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MEMORANDUM

July 26, 2017

TO: Forest Practices Board

FROM: Hans Berge, Adaptive Management Program Administrator

SUBJECT: Recommendations for criteria to establish Potential Habitat Breaks in the Fish Habitat Assessment Method

The Board's motion on 10 May 2017 directed me to work with a group of internal and external technical team to evaluate criteria to be used as potential habitat breaks (PHBs) in the fish habitat assessment methodology (FHAM) as part of the water typing system. In response, I was able to form a strong panel of scientists representing decades of experience in fish habitat relationships along with some biometricians that are very skilled in data analysis. In addition, technical representatives from Forests and Fish caucuses participated and shared important perspectives and insights into the challenges of water tying in the current system.

The attached report represents a lot of work in a very short amount of time and includes recommendations for your consideration with criteria for gradient, stream size, and barriers. These recommendations are based upon data analysis, scientific publications, and personal experience.

The most important challenge for this project was collating existing data. Several caucuses provided data including DNR (GIS data and CMER research), Conservation Caucus, Industrial Forest Landowners (through WFPA), and eastside tribes (UCUT and Kalispel). As you can imagine the data were collected for different purposes and the methods and metadata didn't necessary line up as one would hope. This limited the data that we were able to look at from a purely technical standpoint and those decisions are included in table in the attached report. Ultimately, we were able to use approximately 1,500 data points provided from concurred water typing modifications that had the full set of data needed for evaluations of gradient, size, the interaction between gradient and size, and barriers. We looked for data on the secondary features considered by Policy, but those data were not available.

Peer-reviewed and gray literature were sought for consideration of PHBs. In the attached report you will see what we felt were the most relevant for this exercise, but you'll notice there aren't a lot of studies focused on this type of research. The lack of information, combined with some of the shortcomings in the data used for this analysis highlights the importance of following through on the amendment offered at the May Board meeting to conduct a study to validate PHB criteria.

The expertise of the Panel was most crucial in analyzing the results of the data analysis, considering the relevant literature, and most importantly using experience to interpret the results. After careful consideration and extensive discussion, the Panel recommends that the PHB criteria used for the FHAM include:

1. A change in gradient greater than or equal to 5%
2. A reduction in bankfull width greater than or equal to 30%
3. A barrier gradient over 20% and elevation change over barrier length is greater than the upstream bankfull width.

It is also recommended that the criteria be considered only until a study can be used to validate or develop criteria with greater confidence.

In the report you will see tables (Tables 3 and 4) that highlight tradeoffs between different criteria considered in this analysis. Those comparisons are based on the same dataset and can be compared directly to other alternatives in the tables (e.g., default physical criteria) for your consideration.

If you have any questions or comments about the report or the process, please feel free to contact me via e-mail hans.berge@dnr.wa.gov or 360-902-1909.

Review and recommendations for potential fish habitat breaks to begin protocol surveys to determine end of fish habitat on state and private forest lands in Washington State

Report for the Forest Practices Board

July 27, 2017

Submitted by
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Introduction

The Washington State Forest Practices Rules establish standards for timber harvest and associated activities. The Forest Practices Board (Board) is responsible for rule-making and overseeing the implementation of Forest Practice Rules. The rules are intended to use the best available science to protect fish habitat during timber harvesting operations. The effectiveness of these rules is under review by the Adaptive Management Program (AMP) of the Washington Department of Natural Resources.

Water typing is an important part of applying contemporary forest practice rules since prescriptions in riparian areas of Type F (fish bearing) are different than those adjacent to Type N (non-fish bearing) waters. The definition for fish habitat is defined in WAC 222-16-010 as "…habitat, which is used by fish at any life stage at any time of the year including potential habitat likely to be used by fish, which could be recovered by restoration or management and includes off-channel habitat." Under the "interim" water typing rule (WAC 222-010-031) the practice used to delineate Type F waters has involved the use of either default physical criteria (e.g., 2 feet defined channel within the bankfull width and greater than 20 percent slope) or protocol surveys (e.g., electrofishing) as described in Board Manual Section 13 (http://file.dnr.wa.gov/publications/fp_board_manual_section13.pdf). The result of these surveys has been the development of a water typing map to identify regulatory breaks statewide to apply appropriate forest practice rules (can be found here: http://www.dnr.wa.gov/forest-practices-water-typing).

Establishing a permanent water typing rule has been a priority of the Board since the adoption of the "interim" rule in 2001. In February 2014, the Board was presented with positions for a path forward in establishing a permanent water typing rule by the Timber, Fish and Wildlife Policy Committee (Policy). At that time the Board directed Policy to work on three specific topics where there was tension around a permanent rule. These included: 1) electrofishing, 2) a LiDAR based model, and 3) 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.

After progress was made on off-channel habitat, protocol survey electrofishing, and the LiDAR based model, Policy focused on the water typing protocol itself. While it has been recognized that significant progress has been made to incorporate habitat likely to be used by fish upstream of the last identified fish in a protocol survey, greater specificity is needed to apply criteria consistently across State and private timber lands in Washington. One key issue has been the development of a highly-accurate permanent water typing system that minimizes risk, balances remaining uncertainty and meets overall Forests and Fish Report water typing objectives.

In response, the Forests and Fish caucuses submitted recommendations for the development of a Fish Habitat Assessment Method (FHAM) to be included in the permanent water typing rule that would capture fish habitat as defined in WAC 222-16-010. The intent of the FHAM is to determine the extent of potential or restorable fish habitat and provide a repeatable and enforceable method in determining a specific physical point or feature that captures the end of fish habitat otherwise referred to as the regulatory type break. In May 2017, Policy recommended the Board adopt the FHAM and work on developing specific criteria for potential habitat breaks (PHBs) to be used in the FHAM. The Board accepted the recommendation in May 2017, and directed the AMP Administrator to assemble group of topical experts to recommend PHB criteria to the Board at their 9 August 2017 meeting. The motion from the Board is as follows: "…determine those elements that would constitute a barrier and/or PHB…determine those physical, biological, and chemical elements that would individually or in combination constitute a high probability the PHB is coincident with a significant change in habitat including stream size, stream gradient, the interaction of size and gradient and the presence of barriers that limit accessibility, thus the appropriate point to initiate a protocol [electrofishing] survey".

Potential Habitat Break (PHB) Criteria identification

In June, a group of experts (Panel) in fisheries biology, geomorphology, fish habitat relationships in the forested environment, and water typing was assembled to accomplish the Board's motion and develop recommendations for the definition of PHB. In addition, a technical committee of stakeholder representatives was invited to participate in making recommendations to the Panel and review draft recommendations prior to the report being submitted to the Board. A charter was created to guide their work in making progress on PHB criteria in approximately six weeks (Appendix I).

The members of the Panel include Hans Berge, Pete Bisson, Brian Fransen, Jeff Kershner, Joe Maroney, Phil Roni, Kai Ross, Ray Timm, and Pat Trotter. Additional support provided by Kevin Ceder, Heather Gibbs and Howard Haemmerle.

Stakeholder representatives include Jerry Big Eagle, Chris Conklin, Jamie Glasgow, Marc Gauthier, Debbie Kay, Derek Marks, Don Nauer, Claudine Reynolds, Jason Walter, and Sarah Zaniewski.

Data collation and filtering

To assist with determining PHB protocols, multiple data sets were provided by the caucuses and DNR that included information on the end of fish habitat (EFH). Most of the data were collected to determine, verify, or modify DNR's mapped water typing classifications, and contained descriptions of the uppermost fish (UF) and EFH points. The data were contributed from multiple sources including landowners, state agencies, tribes, environmental programs, and other sources and contained a variety of measurements used to characterize these points (Table 1). Geographically most of the data sets were from Western Washington (Figure 1). Since these data were not collected specifically for the purposes of our analysis, it was critical to analyze each data set to determine whether the data could be used to determine PHB and what types of analysis the data could support. After a careful review of the data, the scientific panel recommended a core set of factors to analyze including gradient, width, the interaction between the two and the presence of barriers. It should be noted that we required electronic data sets that were available as of July 20, 2017. There are potentially thousands of other water type modifications that are available only in pdf format that could not be used for analysis because of the time constraints required to complete the analysis.

