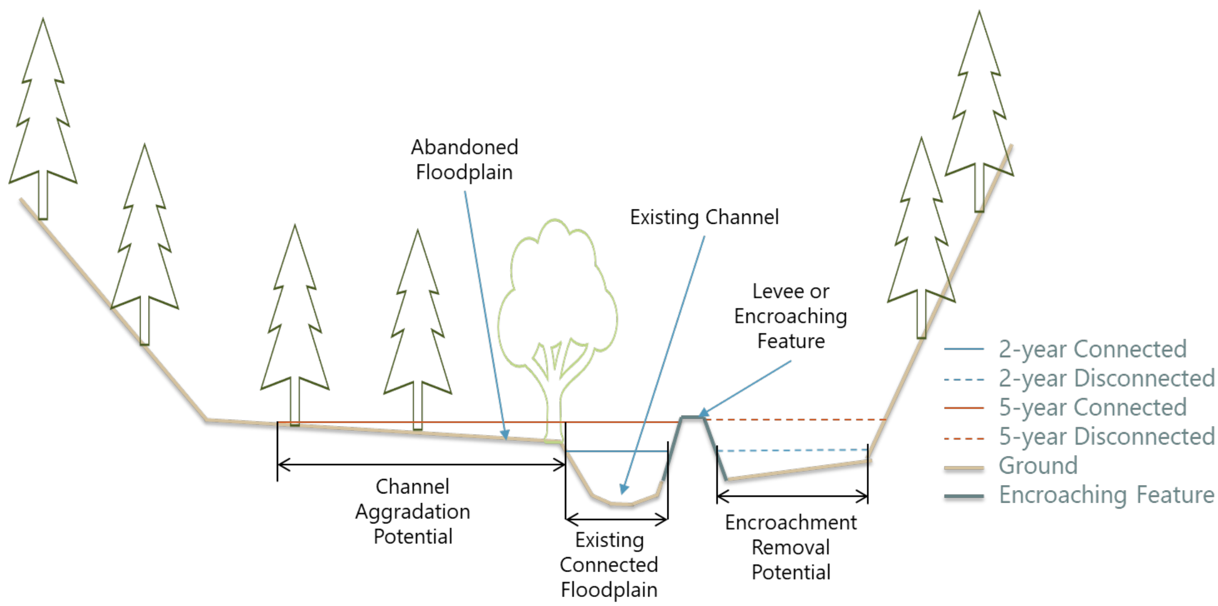
Appendix F
Connectivity Analysis

Floodplain connectivity is an important metric for gauging the state of a riparian area. Connected floodplains provide benefit for nearly all riverine aquatic species in the form of habitat, high-flow refugia, nutrient influx, and woody material. Hydraulically connected floodplains are key in developing riparian areas, which provide the material for instream wood, which in turn forces much of the geomorphic processes associated with the functioning river system. Confining features along the banks of the Tucannon River and within the floodplain influence hydraulic conditions during large floods, affecting local and reach-scale geomorphic processes such as sediment mobility and channel migration. Confining features may be both natural and influenced by anthropogenic activities. Inspections of aerial photography, Light Detection and Ranging (LiDAR), and field reconnaissance were used to identify confining features within the study area. These features include bedrock along the valley wall, alluvial fan deposits, bank armoring (e.g., riprap), levees and pond berms, and road prisms. Additionally, the Tucannon River can be disconnected from the floodplain through channel incision and downcutting. Channel incision is often associated with encroaching features such as levees or bedrock valley walls because straightened channels provide more stream power for sediment transport. Channel incision is often the beginning of a cycle of sediment starvation. The benefits and concept of floodplain connectivity are discussed in greater detail in the main report. The following section describes how floodplain connectivity was assessed for this assessment as well as a detailed review of the results of the assessment.

