

Anadromous Fish Floor Spatial Analysis

Addendum to Findings Report

Prepared for

The Water Typing Rule Committee of the Washington State Forest Practices Board

By

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Report Addendum

Introduction

This addendum supplements the Anadromous Fish Floor Spatial Analysis Findings Report (December 3, 2021) to present the results of additional AFF analyses and map development performed by TerrainWorks at the request of the Water Typing Rule Committee and the AFF Workgroup Pls. The TerrainWorks tasks for this addendum include:

- (1) Conduct additional AFF model runs:
 - a. Remove from the model 15 'concurrent F/N Break Points' identified as having been collected using pre-Emergency Rule protocols, and correct a small Skagit River basin model discrepancy by rebuilding the synthetic network there.
 - b. Produce spreadsheets with bar charts that display the results of the model runs for alternatives D, A(4) 5%, A(4) 7%, and A(4) 10% in the same way results are currently displayed in Figures 6, 7, 9, 10, 11, 12, and 13 in the '*Anadromous Fish Floor Findings Report*'. At the request of the Pls, these charts will include Alternative A.
- (2) Create .pdf maps (1:24,000) for selected basins that display in layers the following:
 - a. The 'Anadromous Core' (upper most extent of SWIFD) as a unique line feature.
 - b. The extent of each AFF alternative (D, A(4) 5%, A(4) 7%, A(4) 10%) as unique line features.
 - c. The reason for the termination of each AFF alternative as unique point features.
 - d. Fish reference data (upper most SWIFD_anadromous, upper most Other_Anadromous, upper most Unknown_Life_history, upper most F/N point, upper most Resident) as both unique point features and as unique line features.

The basins displayed in the maps should strive to meet the following criteria, (1) at least 5 distinct watersheds that include as many vetted F/N points as possible, including the Kalama or Stillman watersheds, (2) includes a range of topographic relief, from low to high.

- (3) Describe with histograms and box and whisker plots the distributions of total stream lengths for each AFF alternative (A, D, A(4) 5%, A(4) 7%, A(4) 10%) that occur (1) above the upper most anadromous fish points (SWIFD), (2) above and below the upper most 'Other_Anadromous' points; and (3) above and below the upper most F/N break points.

Methods

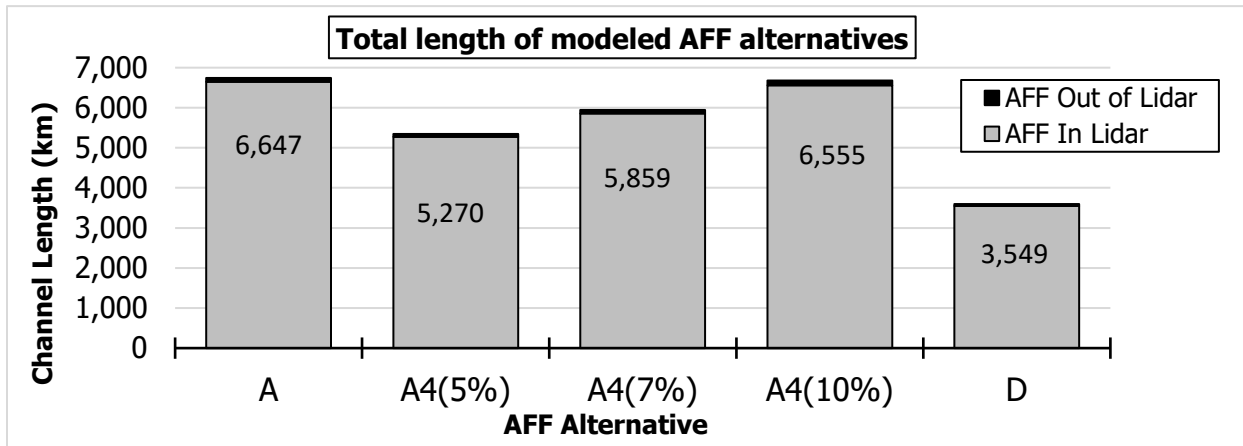
The additional model runs done in this supplementary analysis followed the same process as in the original report but was limited to Alternatives A, A4 (5%), A4 (7%), A4 (10%) and D. The same figures that were generated for the original report were reproduced for these alternatives and are displayed in this addendum. However, data used for these analyses reflect two changes from the original report:

1. Fifteen F/N break points in the Stillman Basin were excluded from these current analyses. These points were from older surveys (1998) and there was some uncertainty about their applicability to the current analysis.
2. For the original analyses, the Skagit Basin was divided into three separate analysis areas because of the large size of the dataset. That resulted in discontinuities in the mainstem rivers represented in

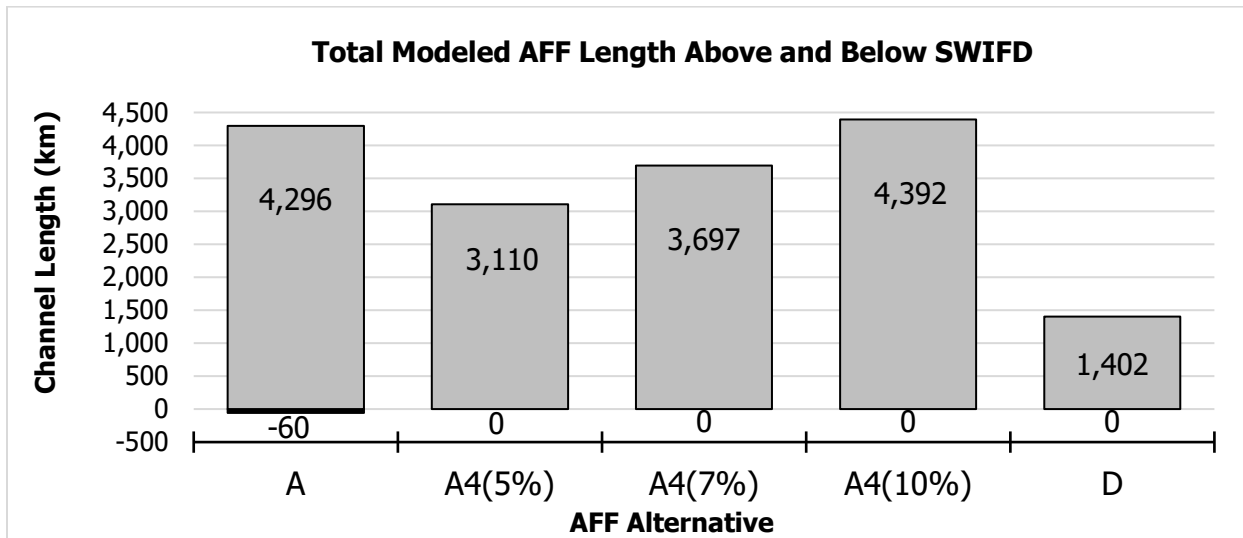
the synthetic stream layer where they crossed the boundary from one analysis area into another. These discontinuities resulted in a slight under-estimate of the total AFF and anadromous-use channel lengths. For these updated analyses, the three areas were combined into one single large analysis area so there are no discontinuities for any channel within the area.

Results of the model runs on A4 (5%), A4 (7%), A4 (10%), and D

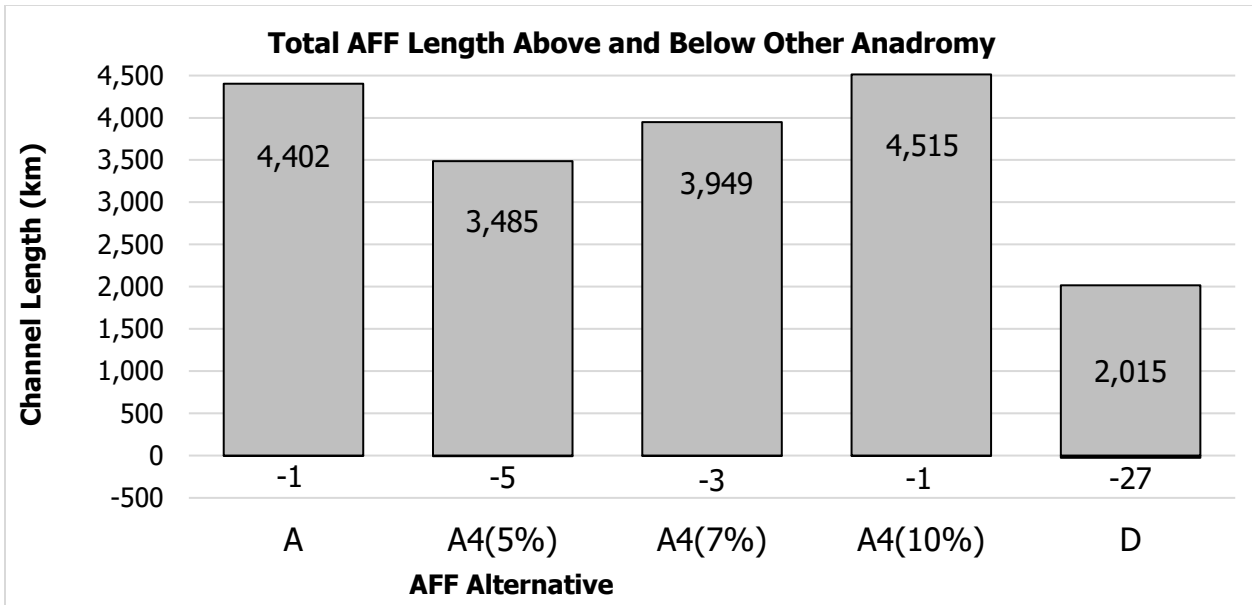
As per the Water Typing Rule Committee’s direction, alternatives A4 (5%), A4 (7%), A4 (10%) and D were run through the TerrainWorks model. Because these model runs were done with 15 fish points removed (see methods), alternatives A and D were also re-analyzed using the model. Below are the results of those model runs, displayed in bar charts in the same format as the charts included in the original report.



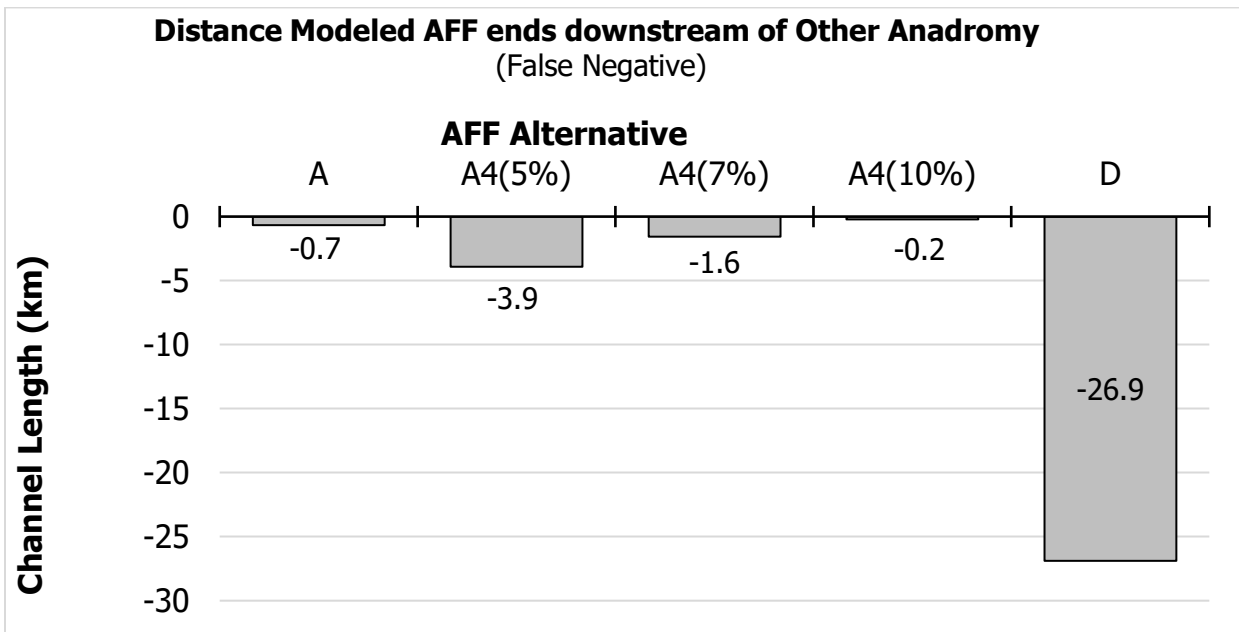
Addendum Figure 1 (equivalent to Figure 6 in main report). Modeled AFF length within and without portions of the analyzed watersheds covered by lidar topographic data.