Criteria for data analysis

All data sets in the analysis included measures of stream size and gradient. Additionally, since we were looking for changes in habitat conditions that could potentially signal a habitat break, we needed measurements of width and gradient both up- and downstream from the EFH point to characterize the change occurring at the point. Based on these requirements, only the data provided by the Washington Forest Protection Association representing data from their member companies (Landowner data) that submit water type modification forms to DNR met these criteria. The data set also contains information on the last fish point, the primary habitat change factor (PHCF), and detailed information about barriers. Moreover, the data set contains 1560 data points, has broad coverage across western Washington, and has data in each of the four major Western Washington ecoregions (Figure 1). None of the other data sets contained measurements of up- and downstream widths (Table 1) and thus could not be used in this exercise. It should be noted that the Landowner data set has a number of limitations including but not limited to geographic coverage, land ownership, and like all the other data sets, it was not collected for the express purpose of our analysis. It does represent the only electronic data we had as of July 20, 2017, to examine different PHB criteria.

Potential Habitat Breaks (PHB) Criteria Considered

For PHB criteria to be useful, they should be simple to understand and measure, avoid having to use subjective judgment wherever possible, accurately reflect boundaries to potential fish habitat likely to be used, and be repeatable in the field. We assume that PHBS apply to all fishes; however, there is little information on the life history, swimming performance and ability to pass obstacles of non-salmonid fishes. Salmonids comprise the uppermost species in many watersheds (Fransen et al. 2003; Cole et al. 2006) and more is known about their life histories, swimming performance, ability to pass obstacles to upstream movement, and habitat preferences than other stream-dwelling fishes. Therefore, the initial criteria for setting numerical thresholds for PHBs is based on the ecology and behavior of salmon (*Oncorhynchus spp.*), trout (*O. spp.*), and chars (*Salvelinus spp.*) with the assumption that criteria for these species would be protective of non-salmonids. Differences do exist between the performance capabilities of various salmonid species but those differences are not great, especially when involving small fish in small streams.

We considered a variety of potential PHB attributes, including the physical features of a stream channel, water quality and quantity parameters, and other potential factors that might contribute to measurable habitat breaks. These attributes were evaluated in terms of their simplicity, objectivity, accuracy, and repeatability in the field, as well as the amount and relevance of existing scientific literature pertaining to each attribute. We concluded that it is possible to identify PHBs based on <u>stream size</u>, <u>channel gradient</u>, and <u>permanent natural barriers</u>. These three attributes satisfied the objectives of simplicity, objectivity, accuracy, and repeatability, can be consistently identified in the field, and could be incorporated into a practical survey protocol. Below we summarize the available scientific literature on these three attributes. This was used to help inform the different combinations of PHB criteria proposed and tested by the Panel.

It should be noted that there are some obvious differences in climate, geology, stream flow, fish distribution and fish species in Eastern and Western Washington. Most notably the stream flow, size, and elevation of forested streams are very different between the two areas of the state. While there may be differences in PHB based on ecoregion, we were unable to evaluate those potential differences due to a limited dataset from the eastern part of the state.

Stream Size

Streams become too small for fish use when they become too narrow, too shallow (or both), for fish to carry out basic life history functions such as respiration and feeding. Feeding area is especially important because salmonids are drift-feeders and need an area large enough to provide sufficient foraging opportunities. Streams that are so small and shallow that respiratory impairment occurs would be unlikely to hold fish unless fish were stranded. In addition, stream channels must possess some type of cover (cobbles, undercut banks, large wood) to provide hiding protection from predators.

The interim rules state that the critical threshold for stream size is 2-ft. and 3-ft. bankfull width for Western and Eastern Washington, respectively (i.e., streams less than 2-ft. or 3-ft wide would be unlikely to support fish use). We are not aware of any data which clearly show that a 2-ft. bankfull channel width threshold, in the absence of other criteria such as channel gradient or pool frequency, accurately reflects the boundary of fish distribution in Washington State streams. Fransen et al. (1998) examined flow and last fish distribution in headwaters streams in Western Washington and suggested that a mean annual flow of 1 cfs. was the threshold for fish bearing and non-fish bearing waters. For some salmonids, small streams may be preferred rearing environments. Rosenfeld et al. (2011) found that cutthroat trout (*O. clarki*) and coho salmon (*O. kisutch*) achieved their highest densities in streams less than 5 m wide in a survey of small streams in coastal British Columbia. Upstream of the anadromous zone, in the uppermost headwaters, fish densities decrease to the point that density-independent factors, not density-dependent factors, govern life history traits such as recruitment, growth and survival (Elliott 1989a, b; 1993; 1994). There is also research, some quite recent using advanced DNA sequencebased methods, showing that strong selection pressures are at work on uppermost fishes, selecting for traits that favor persistence in these environments and against migrations downstream (Northcote et al. 1970; Elliott 1989a, b; 1993; 1994; Whiteley et al. 2017).

In a comparison of the uppermost limit of fish in 58 logged and unlogged watersheds in the western Cascade Mountains, Latterell et al. (2003) found that lack of pools – an indication of shallowness – and decreasing channel width exerted a strong influence over fish absence. They stated (p. 1012) "The likelihood of trout presence declined with increasing channel gradient, decreased pool abundance, and decreased channel width across all sites combined… though trout presence was not related to channel width in unlogged sites." The bankfull width at the limit of trout distribution in the study ranged from 2-16 meters in watersheds with a history of logging, where both pool frequency and residual pool depth ranged over about an order of magnitude at the limit of fish distribution. This study illustrates that, in absolute numbers, the boundary physical conditions between streams capable of supporting fish and streams too small to support fish can be highly variable. However, Latterell et al. (2003) found that incorporating stream size and gradient into a regression-based model produced a tool capable of predicting fish presence or absence in headwater streams.

Abrupt changes in stream size are frequently associated with the upper extent of fish occurrence, often in the absence of other observed influences. Cooperative Monitoring, Evaluation, and Research (CMER) research in eastern Washington identified the upper extent of fish use and a low likelihood of upstream fish use seasonally where small lateral tributary streams intersected larger fish-bearing stream reaches (Cupp 2002; Cole and Lemke 2006; Cole et al. 2006). CMER-sponsored research in western Washington demonstrated high agreement between modeled estimates and field verified measurements of fish occurrence at stream junctions where abrupt changes in stream size occurred (Cupp 2005).

Channel Gradient

Excessive water velocities are a common factor in locating PHBs in small streams. Habitable channels must possess areas where the current will permit fish to hold without being displaced downstream, and if no microhabitats with suitable velocities occur fish will be absent. Sustainable swimming speed is generally a function of body length. Small trout can swim proportionately faster than large fish on a sustained basis relative to body length (Hawkins and

Quinn 1995). The burst speed — the maximum speed a fish can swim for a few seconds — is a function of body length as well and is much higher than the sustained speed. If the water velocity across the entire channel exceeds the physiological capabilities of fish to hold a position or move upstream, a potential habitat break is present. Most information on the relationship between current velocity and salmonid swimming ability was derived from laboratory experimentation, in which fish were held in flumes or tubes with controlled flow rates and little or no turbulence.

The scientific literature suggests that for salmonids ranging in size from 80-140 mm (a typical range for yearling and older salmonids in small streams), sustained swimming can occur at locations where water velocities do not exceed approximately 30 cm/second or about 1 ft./second (Beamish 1978; Bjornn and Reiser 1991). In a laboratory study, MacNutt et al. (2004) demonstrated that upper sustained swimming speeds of cutthroat trout ranged from 3-5 body lengths per second, which corresponds to a 30-50 cm/second current velocity for a 100-mm trout. However, these authors used hatchery trout with body lengths of approximately 300 mm in their study and smaller fish would have been expected to tolerate somewhat lower critical velocities. The burst speed of salmonids of the size range of 80-140 mm is much higher than their sustained speed.

