels and floodplains than with confined or nonmigrating channels. These data are useful for many river basin planning applications, including identification of land use impacts to floodplain habitats and locations with restoration potential for listed salmonids or other species of concern.

Harrelson, C.C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique.

This document is a guide to establishing permanent reference sites for gathering data about the physical characteristics of streams and rivers. The minimum procedure consists of the following: (1) select a site, (2) map the site and location, (3) measure the channel cross-section, (4) survey a longitudinal profile of the channel, (5) measure stream flow, (6) measure bed material, and (7) permanently file the information with the Vigil network. The document includes basic surveying techniques, provides guidelines for identifying bankfull indicators and measuring other important stream characteristics. The object is to establish the baseline of existing physical conditions for the stream channel. With this foundation, changes in the character of streams can be quantified for monitoring purposes or to support other management decisions.

Hill, M.T., W. S. Platts, and R. L. Beschta. 1991. Ecological and geomorphological concepts for instream and out-of-channel flow requirements. Rivers 2(3): 198–210.

Healthy fish populations are dependent on streamflow regimes that protect the ecological integrity of their habitat. Fish habitats are the consequence of linkage among the stream, floodplain, riparian, and upland zones, and watershed geography. Fluvial-geomorphic processes form and control fish habitat. Because of this, multiple in-channel and out-of-channel flows are needed to maintain these processes. We present a conceptual methodology for measuring tour types of streamflow regimes: instream flows, channel maintenance flows, riparian maintenance flows, and valley maintenance flows. The combination of these four streamflow types is designed to protect fish and their habitat. Using a case study of the Salmon River near Whitebird, Idaho, we demonstrate how the methodology could be used to develop a multiple flow recommendation.

Imhof, J. G., J. Fitzgibbon, and W. K. Annable. 1996. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(S1): 312–326.

We present an evaluation system and framework for determining the relations between processes that generate physical features and how these features are used by fish. This information is essential for long-term management of fish habitat within watersheds. The model is hierarchical at three scales: watershed, reach, and site. Physical characteristics at these scales are separated into attributes, features, or variables that provide information on cause-response relationships. An evaluative framework is proposed along with a logical framework to guide analysis. The framework includes a functional analysis of physical characteristics and processes that generate physical habitat and a functional analysis of habitat requirements related to life cycle of an indicator species. An example of a life stage – state analysis is presented. Concepts of “health,” “integrity,” and “fit” are used to assess the physical states and conditions of the environment to determine the potential fit for a species based on its life-cycle requirements.

Johnson, P.A., and T. M. Heil. 1996. Uncertainty in estimating bankfull conditions. Journal of American Water Resource Association 23(6):1283–1291

Bankfull depth and discharge are basic input parameters to stream planform, stream restoration, and highway crossing designs, as well as to the development of hydraulic geometry relationships and the classification of streams. Unfortunately, there are a wide variety of definitions for bankfull that provide a range of values, and the actual selection of bankfull is subjective. In this paper, the relative uncertainty in determining the bankfull depth and discharge is quantified, first by examining the variability in the estimates of bankfull and second by using fuzzy numbers to describe bankfull depth. Fuzzy numbers are used to incorporate uncertainty due to vagueness in the definition of bankfull and subjectivity in the selection of bankfull. Examples are provided that demonstrate the use of a fuzzy bankfull depth in sediment trans. port and in stream classification. Using fuzzy numbers to describe bankfull depth rather than a deterministic value allows the engineer to base designs and decisions on a range of possible values and associated degrees of belief that the bankfull depths take on each value in that range.

Lisle, T.E. 1989. Channel-dynamic control on the establishment of riparian trees after large floods in northwestern California. USDA Forest Service General Technical Report PSW-110. Berkley, CA.

Large floods in northwestern California in the past two decades have mobilized extensive areas of valley floors, removed streamside trees, and widened channels. Channel cross sections were surveyed to illustrate an hypothesis on the linkage between sediment transport, colonization of channel margins by trees, and streambank recovery. Riparian trees, e.g., white alder (*Alnus rhombifolia*), colonize the water's edge at low flow to receive adequate moisture during the dry season. Such stands can endure annual high flows only after the flood-enhanced sediment load declines and the width of the annually mobile bed contracts to the low-flow width. Streambank formation along the low-flow margin can then proceed by deposition of fine sediment and organic debris.