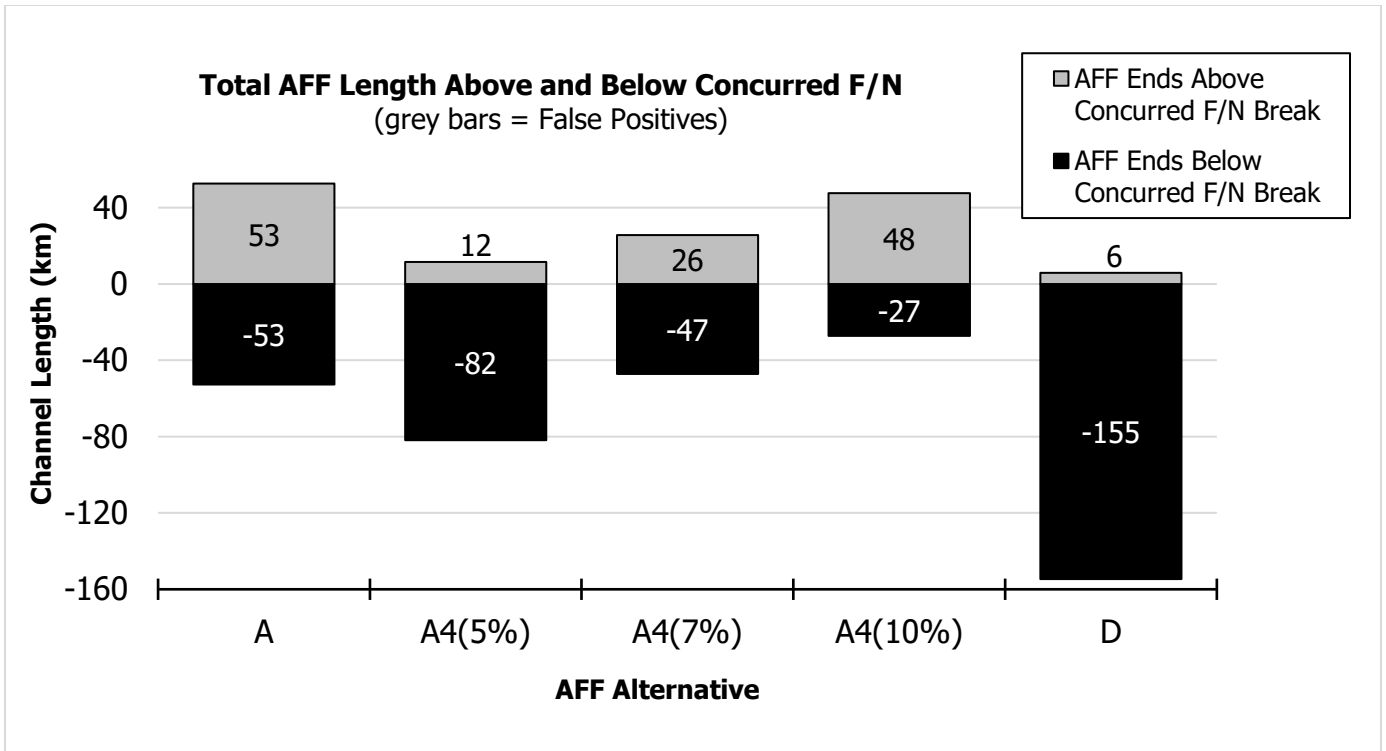
Addendum Figure 2 (equivalent to Figure 7 in main report). Distances of the modeled AFF alternatives above and below the SWIFD anadromous data. Alternatives A4 (5%), A4 (7%), A4 (10%) and D are defined using SWIFD, and so there are no downstream distances. The upstream distances represent the length of those alternatives extending upstream of SWIFD.



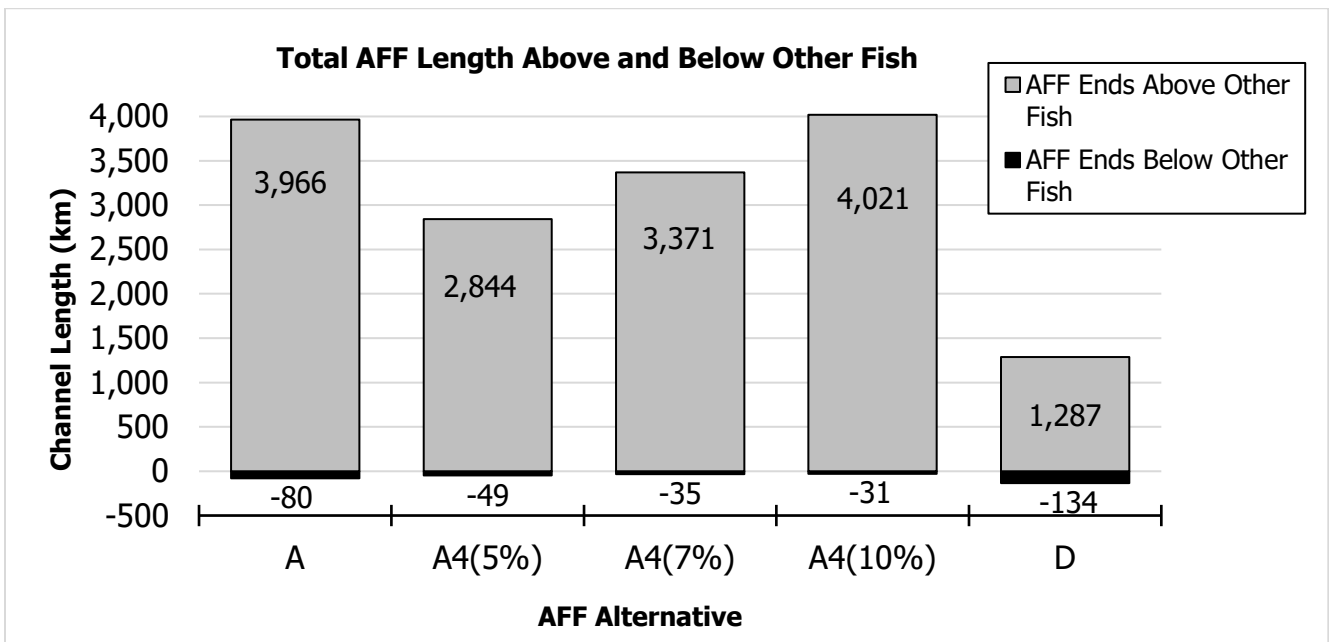
Addendum Figure 3 (equivalent to Figure 9 in main report). Distance the modeled AFF alternatives terminate above and below the 'other anadromy' data points.



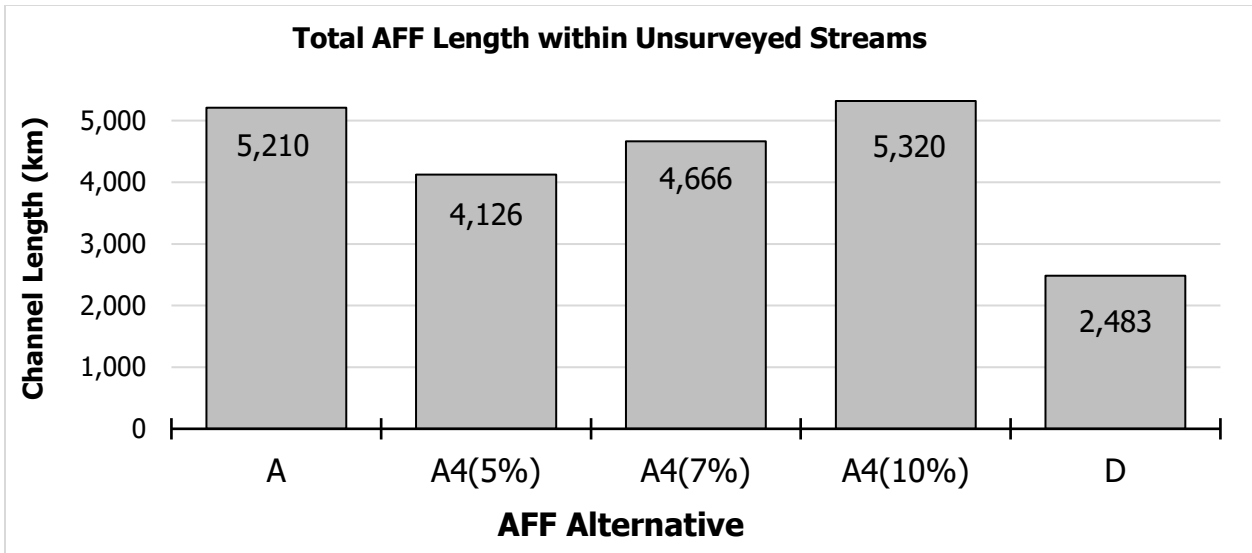
Addendum Figure 4 (equivalent to Figure 10 in main report). Bar chart showing the length of stream in which the modeled AFF ends downstream of the 'other anadromy' data (False Negatives).



Addendum Figure 5 (equivalent to Figure 11 in main report). Distances that the modeled AFF alternatives terminate upstream and downstream of the F/N break point data. The positive bars (grey) are referred to as 'False Positives' in the framework of Figure 2 in the main report.



Addendum Figure 6 (equivalent to Figure 12 in main report). Channel distances of the modeled AFF alternatives above and below 'Other Fish' - reference fish data for resident or 'unknown' life history type.

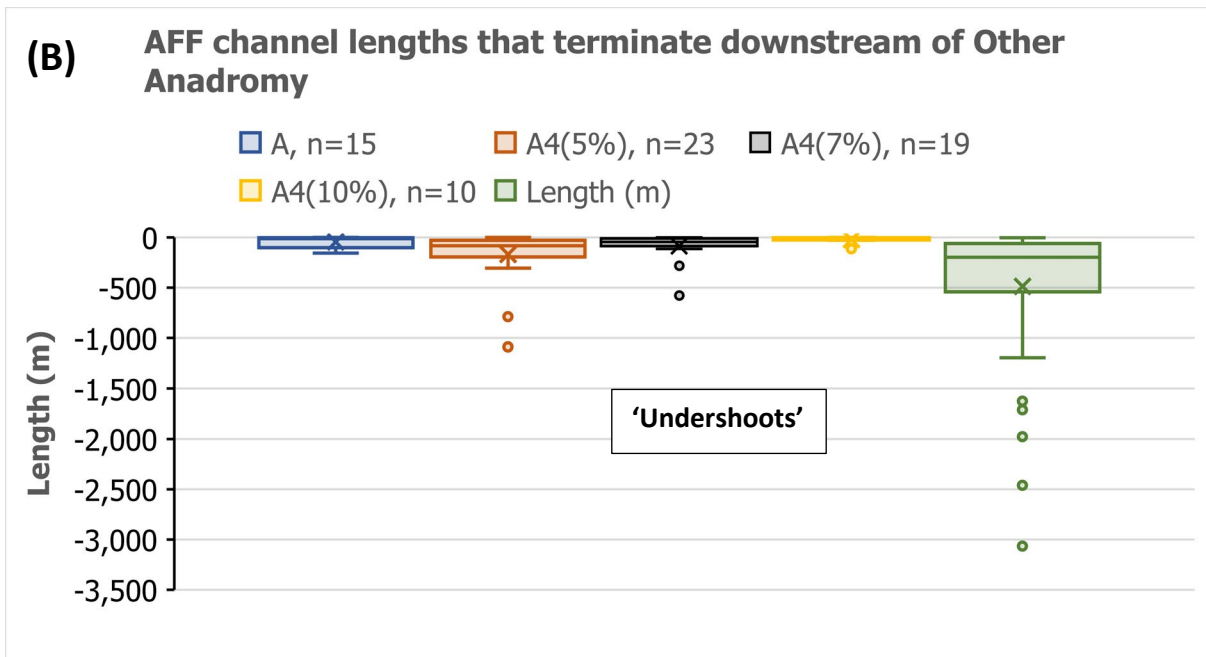
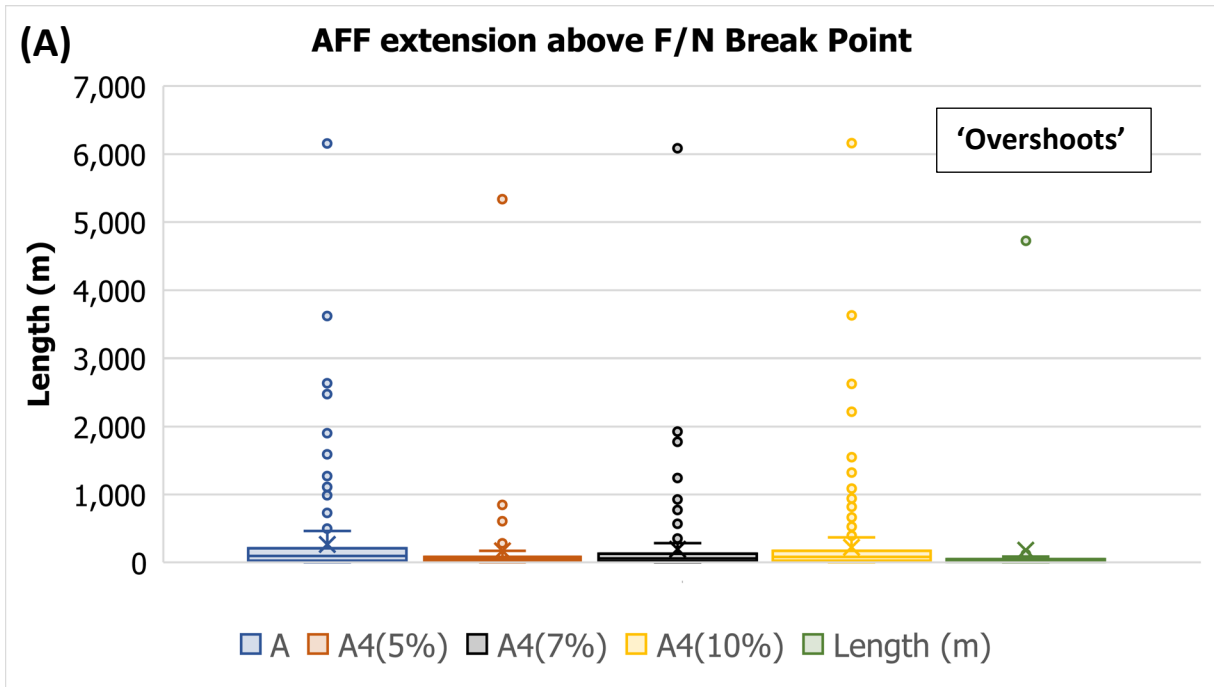