The gradient of a channel is typically a limiting factor for upstream movement of by fish where water velocities are too high and there are no resting habitats. Measuring current speed at all points in a stream reach is not practical and therefore channel gradient is used as a surrogate for the water velocity to which fish are exposed. Latterell et al. (2003) found that channel gradients downstream from the last cutthroat trout in western Washington streams ranged from 1-22%, while gradients upstream from the last fish ranged from 6-37%. As with stream size, these results indicate that the threshold for a PHB based on a single attribute such as gradient is highly variable. Microhabitats suitable for fish occupancy can occur in hydraulically complex steep channels, while streams with somewhat lower gradients but simpler hydraulics may not support fish if suitable rearing velocities are absent from the reach.

Channel roughness exerts a strong influence on the distribution of velocities, with streams possessing abundant roughness elements such as cobbles and boulders providing sites favorable for trout occupancy, while streams without such roughness elements (e.g., bedrock dominated channels) provide few if any holding areas. Establishing a fixed gradient threshold for

PHBs without knowledge of channel roughness can be problematic. Nevertheless, stream gradient was found by Latterell et al. (2003) to be the most important stream attribute in setting the upstream distribution limit of cutthroat trout, and gradient change featured prominently in a logistic regression model developed by Fransen et al. (2006) for predicting the upstream limit of fish in Washington State. It was also an important controlling variable in our analysis of available data and was considered a useful indicator of current velocity and likely fish use.

Permanent Natural Barriers

The ability of fishes to pass obstacles to upstream migration is associated with their swimming and leaping abilities. Swimming abilities of fishes are usually described in terms of three categories of speed (Watts 1974; Beamish 1978; Bell 1991; Hammer 1995; and many others):

- *Cruising speed* is the speed a fish can sustain essentially indefinitely without fatigue or stress, usually 2–4 body lengths per second for salmonids. This is the speed level used during normal migration or movements through gentle currents or low gradient reaches.
- *Prolonged speed* (sometimes called *sustained speed*) is the speed a fish can maintain for a period of several minutes but usually less than 1 hour before fatiguing, typically 4–7 body lengths per second for salmonids (Bell 1991). This is the speed used when confronted with more robust currents or moderate gradients.
- *Burst speed* is a speed a fish can maintain for only a few seconds without fatigue, typically 8–12 body lengths per second for salmonids, but as high as 14 body lengths per second for adult cutthroat trout. Fish accelerate to burst speed when necessary to ascend the short, swiftest, steepest sections of a stream and to leap obstacles. They also use burst swimming to escape predators and capture prey.

Swimming abilities are influenced by water temperature and by the condition of the fish. Swimming ability generally increases with water temperature up to about the point where the physiological tolerance is exceeded—around 22-23 °C [72-73 °F] for most salmonids—and then falls off very rapidly. The better the condition of the fish, the more powerful its swimming performance. Swimming ability is also influenced by the inherited body form of the fish. Juvenile coho salmon have a deep, laterally compressed body form with large median fin area, which is well suited for burst swimming performance but not so good for cruising or prolonged swimming (Taylor and McPhail 1985). Small coastal cutthroat trout typical of uppermost headwater-resident populations have a more fusiform and streamlined body form with smaller median fin area (Bisson et al. 1988) which makes them better than juvenile coho at cruising and prolonged speed when compared size-for-size, but somewhat poorer than juvenile coho in burst swimming ability. Hawkins and Quinn (1996) found that juvenile coastal cutthroat trout were also poorer in burst swimming ability than juvenile steelhead (*O. mykiss*).

When leaping obstacles, fish come out of the water at burst velocity and move in a parabolic trajectory (Powers and Orsborn 1985). Leaping ability also depends on the fish having sufficient water depth at the point of takeoff to enable them to reach burst velocity. One laboratory study suggested that a water depth at least 1.25 times the height of the obstacle was needed for successful jumping (Stuart 1962). More recently, however, Kondrateiff and Myrick (2006) reported that small brook trout (size range 100-150 mm) (*S. fontinalis*) could jump vertical waterfalls as high as 4.7 times their body length from plunge pools only 0.78 times the depth of the obstacle height, and larger brook trout (size ranges 150-200 mm and 200 mm+) could jump waterfalls 3 to 4 times their body length in height if the plunge pool depth was at least 0.54 times the depth of the obstacle height. It seems likely that under the same conditions as Kondrateiff and Myrick's brook trout were tested, the small trout of other species could perform at least as well.

Using the parabola equation of Orsborn and Powers (1985) for leap height, we estimated upstream passage possibility for juvenile coho and cutthroat trout encountering a vertical drop (Table 2). For the juvenile coho, three body lengths were used: 60 mm, 85 mm, and 110 mm (all fork lengths, FL), which span the range of sizes typically attained by sub-yearling coho from mid-June through November. For juvenile coho salmon in this size range, even a 1-ft. vertical drop, if completely spanning the stream, would be a barrier to upstream movement.

For cutthroat trout, a larger size range was used: 80 mm to 160 mm in 20 mm increments (also FL) to encompass the sizes of trout most often encountered in the uppermost parts of the drainage network. Since juvenile coho body shape is more favorable for burst swimming performance, we chose the high end of the typical burst speed range (12 body lengths/sec) for this species. For the more fusiform shape of the cutthroat trout, we chose the mid-point of the burst speed range (10 body lengths/sec). Three leap angles were used in the simulations: 40, 60, and 80 degrees. This analysis suggests that even the largest cutthroat trout would have difficulty passing a

1-ft. vertical obstacle (Table 2). The values shown in the table are certainly not close to the 4.7 body length leap heights reported by Kondratieff and Myrick (2006) for their smallest-size brook trout, suggesting that the vertical barrier criteria established in laboratory studies are not very accurate when predicting barriers in the field. While Kondrateiff and Myrick (2006) did not report burst speeds, back calculation of a burst speed from their data and applying that to the 80 degree jump angle equation of Orsborn and Powers (1985), suggests a leap height of 2.6 ft. for a 150mm (6 in) cutthroat trout.

Barriers represent an extreme case of velocity gradients. For small salmonids (<140 mm, 5.5 in) we speculate that a vertical waterfall of 2.5 ft. is often sufficient to block upstream movement, while cascades or chutes greater than 25% gradient and 10 ft. long usually exceed burst swimming abilities. Furthermore, a pool of sufficient depth must be present at the base of the falls for fish to attain sufficient jumping speed to achieve successful jump height. We emphasize that these values are highly speculative and are based on a combination of laboratory and field investigations. Further research on barriers in small streams is warranted.

Seasonal flow changes can affect the ability of channel attributes to block upstream fish movement. In general, fish undertake directed movements in response to life cycle needs (e.g., reproduction) or to travel to feeding or wintering habitats (Northcote 1978). It is also possible that fish may move upstream in small streams to reach cooler water during warm summer months. Movements often occur at intermediate flows that happen when the stream hydrograph is rising or falling. Stream-dwelling salmonids tend to avoid long-range (> 0.5 km) upstream movements when flows are very high or very low.

Determining that an obstacle in a stream represents a barrier can lead to error when surveys are conducted during extreme base flow conditions. At intermediate flows, water depth is greater and conditions for passage can be more favorable. Higher flows can also inundate areas along the edge of the stream that may offer passage without having to jump the falls or negotiate a cascade. For this reason, care should be exercised before classifying an obstacle as a barrier without some estimation of how the stream would appear at intermediate flow conditions.

Exploratory Analysis and Results

After examining the scientific literature, the Panel discussed several options for potential criteria for gradient, width and barriers to identify a PHB during protocol surveys. We first focused on criteria for channel gradient and width, and investigated whether simple thresholds (e.g. > 20% gradient or < 2 ft. bankfull width) or inflection points where gradient or channel width changed abruptly were useful. We discussed several options including default thresholds, different combinations of thresholds, minimum channel widths, and different combinations of ratio or differences of upstream and downstream gradient and upstream and downstream channel width including criteria and applied in CMER research (Cupp 2002; difference in channel width of 30% or more, and a difference in gradient of 5% or more).