Analysis Overview

The purpose of this analysis is to describe the floodplain connectivity of a reach in a way that can be compared to the other reaches in the system and help inform potential restoration actions. The analysis focused on three characteristics of the floodplain: 1) the area of floodplain currently accessed and connected at a given flow event; 2) the area that could potentially be accessed given the removal of encroaching features; and 3) the area that could be accessed given sediment deposition and reversal of channel incision. Figure F-1 provides a conceptual valley cross section showing these three floodplain characteristics. The existing floodplain and potential floodplains are represented as lengths in this cross section but will be discussed as 2D (areas) for this assessment as the concept in Figure F-1 is applied along the length of the valley for each assessment reach.

Figure F-1
Conceptual Cross Section of Floodplain and Floodplain Potential



Removal of encroaching features and channel bed aggradation (or reversing channel incision) were chosen as potential restoration actions because they are common restoration techniques and are recommended in the main report. They are also two metrics that are directly related to floodplain connectivity, making representations of these actions easily computed using these data. It should be noted that these restoration actions, particularly channel bed aggradation, may be treating symptoms of other underlying problems with the geomorphic processes of the reach. When performing any restoration action, it is essential to consider the underlying drivers behind the current state of the reach in question, and address those as well. The restoration actions discussed here are recommended simply as a measure of potential in the floodplain. The main report explores additional restoration actions, measures, or considerations that may need to be taken to ensure the success of either of the above restoration actions.

Based simply on the frequency of occurrence, outcomes from restoration efforts in the Tucannon River basin are best evaluated on a flow recurrence interval of 2 years or less, and therefore this analysis focuses on that 2-year flow recurrence interval. To assess how much area could potentially be inundated at the 2-year flow event with minimal investment, the analysis examined the 5-year event as a representation of floodplain inundation potential at the 2-year event given positive outcomes from restoration activities. Figure F-1 shows how these flow events relate to the three conceptual floodplain characteristics discussed previously, and Table F-1 describes in more detail how these areas are used in this assessment.

The first step in evaluating the availability and potential for floodplain connectivity was to create relative elevation maps (REMs) based on the water surface elevations from the hydraulic 1D model. The REMs were then projected onto the terrain to determine estimated extents of inundation at the 2-year and 5-year flow events. This method allows all areas to be counted in the floodplain below the water surface elevation at a given point along the thalweg. This has the advantage of counting areas that are not hydraulically connected and that would not otherwise be counted using only the hydraulic model results. However, it should be noted that because these results are based only on the elevations and data from the LiDAR, they may not exactly match the conditions seen at this time in reality. For example, a side channel that is currently inundated because a large log jam has caused a backwater and forced flow down the channel has the possibility of appearing as not connected in these results if that side channel is actually higher in elevation than the water surface would be without the log jam. Therefore, this analysis should be seen as an assessment of how the elevations and channel geometries would be inundated without more temporary features such as log jams. Because these temporary features that could cause these minor inconsistencies may not exist after several high-flow events, this analysis represents a longer-term assessment of the topography and geomorphology of the basin and is appropriate for an analysis of events that occur less frequently.

These results were then trimmed slightly to discount areas that could never reasonably be inundated, such as behind highway prisms, in the Wooten Lakes, or in the town of Starbuck. Additional areas, which are unlikely to be inundated in the foreseeable future but are not impossible based on input from the basin stakeholders, have been labeled as “Unobtainable” and not included in the assessment. However, these areas are still shown on the GIS layers as part of this assessment, for reference, and mostly include agricultural fields with already installed setback levees and other low-lying areas behind levees that are unlikely to be removed.

The final resulting area, example shown in Figure F-2, represents the total amount of floodplain that could possibly be available at the given flow event, including areas that are currently disconnected via levees or other non-anthropogenic features. These floodplain areas were then separated into connected and disconnected areas so that the sum of both represents the total available low-lying floodplain (see Equation F-1). The disconnected areas are any part of the available floodplain that would be inundated during the flow event but are not hydraulically connected to the main channel. These areas can either be completely disconnected or hydraulically disconnected, meaning that, while the area does connect to the floodplain at the downstream end, there is no upstream flow path and the area is unlikely to be inundated through backwater alone. Removing these areas leaves the connected low-lying floodplain (the area that is currently available at a given flood event), as shown in Figure F-3. These areas were evaluated on a project area reach basis and divided by valley length to determine a standardized value.