Myers, W. R. C., J. F. Lyness, and J. Cassells. 2001. Influence of boundary roughness on velocity and discharge in compound river channels. Journal of Hydraulic Research 39(3): 311–319.

Results are presented of an experimental compound channel research programme carried out at the UK Flood Channel Facility including fixed and mobile main channel boundaries together with two floodplain roughnesses. For comparison data from a natural compound river channel are also presented. Velocity and discharge relationships are explored illustrating the complex behaviour of compound river channels and calling attention in particular to the errors incurred in applying conventional methodologies to discharge assessment in overbank flows. Relationships are presented for velocity and discharge ratios which could form the basis of mathematical modelling of overbank flow estimation methods. The research also represents a step towards prototype conformity by the introduction of mobile boundaries.

Nagel, D. E., J. M. Buffington, S. L. Parkes, S. Wenger, and J. R. Goode. 2014. A landscape scale valley confinement algorithm: Delineating unconfined valley bottoms for geomorphic, aquatic, and riparian applications. USDA Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-32, Fort Collins, CO., 42 p.

Valley confinement describes the degree to which bounding topographic features, such as hillslopes, alluvial fans, glacial moraines, and river terraces, limit the lateral extent of the valley floor and the floodplain along a river. Valleys can be broadly classified as confined or unconfined, with corresponding differences in their appearance, vegetation, ground water exchange rates, topographic gradient, and stream characteristics. Unconfined valleys are generally less extensive than confined valleys in montane environments, but host a diverse array of terrestrial and aquatic organisms and provide disproportionately important ecosystem functions. Consequently, identifying the location and abundance of each valley type is increasingly recognized as an important aspect of ecosystem management. In this report, we describe a GIS program called the Valley Confinement Algorithm (VCA) that maps the extent and shape of unconfined valley bottoms using readily available spatial data as input.

The VCA is designed to operate using ESRI ArcGIS software with 1:100,000 scale stream lines from the National Hydrography Dataset (NHDPlusV1) and 10-30 m digital elevation models (DEMs). The algorithm focuses on fluvial applications and therefore only considers channeled valleys. The smallest unconfined valley that can be resolved by the VCA depends on the resolution of the DEM; the VCA is unable to resolve unconfined valleys that are narrower than about two to three times the DEM cell size (i.e., valleys that are 60-90 m in width for a 30 m DEM or 20-30 m for a 10 m DEM). In addition, as bankfull width approaches two times the DEM cell size, the VCA may misinterpret the channel as a narrow unconfined valley. Consequently, care should be exercised in interpreting results in such locations. We conducted field work in central Idaho to document channel characteristics in confined and unconfined valleys mapped by the algorithm. Results showed that channel confinement measured in the field (ratio of valley width to bankfull width) agreed with valley confinement predicted by the algorithm 79% of the time and that channel characteristics were similar to those documented in other studies of confinement. In particular, confined channels typically exhibited steep-gradient step-pool and plane-bed morphologies composed of coarse-grained bed material, with a median channel confinement of about 2 bankfull widths. In contrast, unconfined channels were primarily low-gradient pool-riffle and plane-bed streams composed of finer substrate, with a median channel confinement of about 10 bankfull widths.

We further assessed the accuracy of the algorithm by generating a stratified random sample of points equally partitioned between confined and unconfined valleys as identified by the VCA. Predicted valley types were compared with those observed from digital photos and quadrangle maps. Results showed that the algorithm could differentiate between the two valley types with 89-91% accuracy.

Navratil, O., Albert, M., Herouin, E., and Gresillon, J. 2006. Determination of bankfull discharge magnitude and frequency: comparison of methods on 16 gravel-bed river reaches. Earth Surface Processes and Landforms 31(11): 1345–1363.