To assist with determining the feasibility of different criteria, we used the landowner data set to explore changes in gradient and size that occur at surveyed end of fish habitat points. The data was subset into points that had their EFH points attributed to a change in size and/or gradient as opposed to the points where the EFH was determined by a potential barrier. The panel examined frequency distributions of upstream and downstream measurements, as well as the upstream to downstream ratios and differences for both gradient and channel width (Figures 3 and 4). In these analyses, we observed expected differences between upstream and downstream stream width (smaller channels upstream) and gradients (steeper upstream), and looked into whether differences (upstream - downstream values) or ratios (upstream/downstream values) were most informative in describing the Type F/N regulatory break. In addition to frequency distributions, scatter plots of gradient and width metrics were also employed to examine the interaction between the two metrics, and to visualize where proposed thresholds may occur within the data for further analysis. For example, Figure 5 shows default physical thresholds of greater than 20% gradient and/or channel with less than 2 feet wide.

To assess potential PHB definitions, the landowner data set was used to test the number of surveyed EFH points that would be considered PHBs by a proposed PHB definition. Surveyed data points that do not fall within a proposed PHB definition represents a measure of Type II error: points where the proposed PHB definition fails to capture a surveyed habitat break (false negatives).

The Landowner provided data set contains physical habitat measurements for both the uppermost fish (UF) point, as well as the EFH point. These points are representative of the concurred with Type F/N regulatory breaks. Streams where the UF and EFH points are not coincident are where the concurred point is upstream of the location of the UF and representative of the EFH. This implies that at some point in the concurrence process the habitat change at the

UF point was not a meaningful habitat break. Testing the number of these non-habitat break (NHB) points that a proposed definition would consider a PHB represents a measure of Type I error: a point along the stream classified as a PHB when it is, in fact, not a PHB (false positives). Being able to quantify measures of both Type I and Type II error (failing to classify a point on a stream as a PHB when, in fact, it is a PHB--i.e., a false negative error) is critical to analyzing the trade-offs between different PHB definitions and threshold values. Minimizing one or the other is trivial, the difficulty is finding a balance between the conflicting goals. For example, Figure 6 shows proposed criteria on difference in gradient, and the upstream to downstream ratio. EFH points that do not fall past either threshold represent false negatives (Type II error), and NHB points that fall past the thresholds represent false positives (Type I error). One thing that became clear from the data is that a break is a PHB if it meets either criterion (Figure 5), as less than ¼ of the points meet both criteria, but most points meet either the gradient or the width criteria.

Barriers were analyzed through a similar process. Surveyed points where the EFH was caused by the presence of a barrier feature were used to test proposed definitions, and like above, the number of surveyed barriers causing EFH breaks that were not defined as a PHB by a proposed definition represent a measure of Type II error (false negatives). However, unlike size and gradient, there were no data that could be used to generate measures of false-positives for the barrier points. Therefore, more weight was placed on literature review and expert opinion to assess the tradeoffs between proposed definitions.

The summary results for multiple tested PHB definitions and thresholds are shown in Tables 3 (Habitat thresholds) and Table 4 (Non-vertical Barrier definitions). These suggest that, based on available data, a difference in gradient of 5% or a change in channel width of 30%, which were originally proposed by the Timber Fish and Wildlife Habitat Typing Committee in 1999, performed best in terms of Type I and Type II error. Simple thresholds of gradient of 15% and a width of 3ft had a similar level of Type II error, but had nearly double the type I error. We were concerned that the 5% difference in gradient might work better in steep rather than low gradient channels. However, it appears that, that applying it solely to channels with a downstream gradient steeper than 5% provides similar results and does not greatly improve the performance (Table 3).

The analysis of barrier data was less clear than for gradient and width, but for non-vertical barriers (i.e., waterfalls) the panel thought it was crucial for the definition to scale by stream size. This is also consistent with typical habitat survey procedures (e.g., residual pool depth, habitat unit definition). Moreover, comparing definitions that include stream size to simple upstream thresholds shows a strong increase in the number of captured EFH points caused by barriers.

Recommendations for Interim PHB Criteria

Based on the literature, examination of the performance of the metrics using the available data and professional opinion, we propose the following as interim PHB criteria:

A Potential Habitat Break will be identified at a point along a stream channel where one or more of these changes in stream character is identified:

- a gradient increase > 5%
- bankfull channel width decrease > 30%
- a potential fish passage barrier =an abrupt step in the stream channel with at least 20% slope and minimum elevation change greater than or equal to 1 upstream channel width.

Changes in stream gradient and bankfull channel decreases should be measured over a distance of 20 times the average bankfull width (Rosgen 1996). For tributaries of Type F waters (laterals) the PHB criteria would start at the most downstream end of the tributary and changes associated with PHB criteria would be measured upstream from that location.

While we believe there are differences in stream characteristics between Eastern and Western Washington streams that affect the upstream limits of fish habitat, we did not have adequate data or rationale to recommend different PHB criteria among ecoregions at this time. The proposed study to evaluate these interim criteria should help develop suitable criteria for different parts of the state or ecoregions.

The selection of these as interim criteria was based on several factors. First, the literature clearly supports gradient, width, and fish passage barriers as key factors influencing fish distribution. Other factors such as substrate, geology, channel type and others can influence fish distribution, but were deemed impractical in terms of field implementation and repeatability. Second, we discussed at length and examined with analysis of available data different scenarios with fixed thresholds for gradient and channel width vs. abrupt changes in channel gradient and channel width. While the former is simpler, we felt the latter was more consistent with how habitat breaks are defined in the literature and based on our experience and understanding of how fish view and react to the environment they encounter. Third, our testing and refining of different scenarios against the data we had available – which are by no means perfect or collected specifically to test PHB criteria – indicated that changes in gradient and channel width performed better both in terms of correctly identifying PHB and excluding non-habitat breaks (PHB where crews continued further upstream to locate EFH) (Table 3). We cannot emphasize enough that the data are not perfect and have a number of limitations including having only small number of points from Eastern Washington and were collected largely by landowners on their lands, and should be used with caution. However, they do represent the only high quality data available at the time of our analysis and have largely been reviewed and accepted through a regulatory concurrence process. These data indicate that the proposed criteria perform better than the current interim criteria of 2-ft. bankfull width and 20% gradient (Table 3). The proposed criteria also appear to out-perform other combinations of criteria we examined. Fourth, these criteria, a difference in gradient of 5% and a 30% reduction in channel width, were originally recommended by the Timber Fish and Wildlife Water Typing Committee in 1999 and were successfully applied in a research study. Thus, the proposed interim criteria appear to be implementable.

The determination of the criteria on PHB barriers, is not intended to supersede current deformable barrier definitions. The definition of a barrier for the purposes of PHB was based on our assessment of the literature on fish swimming and leaping performance and passage of at different types of barriers (waterfalls, bedrock chutes, cascades). These data suggested that a drop of 2.5 ft. or a steep chute or cascade of 20% would present a passage barrier for juvenile and small adult salmonids in small streams. Because the barrier length and height should scale to the stream length, we suggested that "barriers" be defined by a 20% or higher local gradient over a variable length channel feature, and a change in elevation of more than 1 channel width. Thus, a barrier in a 2.5-ft. wide stream would need to encompass an elevation change of at least 2.5 ft. The scaling of the elevation change to channel size is based on our best professional judgement and should be validated during the proposed field study described below.

Study to evaluate proposed criteria

Finally, based on the reasons discussed above, these should be viewed as interim criteria to be refined following additional study and data collection. Thus, to assure that the proposed PHB criteria and protocols are optimal, can be consistently applied, are effective or need any refinements, they need to be evaluated with a field study. The goal of the study should be to test criteria, protocols, and supplemental data collection procedures. This will likely include sampling stratified by ecoregion, elevation, season, ownership or other strata.

Specific questions to be answered include:

- Using proposed methodology developed by technical team, do crews identify similar starting point for electrofishing?
- Does approach lead to consistent application and identification of F/N break across landscape?
- Is it important to stratify PHBs at finer scale than simply Eastside/Westside?
- Would adding gradient and streamside thresholds to criteria improve PHB identification?
- Are there other variables that could be used to help better define PHB either in the field or in the office that should be evaluated?