Addendum Figure 7 (equivalent to Figure 13 in main report). *Channel distance where the modeled AFF alternatives extend into streams with no fish data (anadromous, resident, unknown life history or F/N break).*

Overshoot of ‘F/N Break’ points vs undershoot of upper most known ‘Other Anadromy’ points (False Positive vs False Negative)

A consistent pattern seen in the results of the analyses in both the original report and in this addendum is that using higher gradient thresholds to ‘stop’ the AFF results in longer total stream lengths. Also consistently seen in both analyses is that relative to the fish reference points, higher gradient thresholds will more likely ‘overshoot’ the F/N Break points; whereas lower gradient thresholds will more likely cause the modeled AFF to ‘undershoot’ the uppermost known anadromous fish points. Addendum Figure 8 below illustrates this dynamic.

The cases where modeled AFF does not extend to terminal anadromous data points are the undershoots, or “false negatives.” Undershoots of the uppermost anadromy reference points are limited to only ‘Other_Anadromy’ data because SWIFD defines the anadromous core for A4 (5, 7 or 10%) and D. Because of this we use the Other Anadromy data to examine the undershoot values.

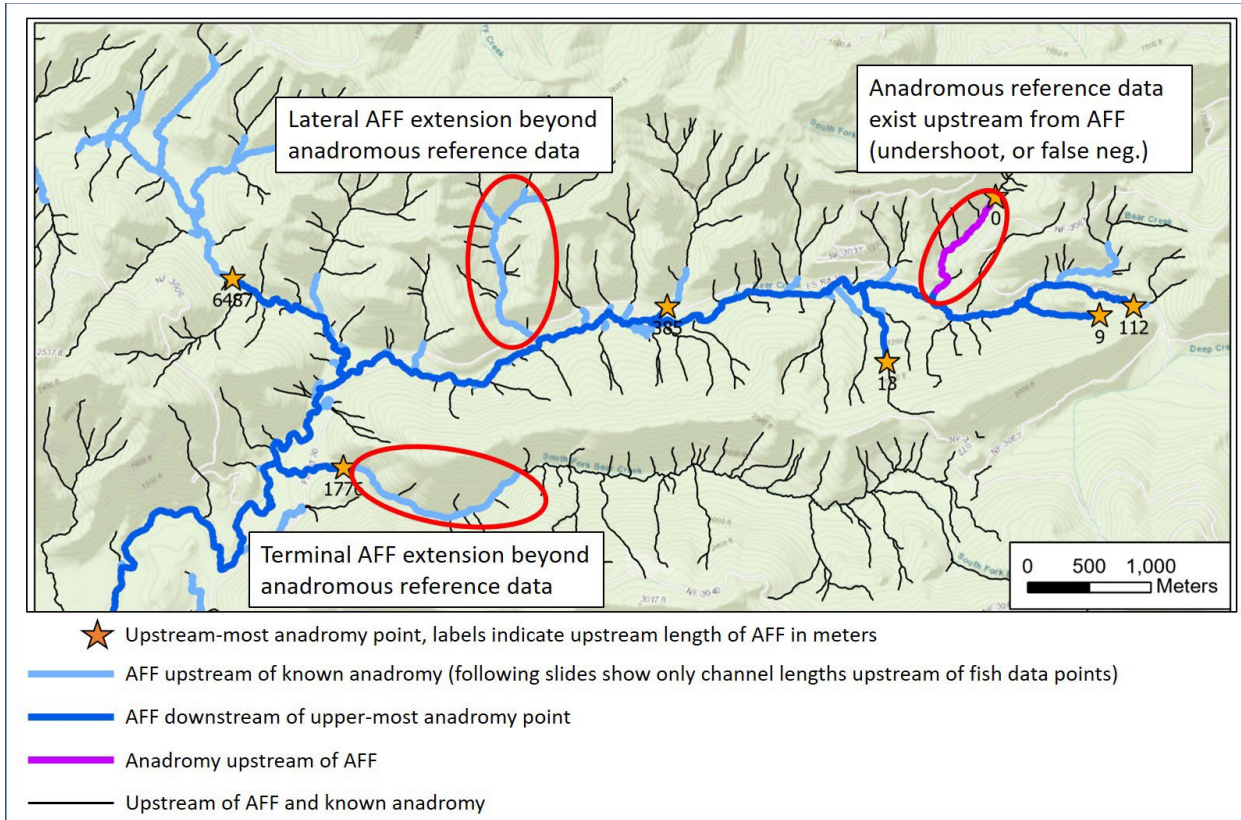


Addendum Figure 8. Box and whisker plots of (A) Stream channel length of the modeled AFF that overshoots the F/N Break points (i.e. False Positives), and (B) Stream channel length of the modeled AFF that undershoots the Other Anadromy points (i.e. False Negatives).

AFF relative to known anadromy

For the following charts/plots we separated the uppermost known fish points from All Anadromy data into their SWIFD and Other Anadromy components to show how the alternatives compare across the

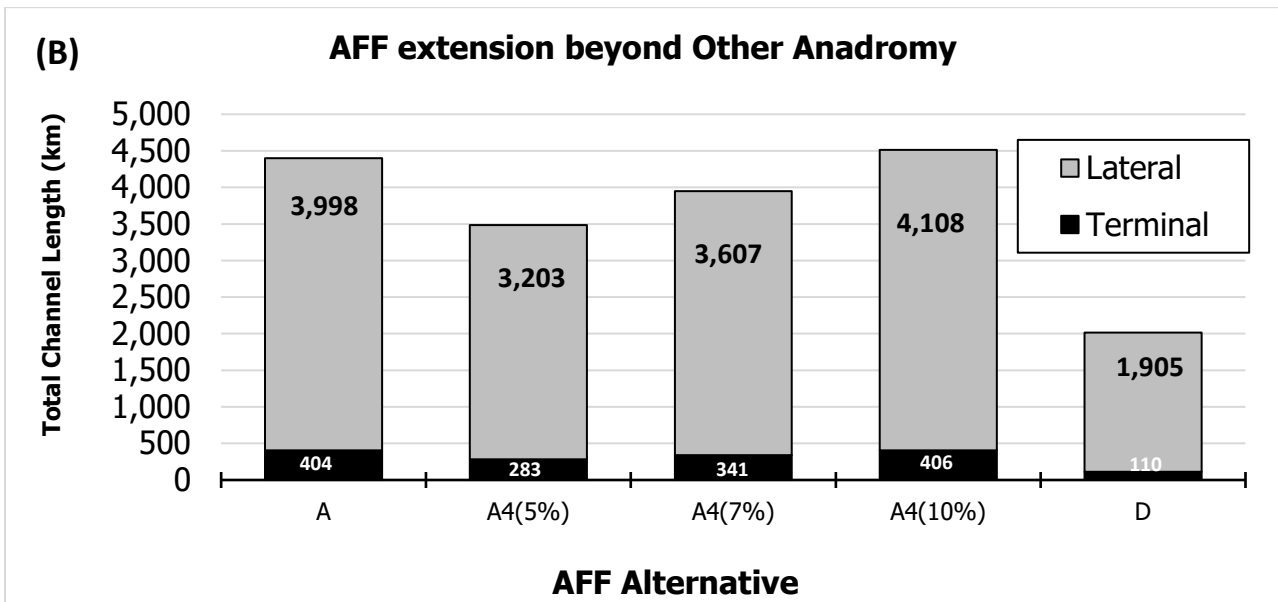
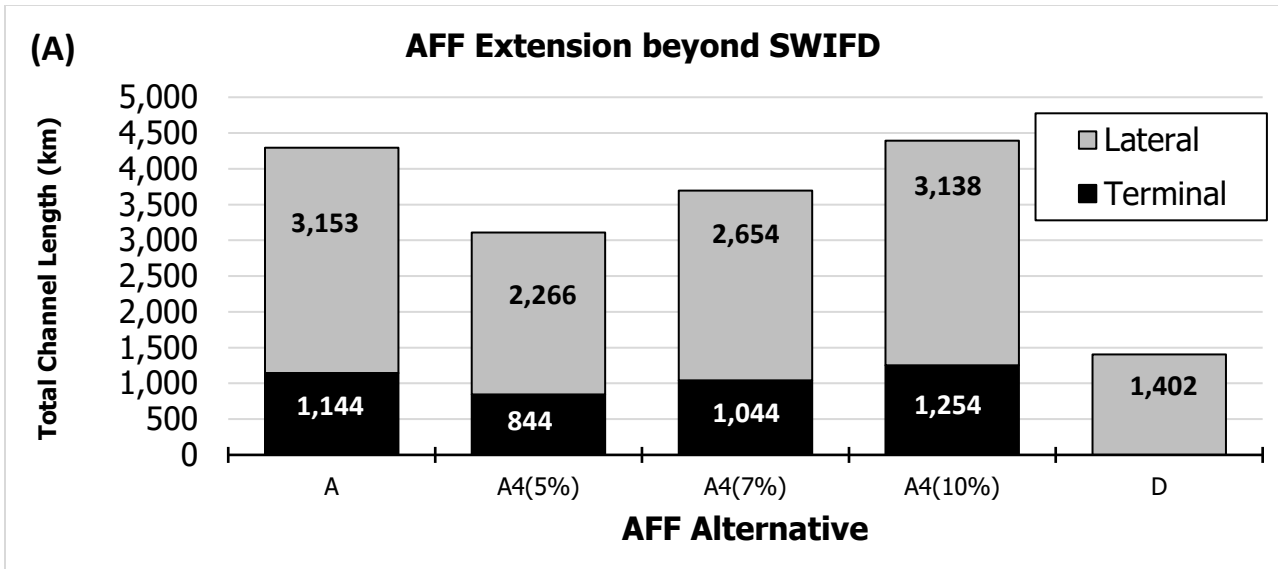
two anadromous datasets. We also sorted the modeled AFF lengths into whether the channel lengths extend upstream of the highest known anadromous point ('terminal' reaches, Alternative A and A4 only) or whether the AFF channel lengths extend upstream into tributaries that lack anadromous fish reference data but are connected to known anadromous streams ('lateral' reaches) (Addendum Figure 9).



Addendum Figure 9. Map image illustrating differences between 'lateral' and 'terminal' streams relative to upper-most anadromy reference data. AFF extension up lateral tributaries is measured from the confluence with a channel having known anadromy. AFF extensions directly upstream of upper-most anadromous reference data are categorized as terminal AFF reaches (Alternatives A and A4 only).

Total channel lengths of modeled AFF above known anadromy

Addendum Figure 10 displays total distances the modeled AFF extends beyond terminal points relative to the modeled AFF extending up connected lateral tributaries.