Bankfull discharge is identified as an important parameter for studying river morphology, sediment motion, flood dynamics and their ecological impacts. In practice, the determination of this discharge and its hydrological characteristics is not easy, and a choice has to be made between several existing methods. To evaluate the impact of the choice of methods, five bankfull elevation definitions and four hydrological characterizations (determination of duration and frequency of exceedance applied to instantaneous or mean daily data) were compared on 16 gravel-bed river reaches located in France (the catchment sizes vary from 10 km2 to 1700 km2). The consistency of bankfull discharge estimated at reach scale and the hydraulic significance of the five elevation definitions were examined. The morphological definitions (Bank Inflection, Top of Bank) were found more relevant than the definitions based on a geometric criterion. The duration of exceedance was preferred to recurrence intervals (partial duration series approach) because it is not limited by the independency of flood events, especially for low discharges like those associated with the Bank Inflection definition. On average, the impacts of the choice of methods were very important for the bankfull discharge magnitude (factor of 1·6 between Bank Inflection and Top of Bank) and duration of exceedance or frequency (respectively a factor 1·8 and 1·9 between mean daily and instantaneous discharge data). The choice of one combination of methods rather than another can significantly modify the conclusions of a comparative analysis in terms of bankfull discharge magnitude and its hydrological characteristics, so that one must be cautious when comparing results from different studies that use different methods.

Radecki-Pawlik, A. 2002. Bankfull discharge in mountain streams: theory and practice. Earth Surface Processes and Landforms 27(2): 115–123.

The results are presented of an investigation of bankfull discharge in two Polish Carpathian streams: Skawica and Krzyworzeka. Existing definitions of river bankfull were reviewed and applied in tests carried out on selected cross-sections of the streams. The Woodyer method was given special attention, with a correspondingly detailed survey of plants characterizing river benches. Riley's bench index method and the methods of Williams, Wolman, Schumm and Brown, and Woloszyn were tested. The report concludes that bankfull discharge value for a mountain stream should not be reported as a single number, but rather as a range of discharges within which one could expect the bankfull value to lie.

Sullivan, S. M. P., and M. C. Watzin. 2009. Stream–floodplain connectivity and fish assemblage diversity in the Champlain Valley, Vermont, USA. Journal of Fish Biology 74(7): 1394–1418.

To evaluate the influence of main channel–floodplain connectivity on fish assemblage diversity in floodplains associated with streams and small rivers, fish assemblages and habitat characteristics were surveyed at 24 stream reaches in the Champlain Valley of Vermont, U.S.A. Fish assemblages differed markedly between the main channel and the floodplain. Fish assemblage diversity was greatest at reaches that exhibited high floodplain connectivity. Whereas certain species inhabited only main channels or floodplains, others utilized both main channel and floodplain habitats. Both floodplain fish α-diversity and γ-diversity of the entire stream corridor were positively correlated with connectivity between the main channel and its floodplain. Consistent with these results, species turnover (as measured by β-diversity) was negatively correlated with floodplain connectivity. Floodplains with waterbodies characterized by a wide range of water depths and turbidity levels exhibited high fish diversity. The results suggest that by separating rivers from their floodplains, incision and subsequent channel widening will have detrimental effects on multiple aspects of fish assemblage diversity across the stream–floodplain ecosystem.

Verry, E.S., Dolloff, C.A., and M. E. Manning, M.E. 2004. Riparian ecotone: a functional definition and delineation for resource assessment. Water, Air & Soil Pollution: Focus 4(1): 67–94.

We propose a geomorphic basis for defining riparian areas using the term: riparian ecotone, discuss how past definitions fall short, and illustrate how a linked sequence of definition, delineation, and riparian sampling are used to accurately assess riparian resources on the ground. Our riparian ecotone is based on the width of the valley (its floodprone area width) plus 30 meters on each side to encompass the important adjacent riparian functions, and 15 meters around obvious landslides. A functionally consistent riparian definition and delineation does not derive from land adjacent to a stream, rather it derives from the valley the stream runs through.

Vondrasek, D. 2015. Delineating forested river habitats and riparian floodplain hydrology with LIDAR. Master's Thesis, University of Washington, Seattle.