The study would test the procedure at many sites (>100) across the landscape with crews from different caucuses and organizations across multiple years. The overall study design, stratification, sample size, and analysis will be developed further during the fall of 2017.

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Tables

Table 1. Available data sets and their Limitations. LF = last fish. EFH = end of fish habitat, BFW = bankfull width. Only the WFPA Landowner Data was determined to be appropriate for purposes of informing PHB protocols.

Data Set Name	Source	Description of data included	Limitations
OlyAB_survey_data_all	Forest Service	Point locations for LF and EFH around the Olympic Peninsula. Upstream and Downstream gradients. BFW at the point.	No measurements of up- and downstream widths
Data set: DNR Watercourses	DNR Open data portal	DNR Hydrography layer. Contains information on water typing for WA streams and rivers.	No Habitat data
seasonal variability sites final Feb10-05_RO21feb2017	Landowners	Point locations for LF and EFH. Up- and downstream gradient, as well as up- and downstream gradient over 300m. Mean wetted width and BFW at the point.	No measurements of up- and downstream widths
WTYP breaks	DNR. GIS tech.	Point locations of water type breaks across WA.	No Habitat data
WTYP Access	DNR	Database of digitized water type modification forms.	No Habitat data
WDFW fish passage	WDFW Web Portal	Web portal detailing fish passage barriers. Emphasis on manmade barriers.	Man-made barriers are not under consideration
WFPA Landowner Example Data Set	Landowners	Compiled land owner water type mod survey data. LF and EFH point descriptions. Contains up- and downstream measurements of	Coarse spatial data (Township Range Section)

		gradient and width. Detailed barrier information.	
Eastside_dc: 02-197 LF Raw Physical Data	Cole et al. 2006	Up and downstream measurements around LF points. Gradient, WW, BFW, and substrate data. Each stream has 6 upstream transects and 6 downstream transects.	Gradient over uniform transect distances. No spatial data.
WFC watertyping data	Wild Fish Conservancy	WFC water typing data. Several files. Detailed information about barriers. Upstream and downstream measurements from points.	No clear indication of EFH points. Gradient reported in ranges over fixed distances (e.g. 3-9%)
Water Typing: WRIA38	DNR	Complete water typing for WRIA 38. Points contain Up and down stream gradient over 100 units	No measurements of up- and downstream widths
Last Fish Model Development	DNR	Model development data. Contains up and downstream Gradient for points. As well as predicted UF and EFH, predicted gradient (up and down stream).	No measurements of up- and downstream widths

Table 2. Estimated maximum leaping height for sub-yearling coho salmon and cutthroat trout based on equation of Orsborn and Power (1985).

Juvenile Coho Salmon				
		Leap Angle		
		40 degrees	60 degrees	80 degrees
Fish Length, ft.	Burst speed, ft./sec	Leap Height, ft.	Leap Height, ft.	Leap Height, ft.
0.20	2.4	0.24	0.27	0.29
0.28	3.4	0.35	0.42	0.46
0.36	4.3	0.48	0.58	0.64
Cutthroat Trout				
0.26	2.6	0.30	0.34	0.36
0.33	3.3	0.40	0.46	0.50
0.39	3.9	0.49	0.57	0.62
0.46	4.6	0.60	0.71	0.78
0.53	5.3	0.71	0.86	0.96

Table 3. Descriptions of PHB habitat metric sets tested, and their performance when applied to the WFPA data. The bolded row highlights the panel's recommendation. Difference indicates downstream width or gradient minus the upstream width or gradient respectively. Ratio indicates the upstream or gradient divided by the downstream width or gradient respectively. Thresholds indicate a discrete value for width or gradient. Percent of EFH points captured indicates the efficacy of the model. Percent of non-habitat breaks captured represents the Type II error (points captured in error, false negatives). *Denotes test of default physical criteria.

Test	Gradient Metric	Gradient Threshold	Width Metric	Width Threshold	Percent of Surveyed EFH points captured	Percent of non-habitat-break points captured
1	Ratio up/down	1.5	Ratio up/down	0.75	90.9%	25.0%
2	Upstream Threshold	15%	Upstream Threshold	2 ft	79.7%	24.7%
3*	Upstream Threshold	20%	Upstream Threshold	2 ft	71.8%	13.6%
4	Upstream Threshold	10%	Upstream Threshold	2 ft	87.6%	56.4%
5	Upstream Threshold	15%	Upstream Threshold	3 ft	91.8%	43.4%
6	Upstream Threshold	15%	Ratio up/down	0.7	89.4%	20.4%
7	**Difference up-down**	**5%**	**Ratio up/down**	**0.7**	**92.0%**	**15.6%**
8	Difference up-down. with DS grad. >5%	5%	Ratio up/down	0.7	87.1%	11.6%

9	Difference up-down.	5% where DS gradient is >10%; 10% change where DS gradient is <= 10%	Ratio up/down	0.7	86.0%	11.0%
10	Difference	5%	Upstream Threshold	2 ft	87.0%	18.6%
11	Difference up-down	5%	Ratio up/down	0.5	86.2%	11.6%
12	Upstream Threshold	15%	Ratio up/down	0.5	81.8%	16.8%
13	Difference up-down	5%	Ratio up/down	0.25	80.3%	10.7%
14	Upstream Threshold	15%	Ratio up/down	0.25	70.2%	14.9%

Table 4. Descriptions of non-vertical barrier habitat break definitions and their performance when applied to the WFPA data. The bolded row highlights the panel's recommendation.

Test	**PHB Definition for Non-Vertical Barriers**	**Percent of barriers captured**
G20E2*W	Barrier gradient over 20% and elevation change over barrier length is greater than twice the upstream channel width.	59.47%
G20E1*W	**Barrier gradient over 20% and elevation change over barrier length is greater than upstream channel width.**	**80.68%**
G20EL20	Barrier gradient over 20% and elevation change over barrier length is greater than 20ft.	24.16%
G20EL10	Barrier gradient over 20% and elevation change over barrier length is greater than 10ft.	57.25%
G20EL5	Barrier gradient over 20% and elevation change over barrier length is greater than 5ft.	84.76%

Figures

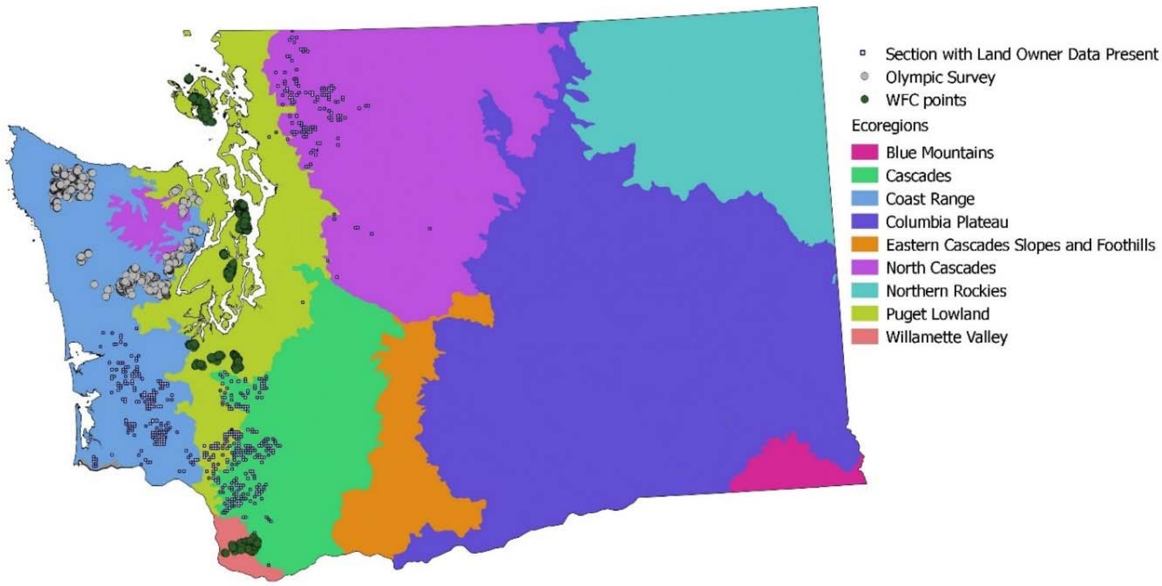

Figure 1. Locations of initial data sets providing end of fish habitat (EFH) data points displayed over level three ecoregions in Washington State. These data sets were screened for consistency to determine the final data set available for analysis.