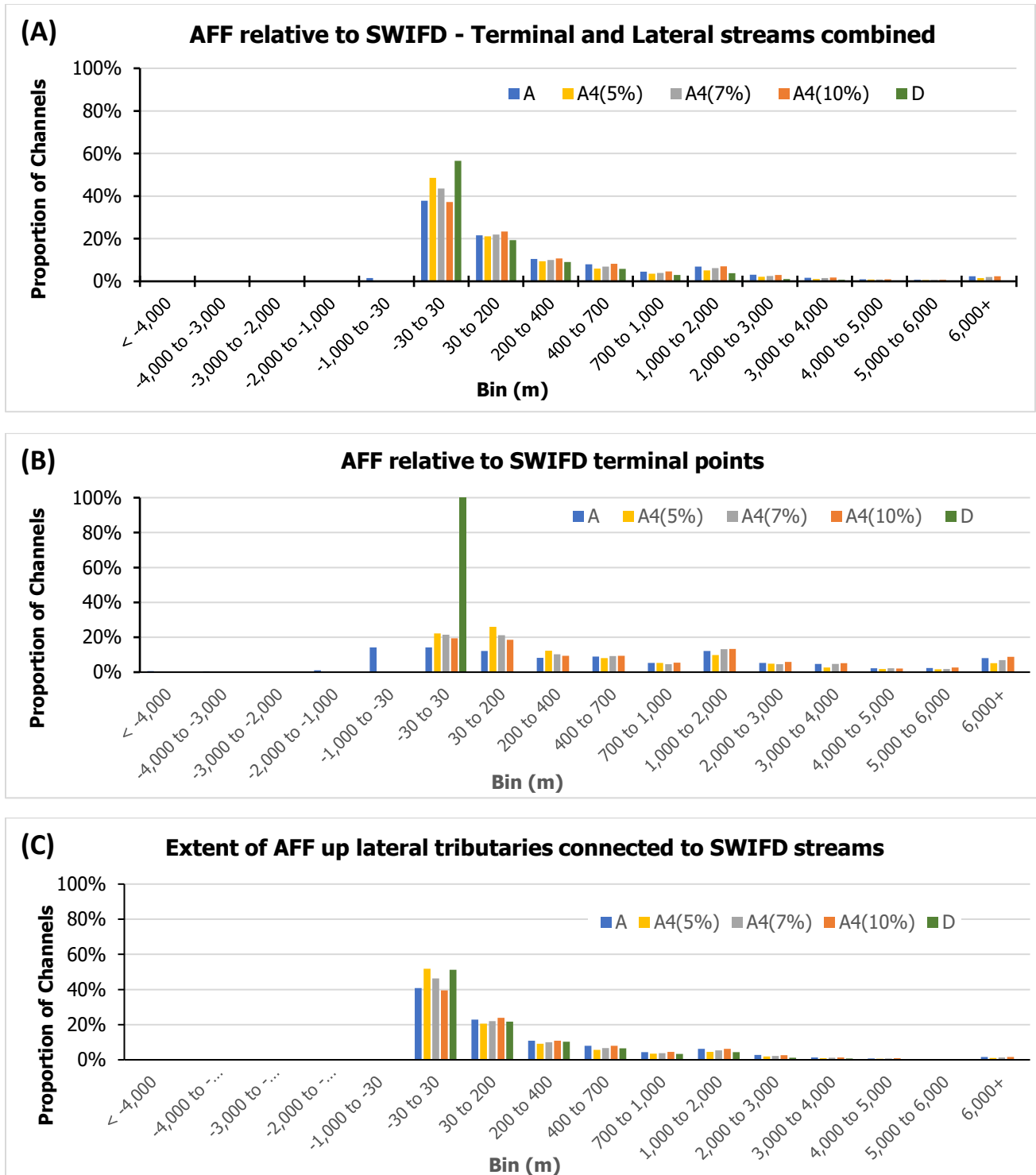


Addendum Figure 10. Total modeled AFF channel length extending beyond uppermost known anadromy points (terminal) and lateral tributaries that connect with known anadromy, based on (A) SWIFD and (B) Other Anadromy reference points.

Extent of AFF relative to SWIFD

SWIFD - Histograms

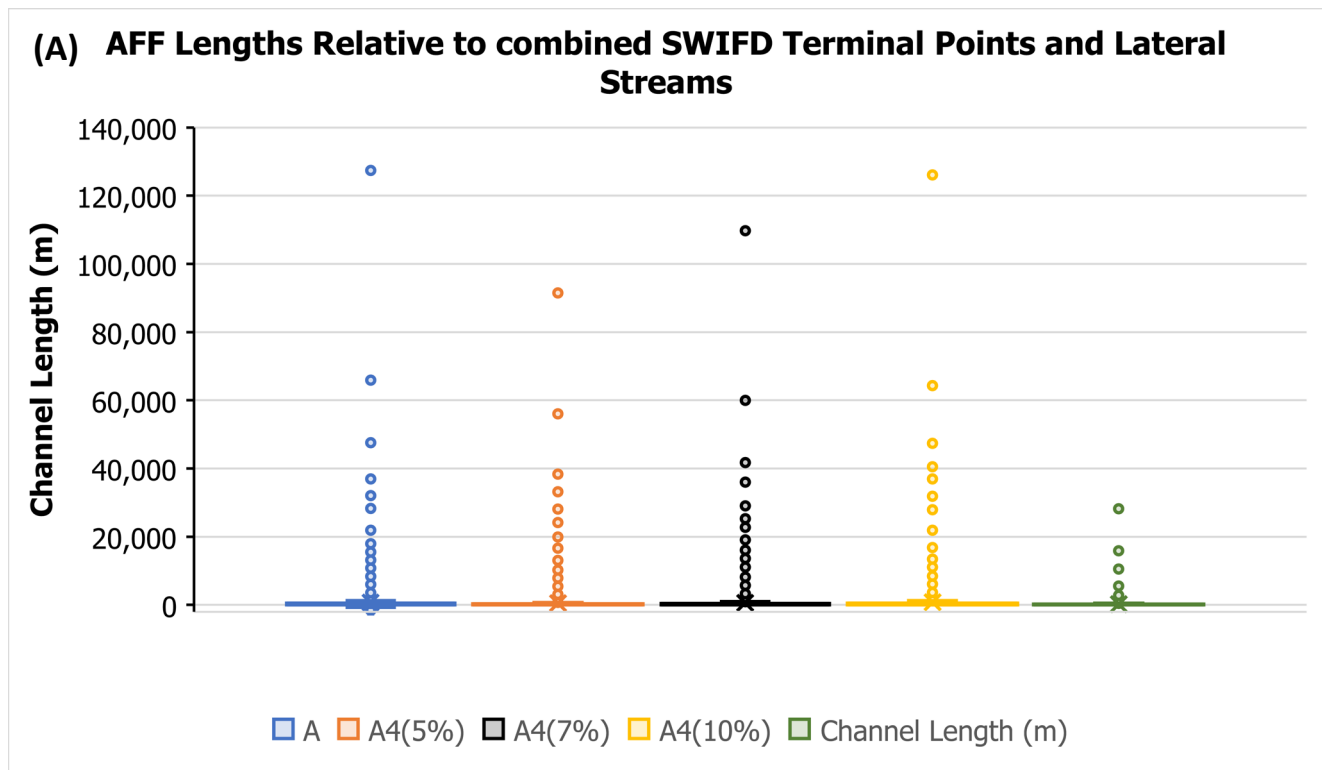
All modeled terminal lengths for Alternative D are zero and Alternative A4 at each gradient threshold have no negative lengths, because SWIFD defines the anadromous core for these alternatives (*Addendum Figure 11 A*).

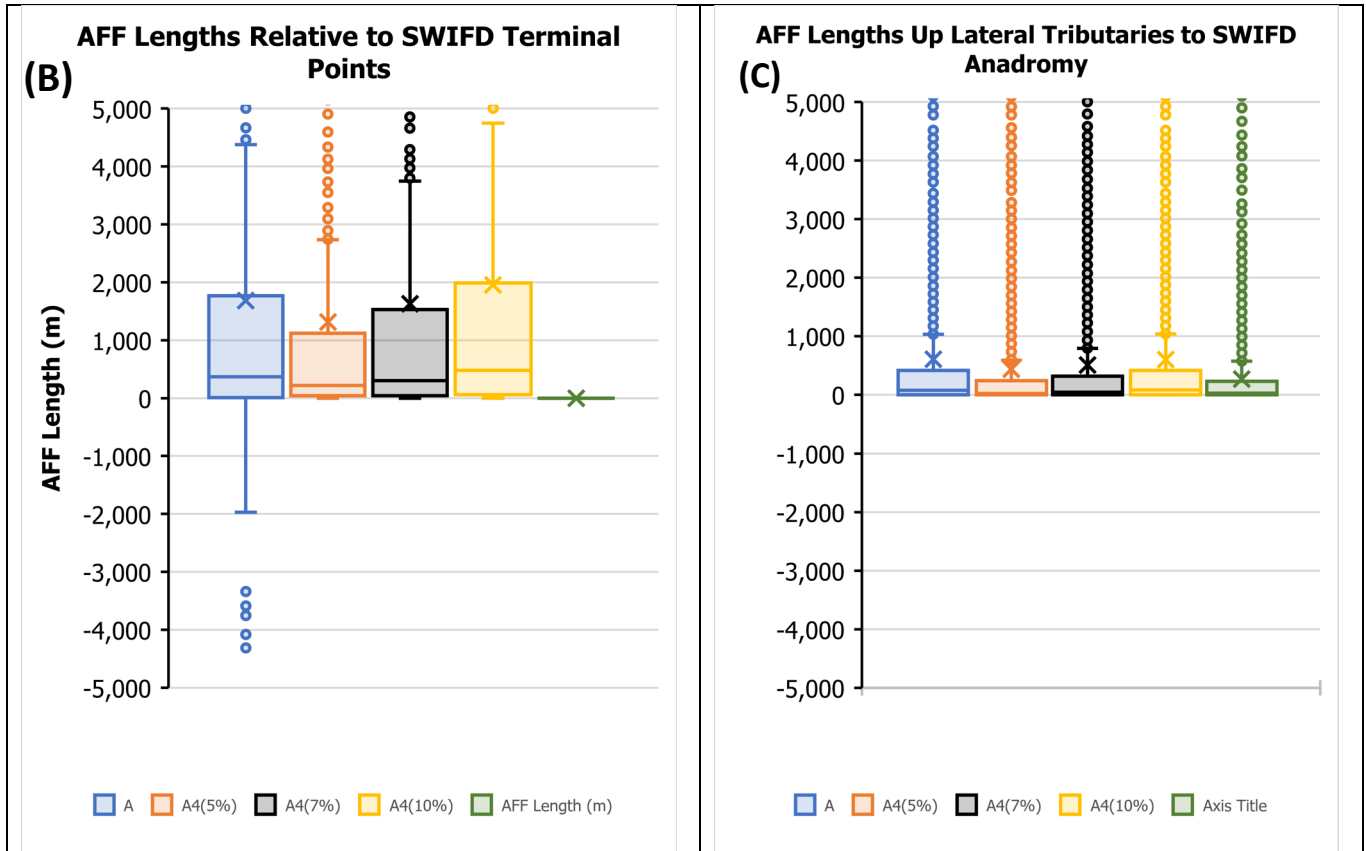


Addendum Figure 11. Frequency histograms of the extent of the modeled AFF relative to (A) Terminal and lateral streams combined, (B) Terminal points, (C) lateral tributaries connected to streams with SWIFD data. The x-axis is truncated for legibility – see Addendum Figure 12 for full range of modeled AFF above terminal anadromous fish reference points.

SWIFD - Box and Whisker plots

For Alternatives A4 and D, the SWIFD data define the anadromous core, so the AFF extends at least to the terminal SWIFD points: there are no negative lengths for these alternatives (*Addendum Figure 12*). For Alternative D, the modeled AFF stops at the terminal SWIFD points, so there are also no positive values for this category. Alternative A references a gradient or natural barrier rather than fish data points and for some channels the modeled AFF does not extend to the terminal SWIFD points, indicated by the negative values, and for other channels the AFF continues beyond the terminal SWIFD points, indicated by extension of the box and whiskers to positive values. In these plots the mean is indicated by the “X” and the median by the horizontal line inside each box. The distributions of AFF lengths upstream of the terminal points are skewed, with a larger proportion of smaller values indicated by the mean being above the median.





Addendum Figure 12. Box and whisker plots for the distributions of AFF lengths upstream of the (A) combined terminal SWIFD points and connected lateral tributaries, (B) upstream of just terminal points, and (C) upstream on lateral tributaries connected to SWIFD streams.

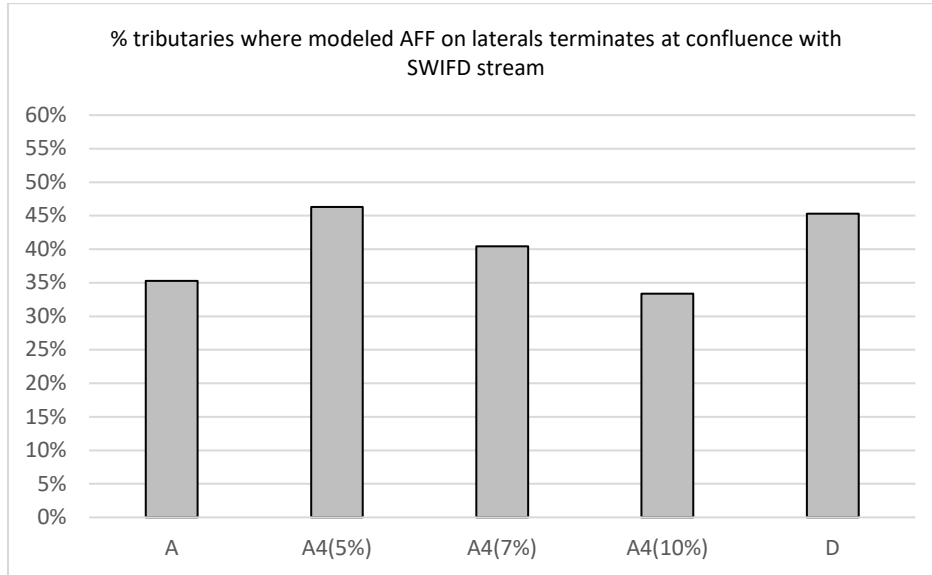
AFF extension up lateral tributaries is measured from the confluence with a channel having known anadromy, so there are no negative values (*Addendum Figure 12 C*).