Rivers and the riparian forest corridor comprise a valuable freshwater ecosystem that has been altered by human activities including timber management, road building, and other land conversions. The habitats of river dependent species in the Pacific Northwest, in particular salmon have often been degraded by these activities. Many salmon runs have become threatened with extinction and have been Endangered Species Act listed. New conservation planning and policies have developed around protecting freshwater habitats and restoring more natural river processes. In WA State, timber landowners, officials from State and Federal agencies, Native tribes, and other stakeholders developed Forest Practice rules and codified a Habitat Conservation Plan with dual goals of providing regulatory surety for timber land owners and helping to recover the threatened salmon runs in forested watersheds. Conserving critical stream ecological functions and potential fish habitats throughout watersheds while managing and regulating timber harvest across the State requires accurate and up-to-date delineation and mapping of channels, tributaries, and off-channel wetlands. Monitoring the effectiveness of protection efforts is necessary but can also be difficult. Agency staff and resources are limited for both day-to-day implementation of Forest Practice rules and adaptive management. The goal of this research has been to develop efficient and accessible methods to delineate wetlands, side-channels, tributaries, and pools and backwaters created by large log jams in forested watersheds. It was also essential to use publicly available LiDAR data and to model these waters at ecologically meaningful flows. I tested a hydraulic model at a 2-year and 50-year flows, and a relative height above river surface model and compared them. I completed two additional remote sensing investigations to correlate channel movement and the locations of off-channel wetlands: an analysis of historical aerial imagery and models of the riparian forest tree establishment using the first-return LiDAR data. The research includes two fieldwork components: an appraisal of the delineated off-channel and active channel water features, and an assessment of the accuracy of the LiDAR under the forest canopy. Both the hydraulic and the relative elevation models accurately delineated the key off-channel and active-channel waters. The historical imagery analysis confirmed past channel movement left many of the side channels and wetlands near to the contemporary active channel. The sequence of tree establishment tracked where channel migration had exposed new banks, colonized first by deciduous trees, then followed by cohorts of conifers, some maturing and achieving great heights. Often the lack of a closed canopy corresponded to the locations of persistent wetlands or midchannel logjams.

Williams, G.P. 1978. Bank-full discharge of rivers. Water Resources Research 14(6): 1141–1154.

Eleven possible definitions of 'bank-full' have been used by various investigators. The active floodplain is the most meaningful bank-full level to the fluvial geomorphologist, whereas the banks of the valley flat are the most important to engineers. Comparison of 16 ways of determining bank-full discharge suggests that bank-full discharge at gaged sites should be obtained from the station's rating curve, where bank-full gage height is determined from a longitudinal profile of the floodplain along the entire reach. At ungaged sites, bank-full discharge can be estimated from the empirical equation of this study or from the Gauckler-Manning equation. In the latter case the resistance coefficient n should be estimated at the field site for bank-full flow; a measured low-flow n should not be used. Bank-full discharge does not have a common recurrence frequency among the rivers studied, and the discharge corresponding to the 1.5-year recurrence interval in most cases does not represent the bank-full discharge.

Wilkerson, G. V. 2008. Improved bankfull discharge prediction using 2-year recurrence-period discharge. Journal of the American Water Resources Association 44(1): 243–258.

Knowledge of bankfull discharge (Qbf) is essential for planners, engineers, geomorphologists, environmentalists, agricultural interests, developments situated on flood prone lands, surface mining and reclamation activities, and others interested in floods and flooding. In conjunction with estimating Qbf, regionalized bankfull hydraulic geometry relationships, which relate Qbf and associated channel dimensions (i.e., width, depth, and cross-section area) to drainage basin area (Ada), are often used. This study seeks to improve upon the common practice of predicting Qbf using Ada exclusively. Specifically, we hypothesize that predictions of Qbf can be improved by including estimates of the 2-year recurrence-period discharge (Q2) in regression models for predicting Qbf. For testing this hypothesis, we used Qbf estimates from 30 reports containing data for streams that span 34 hydrologic regions in 16 states. Corresponding values of Q2 and Ada were compiled from flood-frequency reports and other sources. By comparing statistical measures (i.e., root mean squared error, coefficient of determination, and Akaike's information criterion), we determined that predicting Qbf from Q2 rather than Ada yields consistently better estimates of Qbf. Other principal findings are (1) data are needed for at least 12 sites in a region for reliable hydraulic geometry model selection and (2) an approximate range of values for Qbf ⁄Q2 is 0.10-3.0.

Woodyer, K.D. 1968. Bankfull frequency in rivers. Journal of Hydrology 6(2): 114–142.

The mean frequency with which streams exceed their bankfull or flood-plain level has been claimed to be remarkably constant from site to site. However, this finding is suspect because the range of bankfull frequencies quoted is considerable and it has not been shown that they could belong to one frequency distribution. Therefore, appropriate statistical methods are used here to decide if estimates of bankfull frequency for different sites might belong to one distribution.