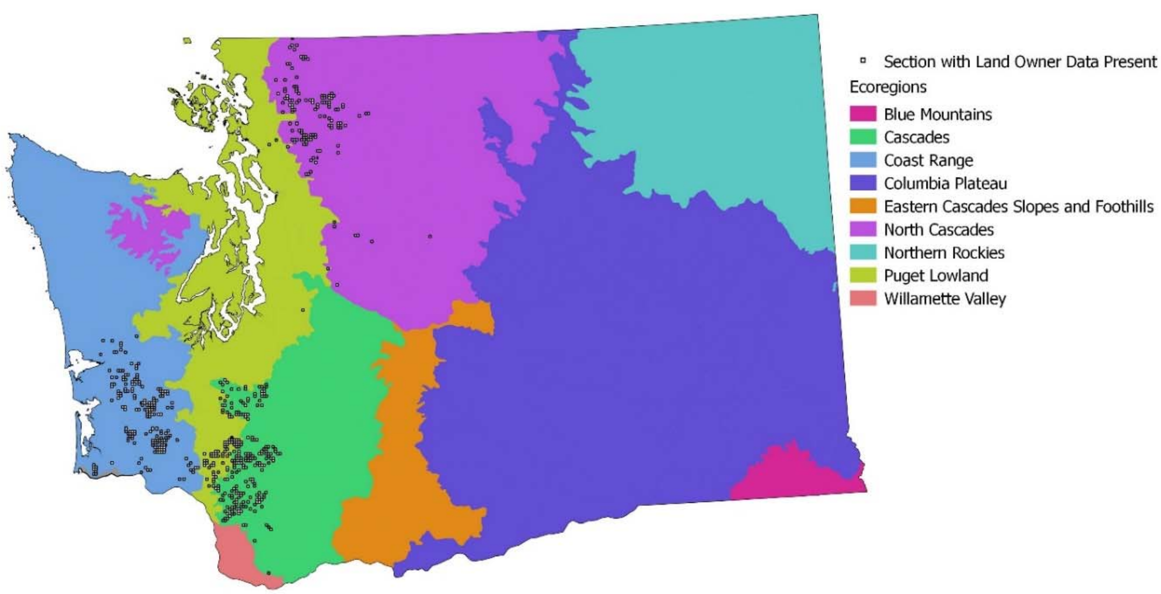

Figure 2. Locations of Landowner data used in analysis displayed over level three ecoregions in Washington State.

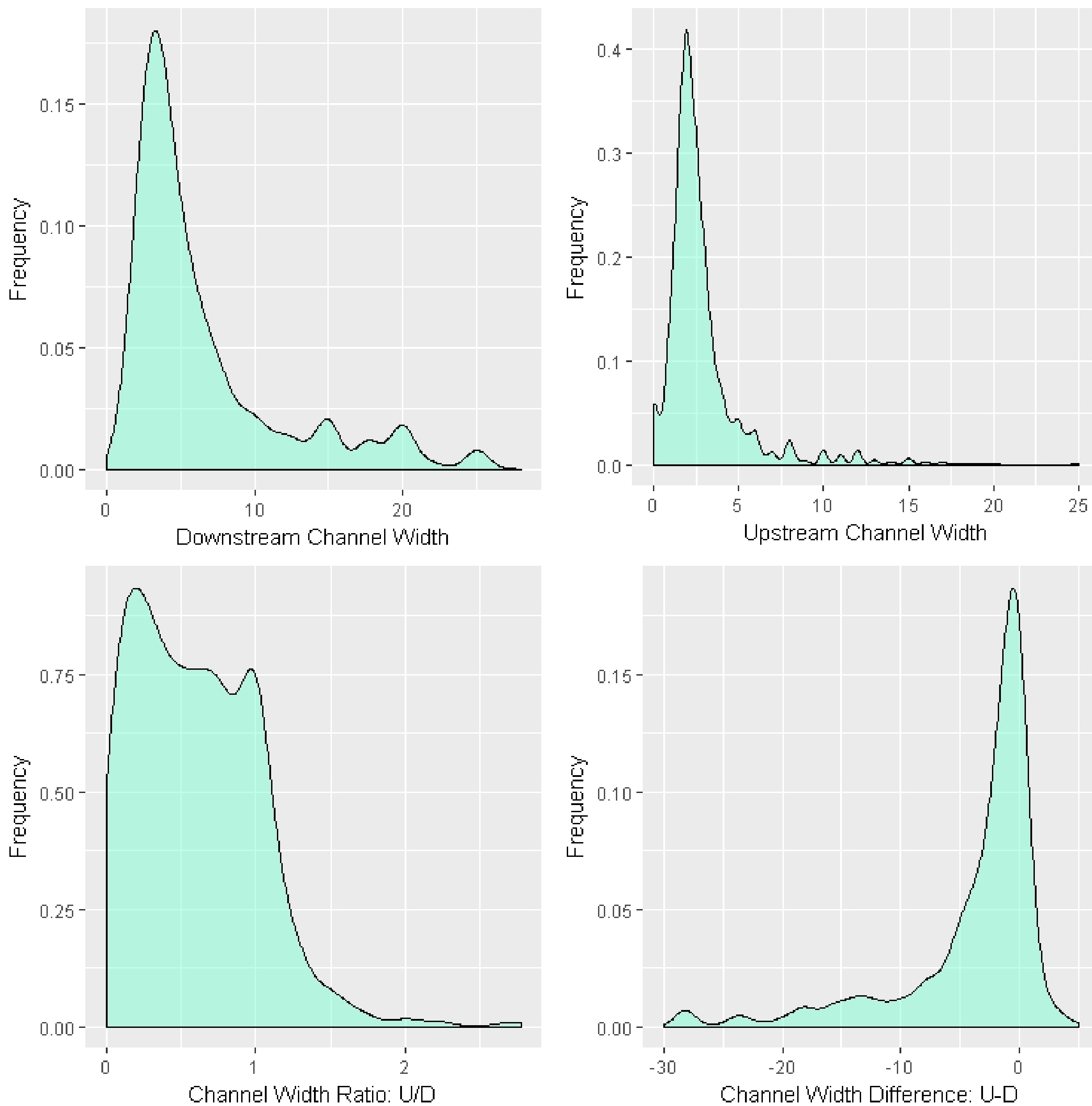

Figure 3. Frequency (%) plots of channel width for concurred end of fish habitat data points in Landowner data. Clockwise from top left: Downstream channel width, upstream channel width, the ratio of upstream width to downstream width, and the difference between upstream and downstream widths.