There are multiple examples of the modeled AFF extending far distances upstream on lateral tributaries from known anadromous waters (*Addendum Figure 12*). Many of these streams fall into the ‘unsurveyed’ category, and the extent salmon are using them is currently unknown. However, in reviewing the magnitude of the outliers, the PIs discovered that when fish reference data were originally provided to Terrainworks for model development, SWIFD data from several Skagit River tributaries were excluded.¹ This explains the presence of several extremely long (>60km) reaches where the AFF alternatives extend beyond anadromous reference points included in the model. These points are recognizable as outliers in the histogram and box-and-whisker figures below (e.g. *Addendum Figure 12 A* & *Addendum Figure 15 A*).

¹ When the AFF analysis was first developed in the Skagit River watershed by the westside tribes in 2019, SWIFD data were not used to estimate anadromous fish distributions. That analysis instead used Skagit-LFA fish points. When the AFF analysis was expanded to include additional watersheds and the decision was made to incorporate SWIFD data into the analysis, the initial plan for the Skagit was to include only basins in the analysis where Skagit-LFA data points were present. However, when the synthetic stream layers were created for the study, these basins were included as part of that effort while the SWIFD data remained excluded, creating the current SWIFD data gap.

The presence of these outliers is the result of erroneous omissions of data that affected all the Alternatives and should not be confused with a deficiency in their performance.

Relative to lateral tributaries, 33% to 46% of the modeled AFF reaches terminate at their confluences and do not extend up these streams (*Addendum Figure 13*).



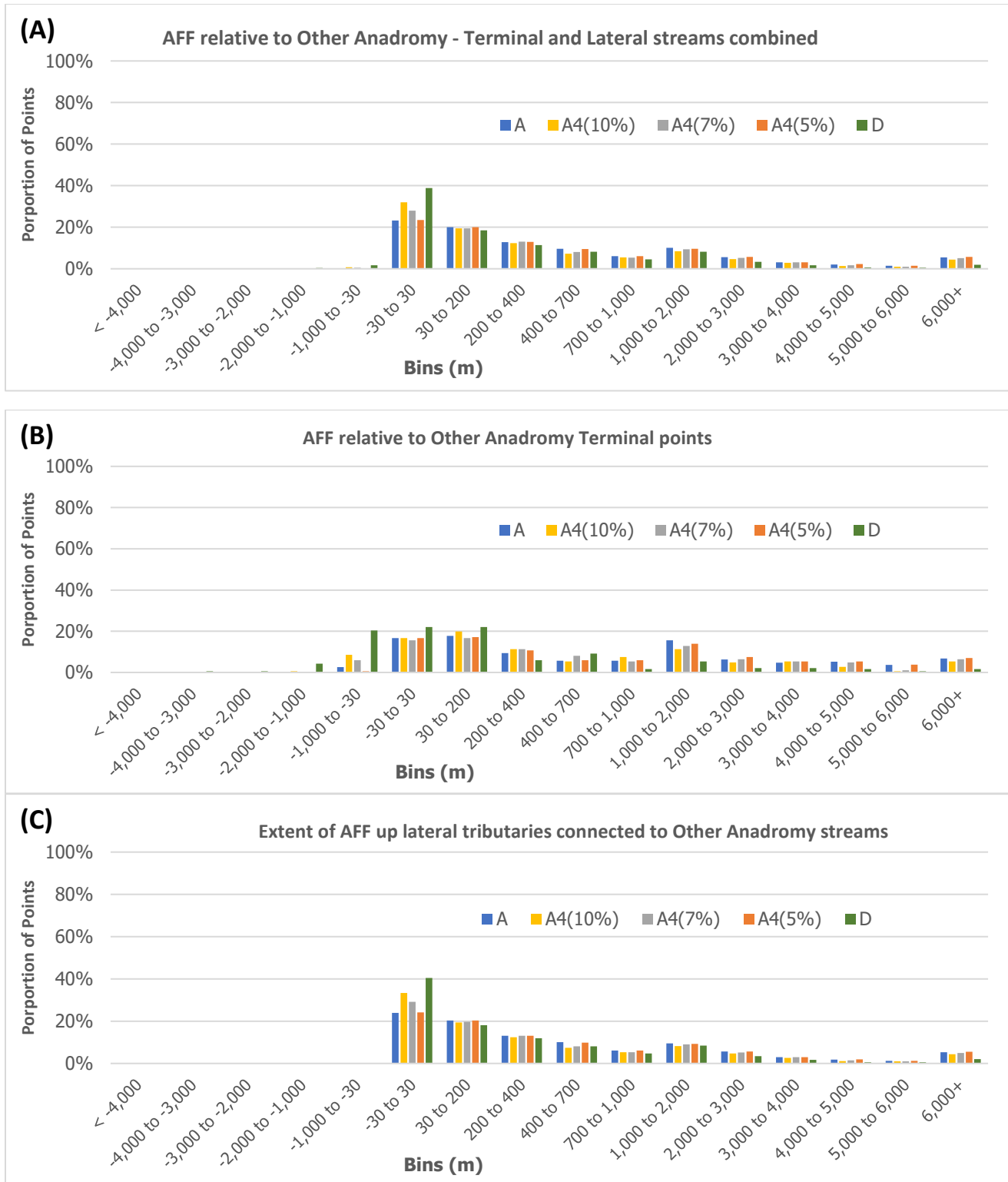
Addendum Figure 13. Occurrence of modeled AFF on SWIFD streams did not extend up lateral streams lacking SWIFD fish data.

Extent of AFF relative to Other Anadromy

Other Anadromy – Histograms

For ‘Other Anadromy’ all alternatives have some channels for which the modeled AFF does not extend to the terminal data points, shown by the bars in the negative bins (*Addendum Figure 14 A & B*).

Where the modeled AFF extends up connected lateral tributaries to Other Anadromy streams, the distance is typically less than a kilometer (*Addendum Figure 14 C*).



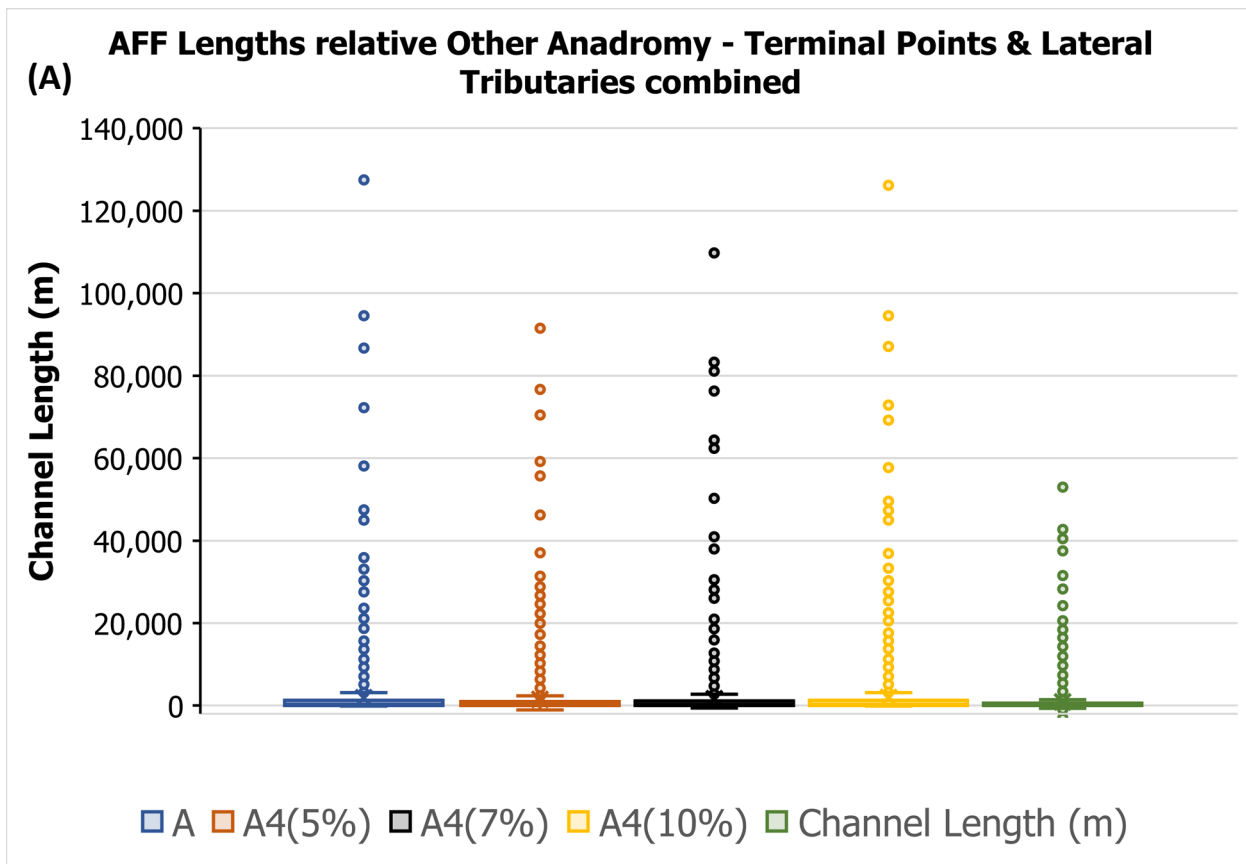
Addendum Figure 14. Frequency histograms of the extent of the modeled AFF relative to (A) Terminal and lateral streams combined, (B) Terminal points, (C) lateral tributaries connected to streams with Other Anadromy data. The x-axis is truncated for legibility – see *Addendum Figure 15* for full range of modeled AFF above terminal anadromous fish reference points.

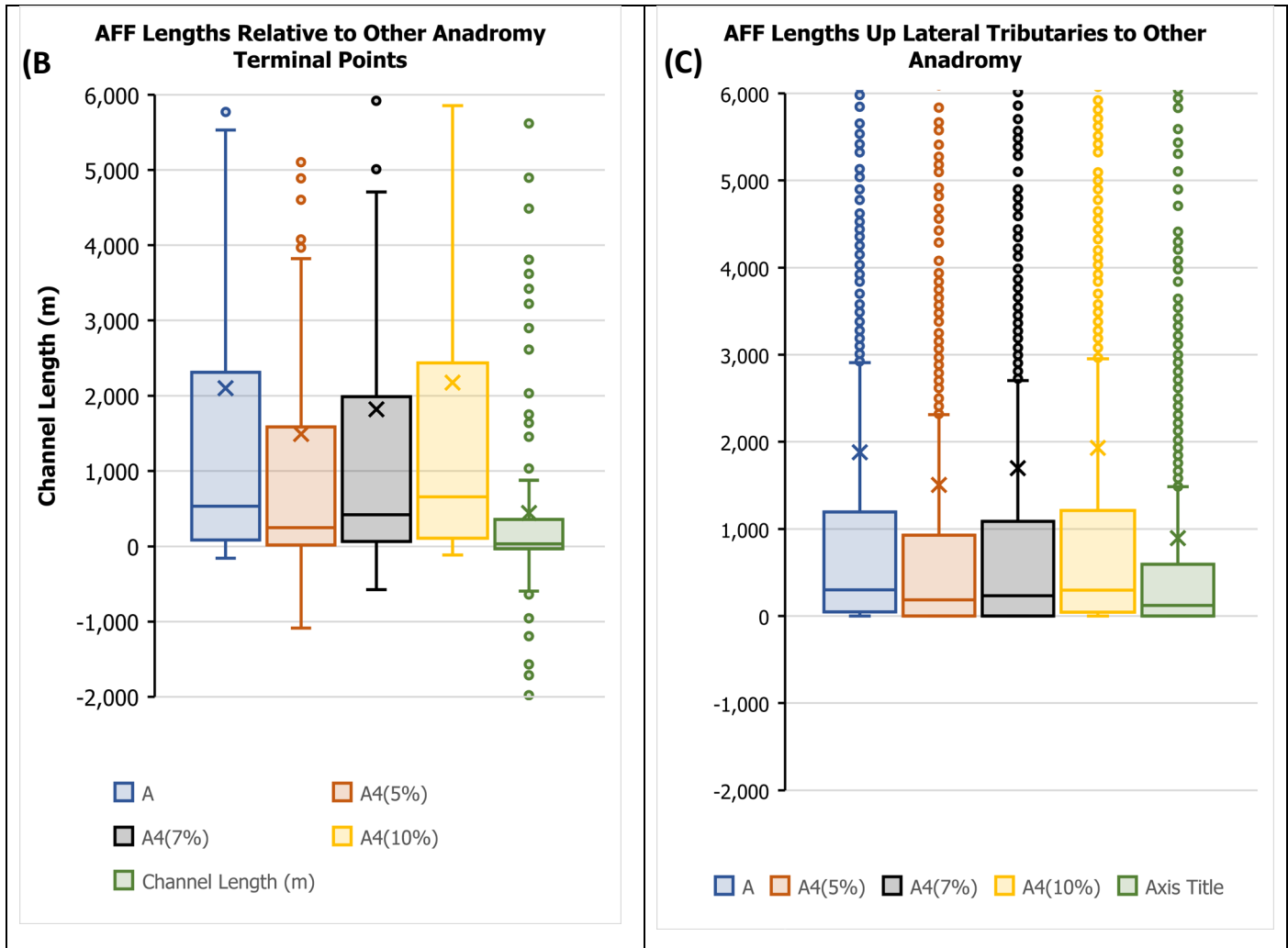
Other Anadromy – Box and Whisker plots

For all alternatives we find examples where the modeled AFF does not extend to terminal Other Anadromy points and other examples where the modeled AFF continues upstream of the terminal points (*Addendum Figure 15 A & B*).