Because of the likelihood of very recent incision of flood-plains, three channel benches are considered as well as the flood-plain. They are identified mainly by their elevation relative to the bed of the stream, and are named “high”, “middle”, and “low” benches. The “high” bench is present only at some sites believed to be recently incised and is therefore assumed to be the equivalent of the flood-plain level. It is shown that there is a reasonable probability that the grouped bankfull frequencies for the “high” bench and flood-plain levels belong to one frequency distribution. Therefore, the assumption that this grouping represents the present flood-plain level appears to be justified; moreover, the claims made for a constant bankfull frequency for the flood-plain level are substantiated in the case of streams in New South Wales. In addition the “middle” bench can be claimed to be associated with a constant bankfull frequency.

The ranges of bankfull frequencies (in terms of the annual maximum series) obtained are:

“Middle” Bench	1.02–1.21 years
“High” Bench – Present Flood-plain Group	1.24–2.69 years

Previous estimates of bankfull frequencies (for the flood-plain level only) embrace both these ranges. The recognition of stream benches is important in identifying the active flood-plain or its equivalent level and in distinguishing flood-plains from terraces.

Technical Working Group
Recommendations to Assist in the Development of Type F Habitat Guidance
5 October 2016

Hans Berge, Adaptive Management Program Adminstrator
Howard Haemmerle, Adaptive Management Project Manager

INTRODUCTION

A Technical Working Group (TWG) was formed by the Adaptive Management Program Administrator to develop recommendations for TFW Policy to consider for guidance to practitioners in establishing the regulatory break between Type F and Type N waters for lands subject to forest practice rules. The first meeting of the group took place on August 16, 2016. The goal for this group was to review the protocol survey methodology based on the Electrofishing Technical Group's work and final report; identifying when the use of a protocol survey is appropriate; and, provide draft recommendations to the AMPA for presentation and discussion at Policy.

TFW Policy gave further direction to the group to use the definition of fish habitat in WAC 222-16-010 (e.g., recoverable habitat, potential habitat likely to be used by fish, off-channel habitat, etc.). Emphasis for the group was placed in describing recommended changes to Board Manual Section 13, without creating the language itself, and consider general water typing goals (accuracy, error, and balancing remaining uncertainty).

Following these directions and relying on their experience and expertise, the group identified the seventeen points that need improvement in the current water typing procedure. Participants reached agreement (consensus) on 14 of 17 points, but were unable to resolve differences of opinions and concerns on the remaining three items (identified in **bold** text below). The group also identified six overarching ideas that need to be considered when evaluating each of the seventeen points and how those points either individually or as a whole could be applied during the development of a permanent water typing rule.

Three primary recommendations are included in this summary document to provide a basis for establishing the F/N break (see 12). These include moving forward with a LiDAR based water typing model, using default physical criteria, and a protocol that uses geomorphic and biological indicators as a basis for determining the location of the F/N Break.

Overarching Ideas for Each Discussion Point

- Necessary to incorporate the concept of "fish habitat" in addition to "fish use"
- Require water typing proposal to proponent to provide adequate rationale for why the F/N break was established where it was. Provide rationale for why stream segments above the proposed F/N break are not likely to be used by fish at any life

stage at any time of the year, including habitat which could be recovered by restoration or management. (per 222-16-010)

- Recommend language that encourages pre-consultation on all water type modification requests to potentially reduce the use of electrofishing and increase acceptance of survey results
- Technical group recommends that in the final water typing rule that - Type F water is equivalent to fish habitat
- Technical group agreed for the purposes of their discussions that the term “fish use” as used in BM13 equates to “last detected fish”.
- Determination of the F/N break incorporates factors that influence the extent of habitat likely to be used by fish over time.

RECOMMENDATIONS

(1) Default Physicals

Assumption: The default physicals will be reviewed for improvements statewide following implementation and acceptance of the Proposal Initiation currently in discussion at TFW Policy.

Recommendation: Clarification of language used to define default physicals criteria for clarity.

Recommendation: Ensure that terms used in Board Manual and rule are consistent (e.g., channel width, defined channel, bankfull width).

Recommendation: Provide guidance on how to establish bankfull average measurement and delineate basin area.