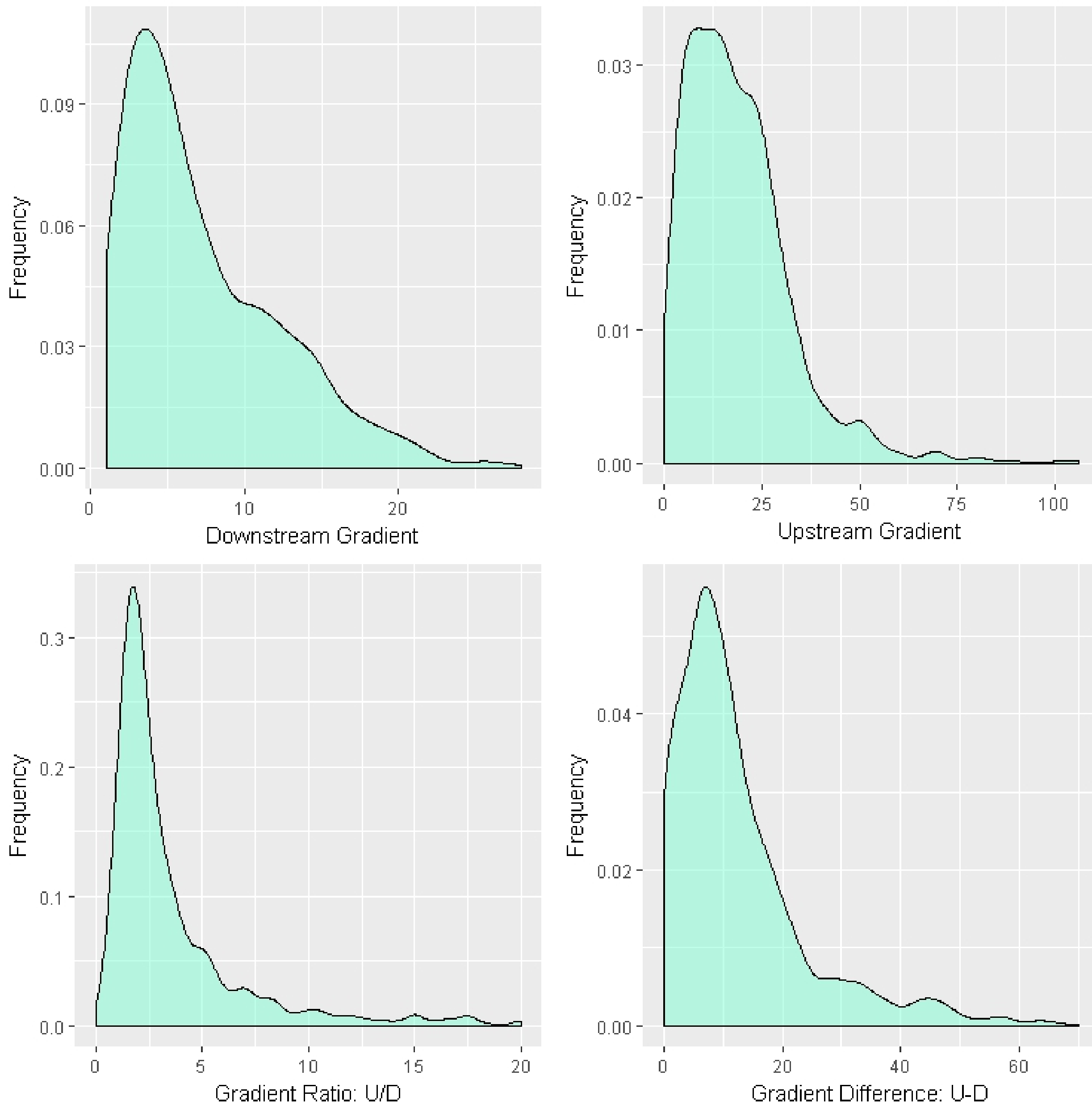

Figure 4. Frequency (%) plots of gradient for concurred end of fish habitat data points in Landowner data. Clockwise from top left: Downstream gradient, upstream gradient, the ratio of upstream gradient to downstream gradient, and the difference between upstream and downstream gradients.

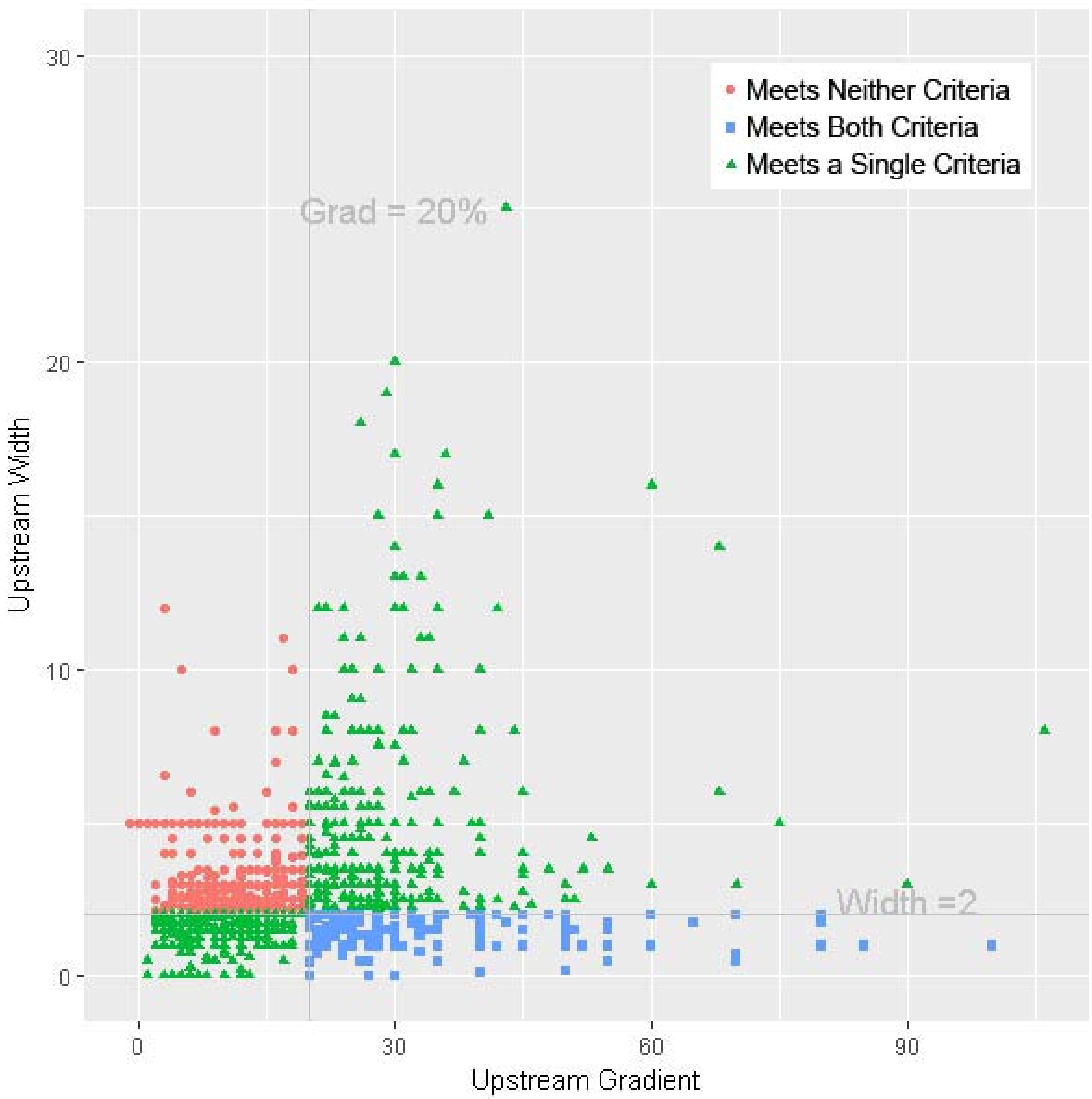

Figure 5. Upstream gradient and upstream channel width for end of fish habitat points from the Landowner data. Horizontal and vertical lines represent the “2-ft. wide and 20% gradient” default physical criteria. Points are categorized by the number of default criteria met. These criteria captured 72% of the EFH points while exhibiting a 14% Type II error rate (Table 3).