AFF extension up lateral tributaries is measured from the confluence with a channel having known anadromy, so there are no negative values (*Addendum Figure 15 C*).

There are multiple examples of the modeled AFF extending far distances upstream on lateral tributaries from known anadromous waters. Many of these streams fall into the ‘unsurveyed’ category, and the extent salmon are using them is currently unknown (*Addendum Figure 15*). The same caveat applies to these results as described in the SWIFD section (See *Addendum Figure 12*, footnote and explanatory text). The large values (outliers) displayed in panel A of *Addendum Figure 15* need to be interpreted with caution as many of the long extensions of the AFF on lateral streams upstream of ‘Other Anadromy’ streams are on tributaries in the Skagit with known anadromy data (SWIFD) that were erroneously omitted from the analyses.





Addendum Figure 15. Box and whisker plots for the distributions of AFF lengths upstream of the (A) combined terminal Other Anadromy points and connected lateral tributaries, (B) upstream of just terminal points, and (C) upstream on lateral tributaries connected to Other Anadromy streams. AFF extension up lateral tributaries is measured from the confluence with a channel having known anadromy, so there are no negative values. The 'x' in the plots indicates the mean, the line in the box indicates the median.

Addendum Table 1 lists the mean and median distances the modeled AFF extends beyond the terminal known anadromy points and upstream on connected lateral tributaries.

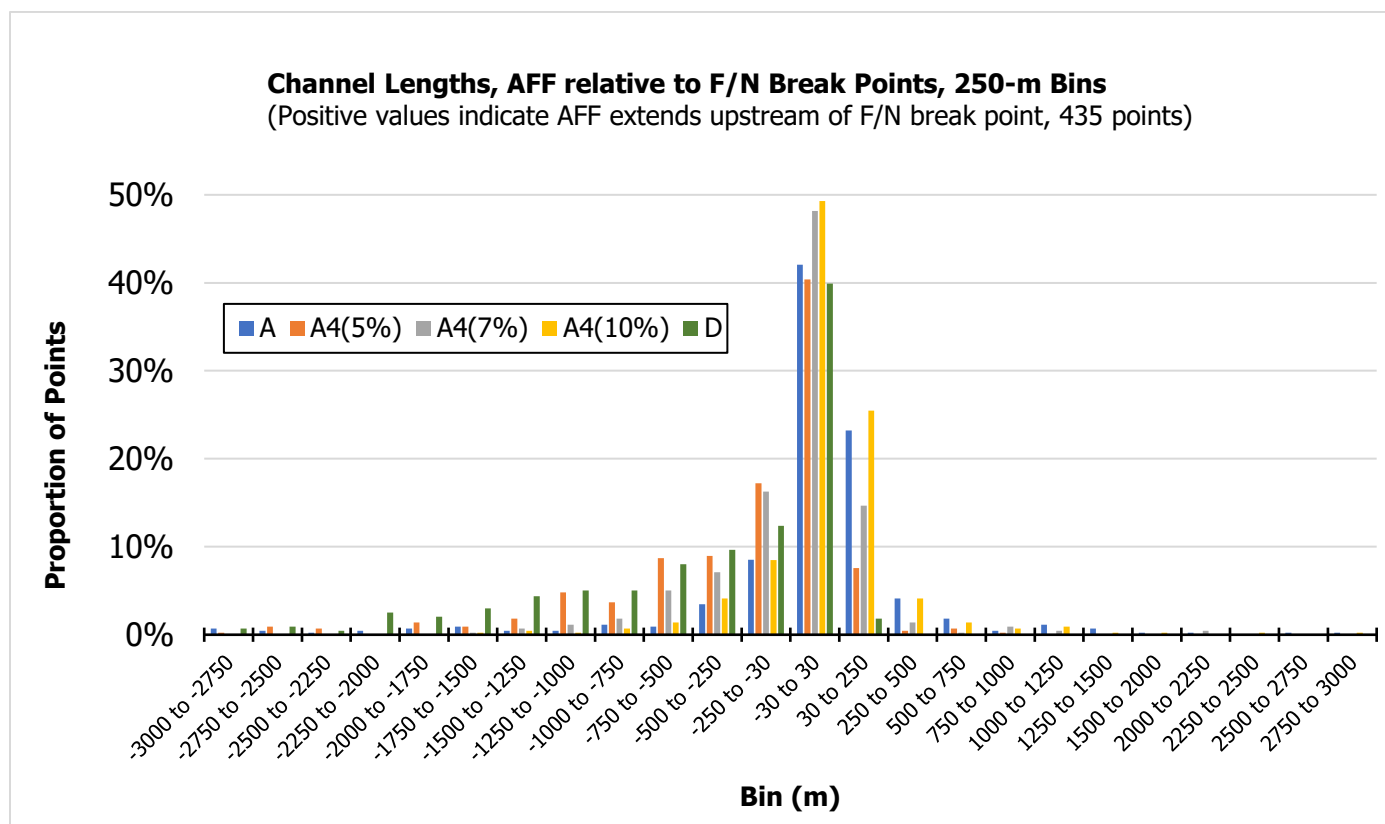
Most of the modeled AFF extends less than 500 meters beyond the terminal points of known anadromy on SWIFD streams in all of the alternatives (*Addendum Table 1*), and less than 100 meters up connected lateral tributaries to SWIFD streams (that currently don't have anadromy data).

Addendum Table 1. Summary of mean and median distances modeled AFF extends beyond terminal points and up connected lateral tributaries relative to both SWIFD and Other Anadromy streams.

Alternative	SWIFD					Other Anadromy				
	A	A4(5%)	A4(7%)	A4(10%)	D	A	A4(5%)	A4(7%)	A4(10%)	D
Combined Terminal & Lateral										
Mean (m)	724	532	632	751	240	1,898	1,502	1,703	1,948	858
Median (m)	86	35	57	97	0	310	190	239	307	109
Terminal										
Mean (m)	1,682	1,316	1,628	1,957	0	2,101	1,490	1,817	2,172	445
Median (m)	365	220	304	480	0	533	250	421	659	35
Lateral										
Mean (m)	606	435	510	603	269	1,879	1,506	1,696	1,931	896
Median (m)	74	23	44	81	26	300	185	233	296	120

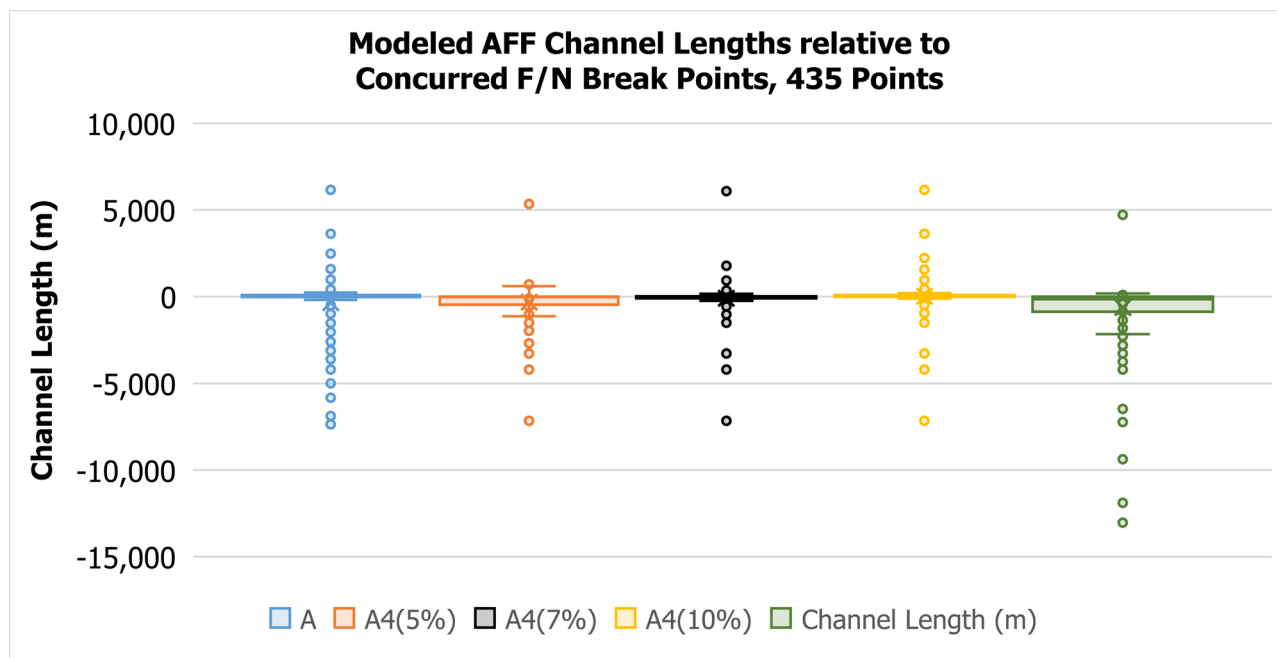
AFF relative to F/N Break Points

Frequency histograms of the modeled AFF stream channels show that a plurality of the AFF in all alternatives terminate within +/- 30 meters of the F/N break (Addendum Figure 16).



Addendum Figure 16. Frequency histogram of the proportion of the streams that fall within the AFF by alternative. Given the imprecision of the mapping translation and lidar interpretation, the AFF streams that fall within the -30 to 30 meter bin are considered coincident with the F/N break points.

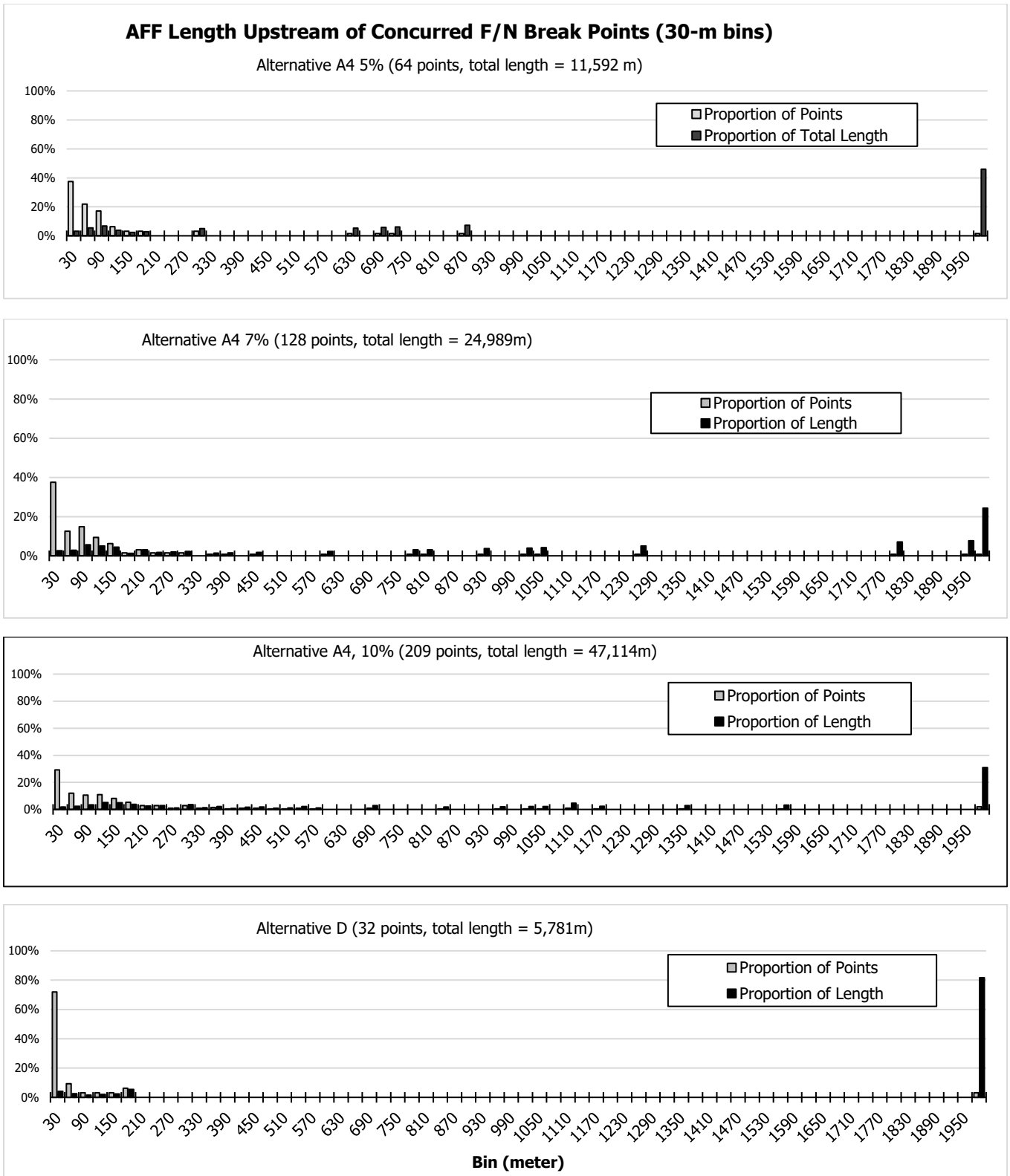
Another way to look at these patterns is with box and whisker plots (*Addendum Figure 17*). As with the frequency histograms, these show the AFF termination points tightly clustered around the F/N break points. The lower whisker boundaries in alternative A4 (5%) and D reach further downstream than the other alternatives, showing there is greater tendency for the modeled AFF to terminate downstream of the F/N break points for these alternatives relative to the other alternatives. The box and whisker plots also show there are locations where each AFF extends upstream of the F/N break point by multiple kilometers.