Recommend that Small Forest Landowner Office be provided funding to provide this assistance.

(2) Verifying Fish Presence/Absence above Permanent Natural Barriers.

Recommendation: The presence of a permanent natural barrier in itself does not justify the establishment of the F/N break at that point. A protocol survey is required above a permanent natural barrier to demonstrate fish presence/absence in determining location of F/N break, if the proponent is not using default physical criteria or some other method.

Recommendation: Streams that meet the default physical criteria for presumed fish presence above a natural barrier should be treated as Type F streams unless fish “absence” is demonstrated or a water type modification form is submitted.

Recommendation: If fish are detected above the PNB, caution should be exercised above PNB to avoid potential impacts to small isolated populations.

(3) What Generally Describes a Permanent Natural Barrier?

<u>Group could not come to a consensus recommendation on this issue.</u>

Recommendation: Create guidance on how to describe what constitutes a "permanent natural barrier" using multiple criteria (e.g. permanence of feature, gradient changes, vertical drop, grade, length, stream size, formative feature, confinement, plunge pool depth, etc.).

- A 20% gradient alone or a channel less than 2 feet width at bankfull does not constitute a permanent natural barrier that leads to a miss application of the process resulting in the termination of surveys and possible miss identification of the F/N break.

(4) A temporary natural blockage alone is not a feature that can be used to establish F/N break.

Recommendation: A temporary natural blockage alone should not be a feature that is used to establish F/N break (*e.g. beaver dams, debris steps, wood, etc.)*.

(5) Use of Protocol Surveys above Man-made Barriers.

<u>Group could not come to a consensus recommendation on this issue. Minority opinion: Upstream from man-made barriers default physical criteria should be used to determine the extent of fish habitat. Protocol surveys should not be performed above a man-made barrier without prior consultation with DNR, WDFW, and affected tribes.</u>

Recommendation: Proponent should document how their proposed F/N break encompasses the full extent of fish habitat, and how protocol survey data were included in their decision. The distribution of fish above man-made barriers may not reflect the full extent of fish habitat in absence of the barrier. Presence of a man-made barrier alone is not sufficient to establish location of the F/N break. Consultation with DNR, WDFW, and affected tribes may be helpful in clarifying necessary information to be used in establishing the F/N break.

(6) Habitat disturbances (e.g., debris flow influenced) or Habitat Degradation.

Recommendation: Proponent should document how their proposed F/N break encompasses the full extent of fish habitat, and how protocol survey data were included in their decision. The distribution of fish in disturbed or degraded habitats may not reflect the full extent of fish habitat. Consultation with DNR, WDFW, and affected tribes may be helpful in clarifying necessary information to be used in establishing the F/N break.

- When there is evidence of stream disturbance that might affect the ability to detect fish as well as determine the appropriate F/N break, the proponent can default to physical criteria for determining the upper extent of fish habitat or request ID team review. Without ID Team intervention the proponent should provide documentation including:
    - A description of the disturbance, including length of stream, how stream habitat has been modified (aggradation, subsurface flows, isolated pools, loss of gravel, increased sediment, scouring to bedrock, etc.).
    - How the disturbance factors might affect results (utility) of a fish survey.

- How the disturbance factor, might affect the uppermost extent of fish distribution or habitat in the stream system (e.g., relative density and/or condition of fish populations downstream of disturbance, temporary barriers (exposed bedrock features, temporary wood jams or subsurface flows, etc.), loss of spawning gravels, buried pools, etc.

(7) Drought

- Recommendation: Keep existing BM language (under Part 2 of BM13 "Drought Conditions and other Factors Affecting Population Distribution") and add – Proponent to supply rationale on why the proposed F/N break is appropriate given stream flow at time of survey. Recommend that a standalone section is created within the Board Manual dealing with drought.
- Drought should not affect the placement of the F/N break.
- Pre-consultation is recommended prior to conducting a protocol survey during a declared drought.
- Recommend review appropriate stream flow metrics as it relates to this topic (e.g., review 75% is currently applied by Ecology – more science is required)
- During a declared drought season, before the proponent considers conducting protocol surveys on any streams, they should check the current status of the specific stream using the appropriate website link (to be determined).
- If the basin or sub-basin is subject to drought the proponent can default to physical criteria or, if conducting a protocol survey, provide justification that the determination of the F/N break was not affected by the drought or a proponent describe how the drought conditions influenced the effectiveness of the survey method used and the placement of the F/N break.
- Permanent changes to the hydro-layer that include electrofishing conducted in a basin subject to drought are less likely to be approved unless the protocol survey provides clear and convincing justification as to how the distribution of fish or ability for the protocol survey to detect fish and their identification of the upper extent of fish habitat was not affected by drought. The concern is that drought-influenced protocol surveys may indicate that the upper extent of fish use is lower in the stream system than it would be under "normal" flows, resulting in under-representation of Type F waters.