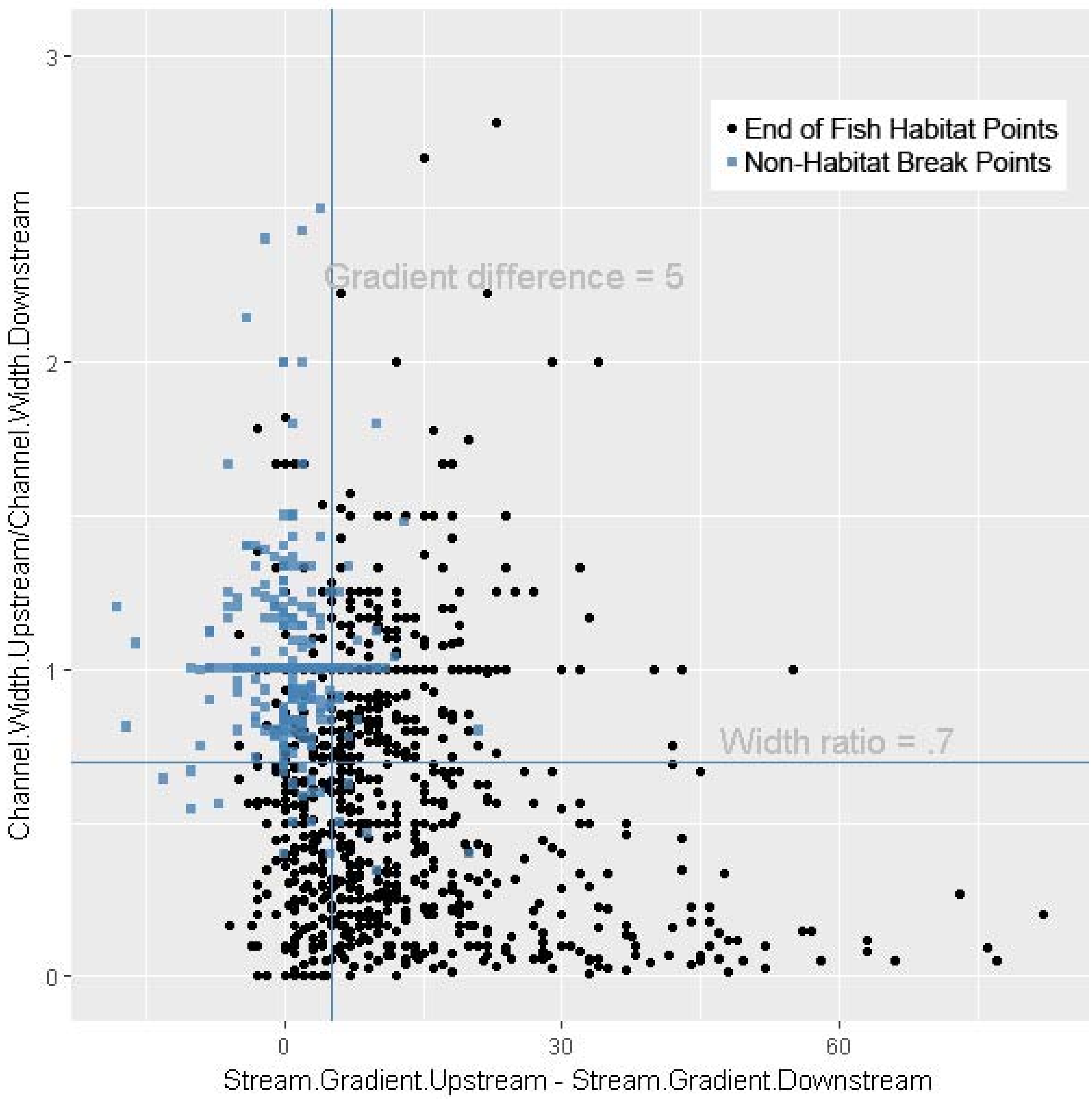

Figure 6. Scatter plot of the upstream to downstream gradient difference and upstream to downstream width ratios of end of fish habitat and non-habitat break points. The horizontal and vertical lines represent the proposed interim PHB thresholds. This model captures 92% of the EFH with a 15.5% Type II error rate (Table 3). The blue points represent locations where the upper extent of surveyed fish use was not considered the extent of fish habitat by the surveyor, and an extension of Type F waters was made.

Appendix I

Potential Habitat Break Project Charter
June 12, 2017

I. Introduction and Project Description

In 2014, the Forest Practices Board (Board) directed the TFW Policy Committee (Policy) to complete recommendations for options for a permanent water-typing system rule. When completed, the permanent water-typing system will establish how to classify streams, lakes, and ponds as Type S, F, Np, and Ns waters. Policy provided the Forest Practices Board (Board) a set of recommendations for a permanent water-typing system rule in May 2017. On 10 May 2017, the Board passed two motions for next steps necessary for development of a permanent water-typing rule.

The motions directed the AMPA (Adaptive Management Program Administrator) to convene and lead a group of internal and external science/technical experts to work under the direction of the Board to identify team members and to determine those criteria that would constitute a PHB (potential habitat break) that could be used in the FHAM (fish habitat assessment methodology) framework to establish the regulatory break between Type F and Type N waters of the state.

The Board directed that the group review the current FHAM listed habitat break elements for combinations of primary and secondary features to determine those physical, biological, or chemical constituents that could constitute a significant change in habitat that would provide the appropriate point for a protocol survey. The Board would like to receive recommendations from the AMPA's group at their 9 August 2017 meeting.

Primary considerations include:

- Permanent natural barriers
- Stream gradient
- Stream size: width, basin size, channel size
- The interaction between size and gradient

Secondary considerations include:

- Water quantity
- Stream substrate
- Water quality

- Primary/secondary production (food)
- Geomorphology: step pools, pool-riffle, plane-bed, or bedrock/boulder cascades.
- Temporal considerations (the end of habitat is not deformable)

II. Membership

Science Panel:

Hans Berge (AMPA)	Howard Haemmerle (PM)	Brian Fransen
Ray Timm (lead writer)	Pete Bisson	Joe Maroney
Pat Trotter	Jeff Kershner	

Caucus Representatives - Technical Staff:

Chris Mendoza, CC	Jamie Glasgow, CC
Don Nauer, WDFW	Jason Walter, Industrial Landowners
Claudine Reynolds, Industrial Landowners	Sarah Zaniewski, Westside Tribes
Derek Marks, Westside Tribes	Debbie Kay, Westside Tribes
Marc Gauthier, Eastside Tribes	

III. Problem Statement

The resource objective and performance target associated with water typing are still important goals of the Board. The identification of regulatory F/N breaks using a field assessment methodology that accurately and reasonably identifies the uppermost extent of fish habitat likely to be used, as defined in WAC 222-16-010 and provides a methodology which is implementable and enforceable has been exceeding difficult to develop for forest practice application in the State of Washington. An approach being considered is to address the identification of fish habitat through the development of potential habitat breaks and through the assessment of permanent natural barriers to fish passage.

IV. Tasks & Responsibilities:

Task	Responsibilities
1. Attend science panel meetings	Active in person participation at a minimum of three science panel meetings
2. Provide review of data and other documents as needed	a. Review existing data and work with members of the group on analysis b. Review existing literature relevant to the topic

	c. Meet with stakeholders engaged in water typing to understand perspectives, pitfalls, and important issues to address in the analysis d. Review the work of biometricians analyzing existing data
3. Determine options for the evaluation of potential habitat break features	a. Participate in discussion of potential habitat breaks b. Make recommendations for the evaluation of criteria to be used for potential habitat break features
4. Coauthor summary report and recommendations for the Forest Practices Board	Summary report and recommendations
5. Develop a study design to validate the fish habitat assessment methodology	Study Design
6. CMER review	Revised draft report that incorporates CMER comments
7. ISPR review of study plan	a. Work with panel to respond to comments from ISPR
	b. Revised draft report that incorporates ISPR comments
8. Final CMER approved study plan	Final approved study plan
9. Provide any additional assistance requested by DNR relating to Type F/N break identification	TBD

V. Deliverables:

1. Potential Habitat Breaks Charter
2. Status report to the Board
3. Summary report and recommendations for the Forest Practices Board
4. Supporting documentation/data
5. Study design

VI. Group Process, Reporting, and Support:

1. Science Panel/Policy subgroup are primary participants; caucus technical staff and/or CMER subgroup may participate when needed and called upon by Policy subgroup
2. Update e-mails sent to the Board every two weeks until delivery of the report in August 2017
3. Support is expected from AMP, caucus technical staff and CMER (see task list)
4. Schedule meetings every two weeks
5. Designate recorder for each meeting

VII. Adaptive Management Program Ground Rules:
TFW ground rules in affect

VIII. Timeline
First science panel/subgroup meeting to be held on 14-15 June 2017; subsequent meetings will be scheduled approximately every two weeks with the goal of completing this work by the August 2017 Forest Practices Board meeting. Accomplishing assigned tasks between meetings, punctual attendance, and being prepared for meetings will facilitate regular progress towards meeting this goal.