Addendum Figure 17. Box and whisker plots of the AFF alternatives relative to the F/N break points.

Overshoot channel length distributions relative to F/N Break Points

Frequency histograms of the individual overshoot channel reaches, where the modeled AFF extends above F/N Break points, show that while a majority of these channels in all the alternatives extend less than 100 meters above F/N break, there are locations where the overshoots extend long distances (several kilometers) upstream of the F/N breaks (*Addendum Figure 18*). As a result of these long distances, relatively few of these overshoot locations account for large proportions of the total ‘overshoot’ stream lengths.



Addendum Figure 18. Frequency histograms of the AFF lengths that ‘overshoot’ the F/N break points, sorted into 30 meter bins. The light grey bars show the proportion of stream reaches observed within each bin; the dark bars show what proportion of the total ‘overshoot’ stream length each bin represents. Sample sizes and total overshoot distances for each alternative are provided in the title for each graph.

Addendum Table 2. Total channel lengths (kilometers) for each AFF alternative and stream categories.¹

Stream category	AFF Alternative				
	A	A4 (5%)	A4 (7%)	A4 (10%)	D
Total AFF length	6,647	5,270	5,859	6,555	3,549
AFF in streams with no fish data	5,210	4,125	4,665	5,319	2,482
AFF overlap with fish data					
Overlap of AFF and all anadromy	2,155	NA	NA	NA	NA
Overlap of AFF and SWIFD	2,083	NA	NA	NA	NA
Overlap of AFF and other anadromy	1,060	1,056	1,058	1,059	1,034
AFF ends downstream of highest fish points					
AFF ends downstream of all anadromy	60	NA	NA	NA	NA
AFF ends downstream of SWIFD	60	NA	NA	NA	NA
AFF ends downstream of other anadromy	0.7	5	3	1	27
AFF ends downstream of other fish	80	49	35	31	134
AFF ends upstream of highest fish points					
AFF ends upstream of all anadromy	4,258	3,061	3,647	4,343	1,362
AFF ends upstream of SWIFD	4,296	3,110	3,697	4,392	1,402
AFF ends upstream of other anadromy	4,402	3,485	3,949	4,515	2,015
AFF ends upstream of other fish	3,966	2,844	3,371	4,021	1,287
Relation of AFF with F/N Break points					
AFF ends below F/N break	53	82	47	27	155
AFF ends above F/N break	53	12	26	48	6

¹ Results should be compared between alternatives (within rows), not between stream categories (within columns) because the stream categories use reference fish occurrence data with different sample sizes.

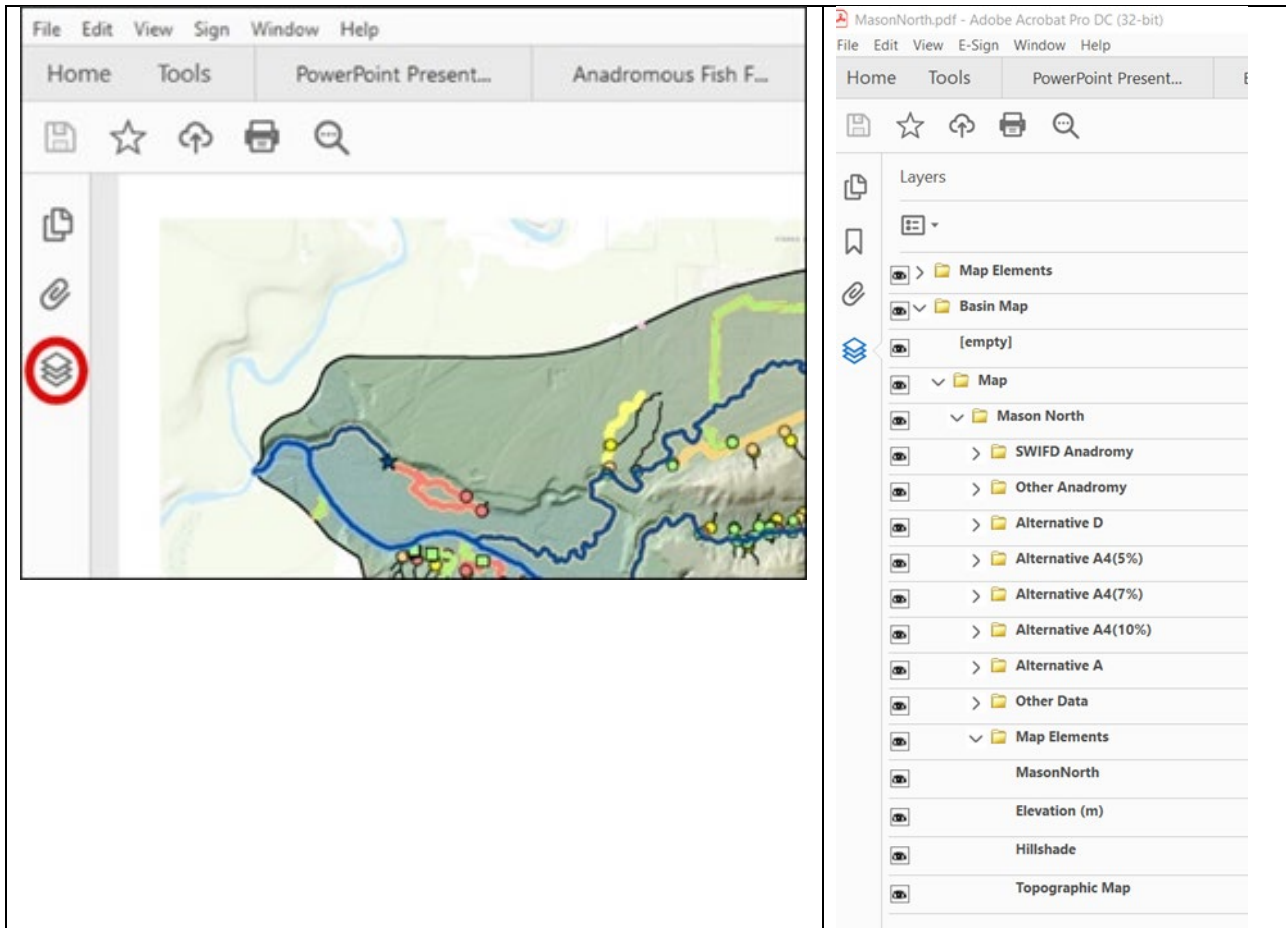
Maps of Selected Basins

Interactive PDF maps of 5 basins were produced. These maps can be downloaded here:

<https://terrainworks.sharefile.com/d-s2ce904cead064489a929c5c02e1f0d64>

The maps are in PDF format and have many layers that can be turned on or off at the reader's preference. In order to allow the reader to look at the map in a way that makes most sense for them, each alternative listed (A, A4(5%), A4(7%), A4(10%), and D) has two layers that show the AFF as either a line extending the full length or as points at the extent of the floor ("end points").

To turn layers on and off in the PDF, click on the layer icon on the panel to the left of the window in adobe reader (Addendum Figure 19).

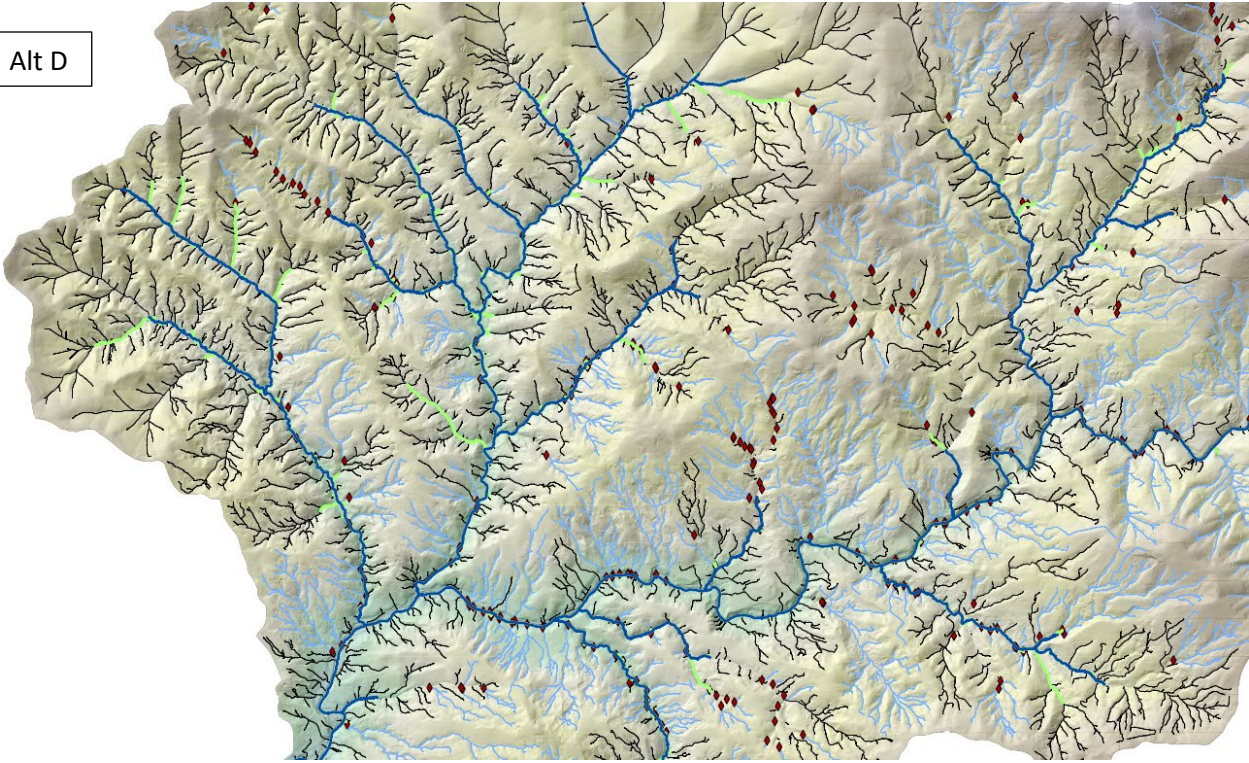


Addendum Figure 19. Screenshot images of Adobe Reader user interface illustrating how to turn on data layers in the PDF maps.