(8) Role of Electrofishing for informing the end of Fish Habitat

Recommendation: Clarify guidance on how electrofishing informs the F/N break.

- Electrofishing results provide data specific to species and location of the last fish detected during a single survey. Information on the last detected fish provides a useful starting point to inform the placement of the F/N break.

(9) Using Gradient to End Protocol Survey.

Recommendation: Require proponent to provide rationale on use of gradient change to determine end of survey point.

- A 20% gradient alone does not constitute a stopping point of a protocol survey. Proponent will need to provide rationale that the gradient either remains at 20% or greater or that the habitat conditions upstream do not support fish life.
- Proponent should provide information on changes in gradient and distance over which it occurred.

Recommendation: Define what “remains 20%” means in terms of survey effort and the determination of the F/N break. Group proposes that “remains” means to “channel head”.

(10) Using Dry Stream Reaches Inappropriately to End Protocol Surveys and establish the F/N break.

- Recommendation: Protocol survey requirements and application of default physical criteria still apply regardless of the presence of flowing water
- The absence of flowing water, alone, should not be used to justify the F/N Break.
- Segments upstream of intermittent flow that meet the default physical criteria should be investigated for isolated fish populations and perched fish habitat

(11) Provide guidance on how to identify F/N break when reach edge of property ownership prior to end of survey, lack of access, etc.

Recommendation: Provide guidance on how to type waters when proponent reaches edge of property ownership prior to end of survey, lack of access, etc.

- Map layer needed that identifies current known distribution of fish within a stream. Data from a variety of sources could be used to develop layer. Need to identify keeper of data and how data provided. Water type data base should incorporate a criterion/symbology for a code to indicate the basis for the determination of the upper extent of fish habitat or fish distribution Recommendation: Consultation with DNR, WDFW, Ecology and affected Tribes is recommended. Alternatively, proponent may use default physical criteria.

(12) What’s missing - how to provide guidance on criteria that helps identify habitat that is “likely to be used by fish”

Require proponent to provide adequate rationale for why the F/N break was established where it was. Provide rationale for why stream segments above the proposed F/N break are not likely to be used by fish at any life stage at any time of the year, including habitat which could be recovered by restoration or management. (per 222-16-010)

Recommendation: Provide a definition of “likely to be used”.

Recommendation: Provide better documentation on what is meant by “recoverable habitat” in -010.

- Include water quality parameters to help define/determine fish habitat.

KEY: How to find it in the field not in the rule.

(13) What is the definition of “Defined Channel”?

Recommendation: Clarify definition of defined channel within the bank full width.

Recommendation: Rectify the differences/disconnect between the rule language, Board Manual, and Definition (-010). “Defined channel inside the Bankfull width, defined channel, bankfull width, etc.

Recommendation: Provide clarification and guidance on whether “connection” should be used instead of “defined” or “undefined” channel when determining water type.

(14) Survey Timing for Streams

Recommendation: Based on practitioner experience, no “perfect window” exists and the current window as defined by Board Manual 13 (March 1-July 15) is appropriate in most cases for western Washington.

Recommendation: Review science to determine if a shift/alternative timing for eastside surveys is necessary.

(15) Pre-survey Meetings and Notifications

Recommendation: Keep existing Board Manual 13 language (last sentence Part 3 ”Due to the complexities in anticipating when fish will be seasonally active, survey timing should be determined in consultation with WDFW and affected tribes prior to conducting a survey”).

Recommendation: Provide clarity that the need for pre-survey consultation applies to all proponents and reviewers regardless of stream size.

(16) Improve Documentation and Record Keeping

Recommendation: Identifying a clearing house for fish distribution data and fund this activity at WDFW.

- Create a widely available database of known fish distributions. If changes to stream location or water types are proposed and accepted for a FPA those changes should be reflected in a centralized GIS database to prevent unnecessary surveys. WDFW becomes holder of fish distribution data,
- have data submitted in a required format,
- should be a funded activity - currently is not,
- verified and non-verified data could be included,
- all of this would result in another tool that could be used in conjunction with the various other tools, and
- include fish presence data in FPAs)

Recommendation: Proponent contact DNR Forest Practices forester for help in determining if previously approved water type forms exist for the stream/basin of interest.

Recommendation: Improve the water type modification form (e.g., to include values and not check boxes such as bankfull measurements rather than a single value). Fish presence data from FPAs worksheet is captured and incorporated into a yet to be specified data base. This does not include the designation of waters as type F in an FPA based on default physical criteria.

Recommendation: Look into development of a single clearing house for data on anthropogenic and natural barriers that would be available to proponents.

(17) Training and Certification

Recommendation: Training with certification for water typing should be made available.

- A demonstrated level (TBD) of expertise may be substituted for training.
- Training and certification should be available for reviewers as well as surveyors.

(18) Using Gradient to Designate F/N Break. (<u>Group did not fully discuss and come to agreement on the language provided here</u>)

Recommendation: Require proponent to provide rationale on - if or how their interpretation of existing grade break was used in the determination of F/N break.

- *Gradient alone (e.g., a completed protocol survey) does not constitute a permanent natural barrier.*

Recommendation: Define what “remains 20%” means in terms of survey effort and the determination of F/N break.

Conclusion

Several proposals were discussed by the TWG at their final meeting on October 3, 2016 that seek to provide guidance in establishing the extent of fish habitat (F/N Break). These proposals fall into general categories of modeling, default physical criteria, and a habitat based assessment (geomorphology and biological indicators) to determine the F/N Break. The three proposals are described below.

Water Type Model: Results of the pilot LiDAR water typing project suggest that modeling could be a viable tool in establishing the F/N Break. Further work is necessary and a path forward has been presented to TFW Policy for consideration.

Default Physical Criteria: A proposal was made to use the default physical criteria as a basis for identifying the extent of fish habitat. The proposal is to use default physical criteria until a permanent natural barrier (PNB) is encountered, at which point the barrier is documented and described. At that point, a protocol electrofishing survey would be initiated. If a fish were found, then use default physicals until the next PNB, at which point the protocol repeats itself. This approach requires developing defensible definitions of PNBs. Part of this proposal would include an element of consultation to consider if there are specific circumstances that preclude fish from utilizing the extent of habitat identified by the default physical criteria.

Habitat Assessment Method: This method requires the proponent to evaluate the following elements into a proposal in establishment of the F/N break. The following items would be included in each proposal and would help the proponent and review team communicate on specific topics necessary for approval.

1. Describe what is known about fish use in proximity to the proposed F/N break.
2. Explain how fish species occurrence and abundance was used in the proposed location of the F/N break.
3. How did you consider the morphology of the stream in establishing the location of the proposed F/N break?
4. How did you consider stream gradient in establishing the location of the proposed F/N break?
5. How did stream size influence the location of the proposed F/N break?
6. Describe the role of basin size, bankfull width, and bankfull depth in identifying the location of the proposed F/N break.
7. What role did channel confinement play in the location of the proposed F/N break?
8. How did connectivity to habitat downstream influence the location of the proposed F/N break?
9. How was perched habitat considered in the proposed location of the F/N break?
10. Did substrate effect the proposed location of the F/N break? If so, how?
11. Was channel complexity considered in the determination of the F/N break?
12. Was pool frequency a factor used in the location of the proposed break? If so, how?
13. How did you consider water quality in the proposed location of the F/N break?
14. How did the current flow regime influence the proposed F/N break?
15. How were biotic factors (e.g., primary productivity, vegetation, presence of other species) considered in the proposed F/N break?
16. How did disturbance (e.g., landslides, debris flows, channel head-cutting) influence the location of the F/N break?
17. How did the presence of barriers and blockages (natural and anthropogenic) influence your proposed F/N break?
18. How did you consider fish habitat that may be recoverable in the proposed location of the F/N break?

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