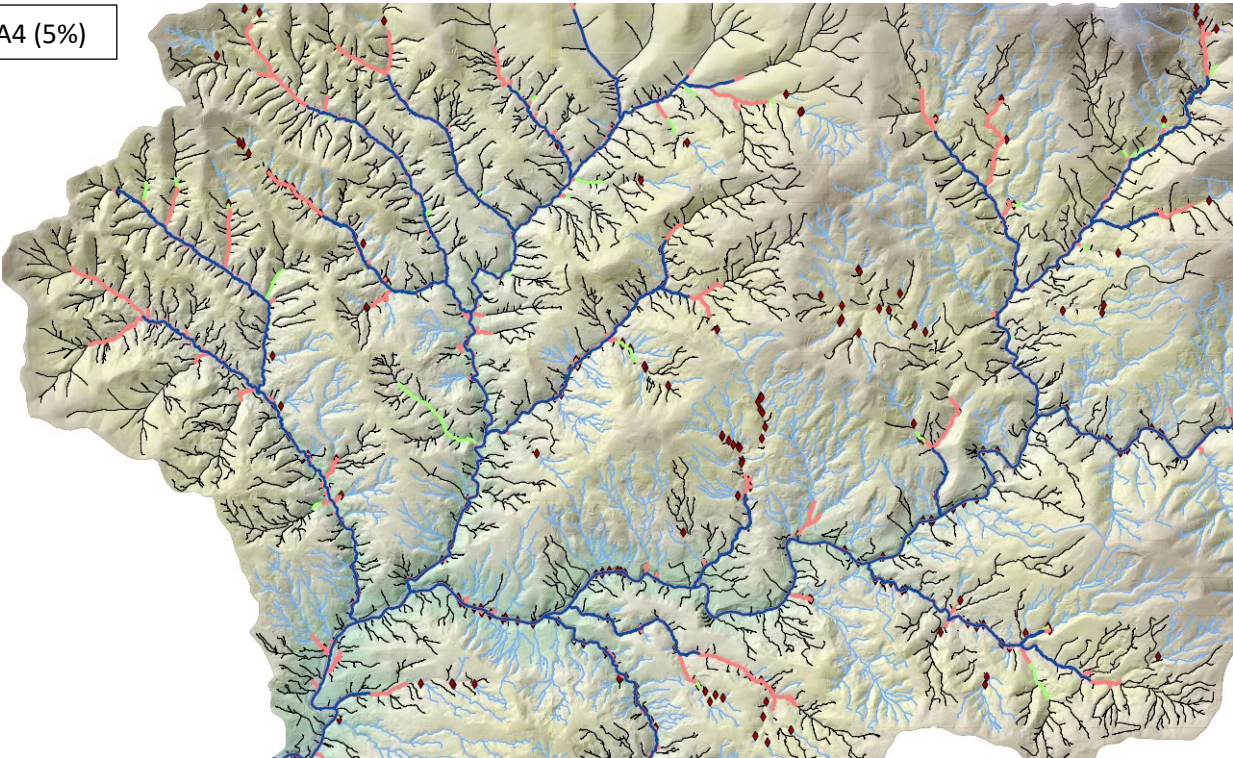
To interact with the maps, open the map using Adobe Reader. Click the stacked icon in the upper right corner of the map page (see panel to left, above) for a drop-down menu from which you can expand the Map Frame and see a list of the available layers. Click on the squares (eye) next to each layer in order to turn that layer on or off. Click on the arrow (>) to see nested layers.

Addendum Figure 20 is a series of images taken from the PDF map of the Kalama that shows how alternatives D, A4 (5%), A4 (7%), A4 (10%) look relative to each other and to the F/N Break points. Included on these maps are streams that have been surveyed and no fish were observed ('verified no fish use'), along with streams that have not been surveyed ('unknown fish use').

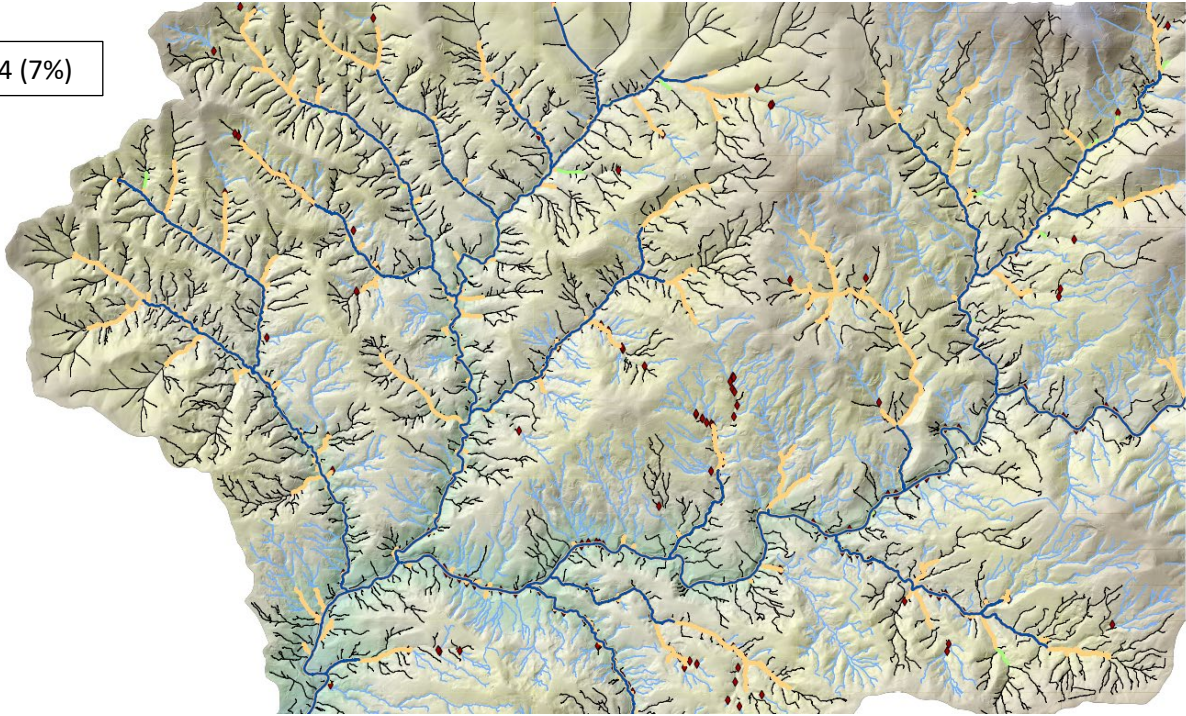
Alt D



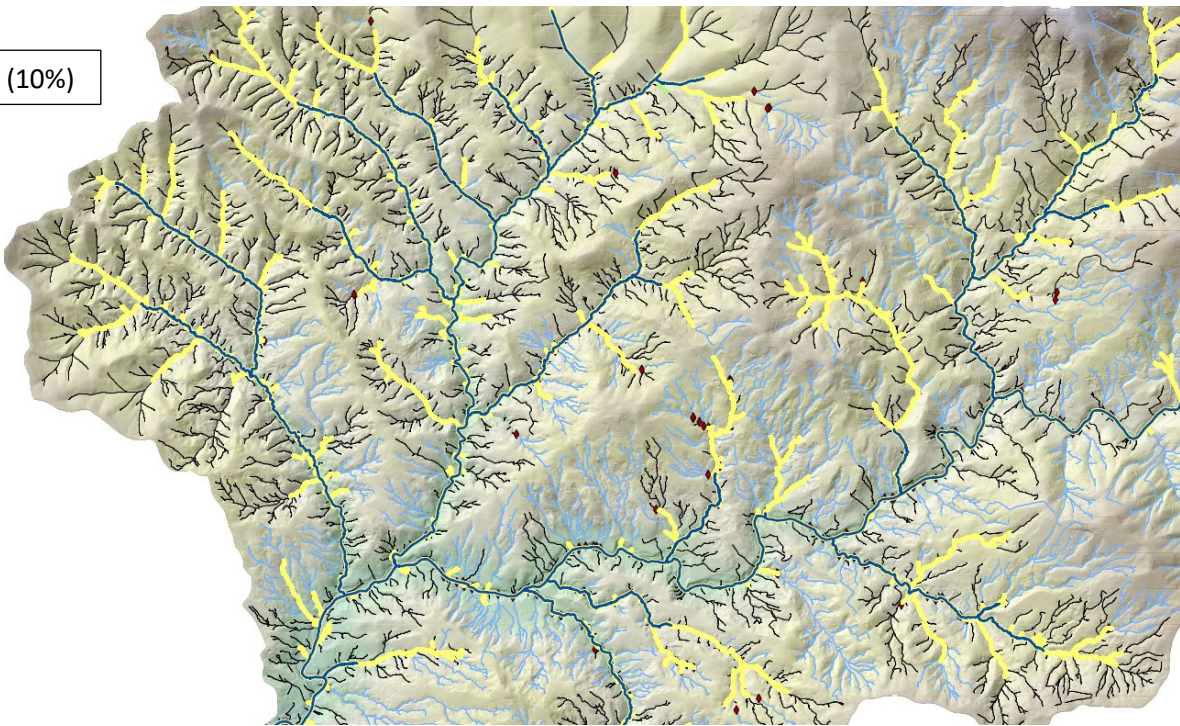
Alt A4 (5%)



Alt A4 (7%)



Alt A4 (10%)



Addendum Figure 20. Basins in the Kalama Watershed that show how the alternatives compare with each other and with the F/N Break points. The dark blue line represents SWIFD (anadromous core) and the red diamonds represent F/N Break points. Light blue lines represent 'verified no fish use' based on current protocol survey methods, black lines represent 'unknown fish use.' Alternative D is displayed as a green line, Alternative A4 (5%) as a red line, Alternative A4 (7%) as an orange line, and Alternative A4 (10%) as a yellow line. In the series of screen shots starting with 'Alt D,' each subsequent alternative is left on, so that by the fourth panel each of the AFF alternative layers remain on.

Discussion

In preparing this addendum the Pls found that the AFFs reliant on a SWIFD core (A4 and D) did not extend up small streams lacking SWIFD data that drain directly into Puget Sound, because the SWIFD layer does not extend into Puget Sound. Future runs of the model should be coded to treat shorelines of the state as within SWIFD.

Another discovery, mentioned in the results above, was that when fish reference data were originally provided to Terrainworks for model development, SWIFD data from several Skagit River tributaries were excluded. This explains the presence of several extremely long (>60km) reaches where the AFF alternatives extend beyond known anadromous reference points. These points are recognizable as outliers in the histogram and box-and-whisker figures (e.g. *Addendum Figure 12 A*, *Addendum Figure 15 A*). The presence of these outliers is the result of erroneous omissions of data that affected all the Alternatives and should not be confused with a deficiency in their performance.

Alternative D

- a. Total modeled AFF channel length was lower under alternative D than any of the A4 alternatives (*Addendum Figure 1*; *Addendum Figure 7*).
- b. The total AFF channel length predicted by the model to occur above the fish reference points (SWIFD, Other Anadromy, F/N Break Points, Other Fish) was lower under alternative D than any of the A4 alternatives (*Addendum Figure 2*; *Addendum Figure 3*; *Addendum Figure 5*; *Addendum Figure 6*).
- c. The occurrence of the AFF terminating downstream of uppermost Other Anadromy reference data was higher under Alternative D than any of the A4 alternatives (*Addendum Figure 3*; *Addendum Figure 4*).

Alternative A4

Similar to findings presented in the main report (December 3, 2021), as the A4 gradient threshold values increase the total modeled AFF lengths increase (*Addendum Figure 1*). Also similar to the findings presented in the main report, as gradient threshold values increase there is an associated:

- a. Increase in the total modeled AFF channel length upstream of fish reference points (SWIFD, Other Anadromy, F/N Break Points, Other Fish) (*Addendum Figure 2*; *Addendum Figure 3*, *Addendum Figure 5*; *Addendum Figure 6*).
- b. Increase in the total modeled AFF channel length in Unsurveyed Streams (*Addendum Figure 7*).
- c. Reduction in the occurrence of the AFF terminating downstream of uppermost Other Anadromy reference data (*Addendum Figure 3*; *Addendum Figure 4*, *Addendum Figure 8*).

Patterns in the distribution of individual channel lengths that terminate below or extend beyond known anadromy

Terminal points

- a. AFF extension upstream of terminal points is less than 1 kilometer for most cases, although there are multiple cases where the modeled AFF extends well over 10 kilometers upstream of the terminal points (*Addendum Figure 12*; *Addendum Figure 15*, *Addendum Table 1*).

- b. The distribution of AFF lengths upstream of the terminal points extends to larger positive values as the sustained-gradient threshold increases (Addendum Figure 12; Addendum Figure 15; Addendum Table 1).

Lateral tributaries

- a. Most modeled AFF extends less than 500 meters up lateral tributaries connected to Other Anadromy streams, and less than 100 meters on tributaries connected to SWIFD streams. There are however examples of the modeled AFF extending much greater distances (Addendum Figure 11; Addendum Figure 14, Addendum Table 1).
- b. Tributaries connected to 'Other Anadromy' streams tend to have longer modeled AFF lengths than tributaries to SWIFD (Addendum Table 1)
- c. The patterns for both SWIFD and Other Anadromy are similar: the distributions are dominated by shorter lengths, indicated by the median being less than the mean (Addendum Figure 12; Addendum Figure 15; Addendum Table 1).
- d. The average length that the modeled AFFs extend upstream on lateral tributaries increases with increasing sustained-gradient threshold (Addendum Table 1).
- e. On average, the AFF extends up connected laterals the shortest distances on Alternative D, and the longest distance on alternatives that use a 10% gradient threshold (Addendum Table 1).
- f. Alternative D uses PHBs to define the upstream extent of the AFF and these tend to occur downstream of the modeled sustained-gradient thresholds, indicated by the shorter average lengths of AFF extension into lateral tributaries (Addendum Table 1).

Patterns in the distribution of individual channel lengths that 'undershoot' and 'overshoot' Type F/N Break points

- a. The modeled AFF tends to terminate on streams near the F/N break points in all the alternatives (Addendum Figure 17).
- b. For all AFF alternatives, a large portion of the total AFF stream channel length upstream of F/N Break Points (overshoots) is associated with a relatively small number of points (Addendum Figure 18).