Equation F-1

$$C_{yp} + D_{yp} = A_{yp}$$

where:

A_{yp}	=	available floodplain per valley length
D_{yp}	=	disconnected floodplain per valley length
C_{yp}	=	connected floodplain per valley length
Y	=	any given flow recurrence interval (2-year or 5-year)
P	=	any given project area

Figure F-2
Total Available Floodplain for 2-year and 5-year Flow Events

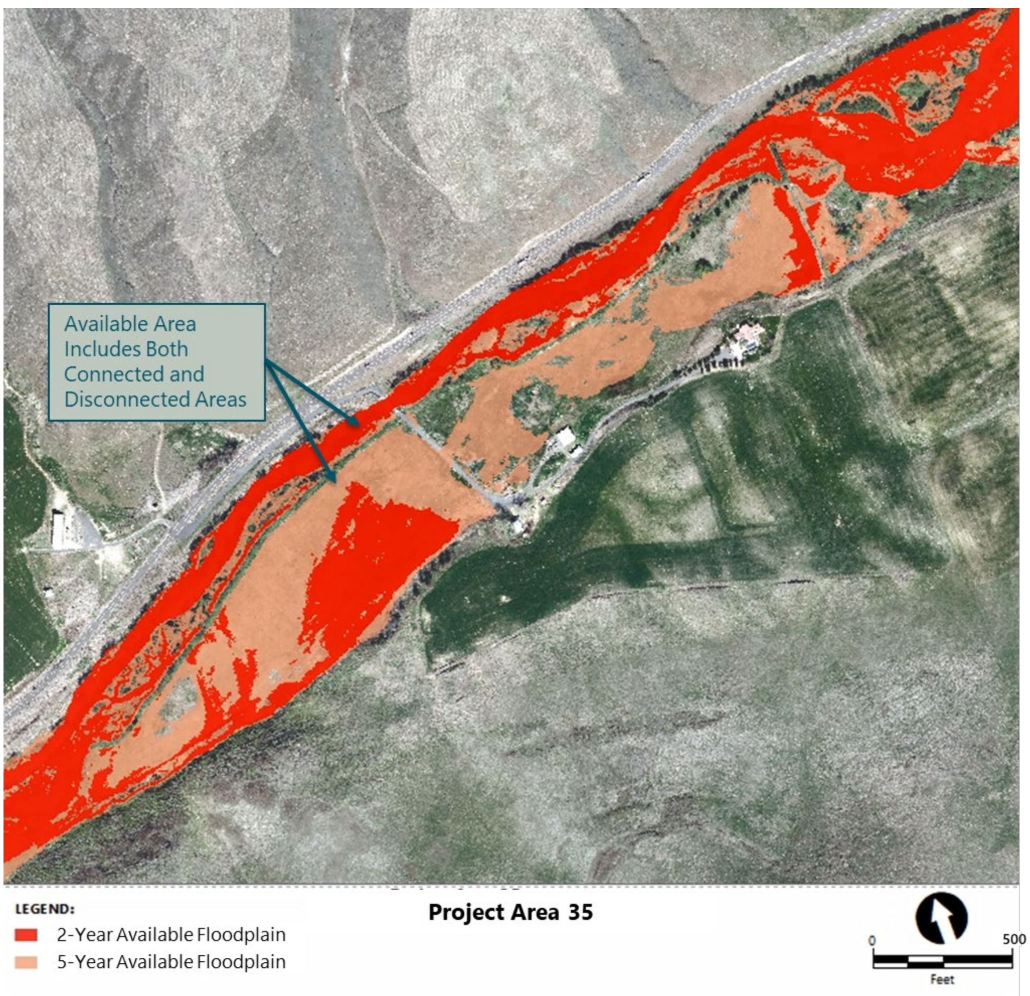
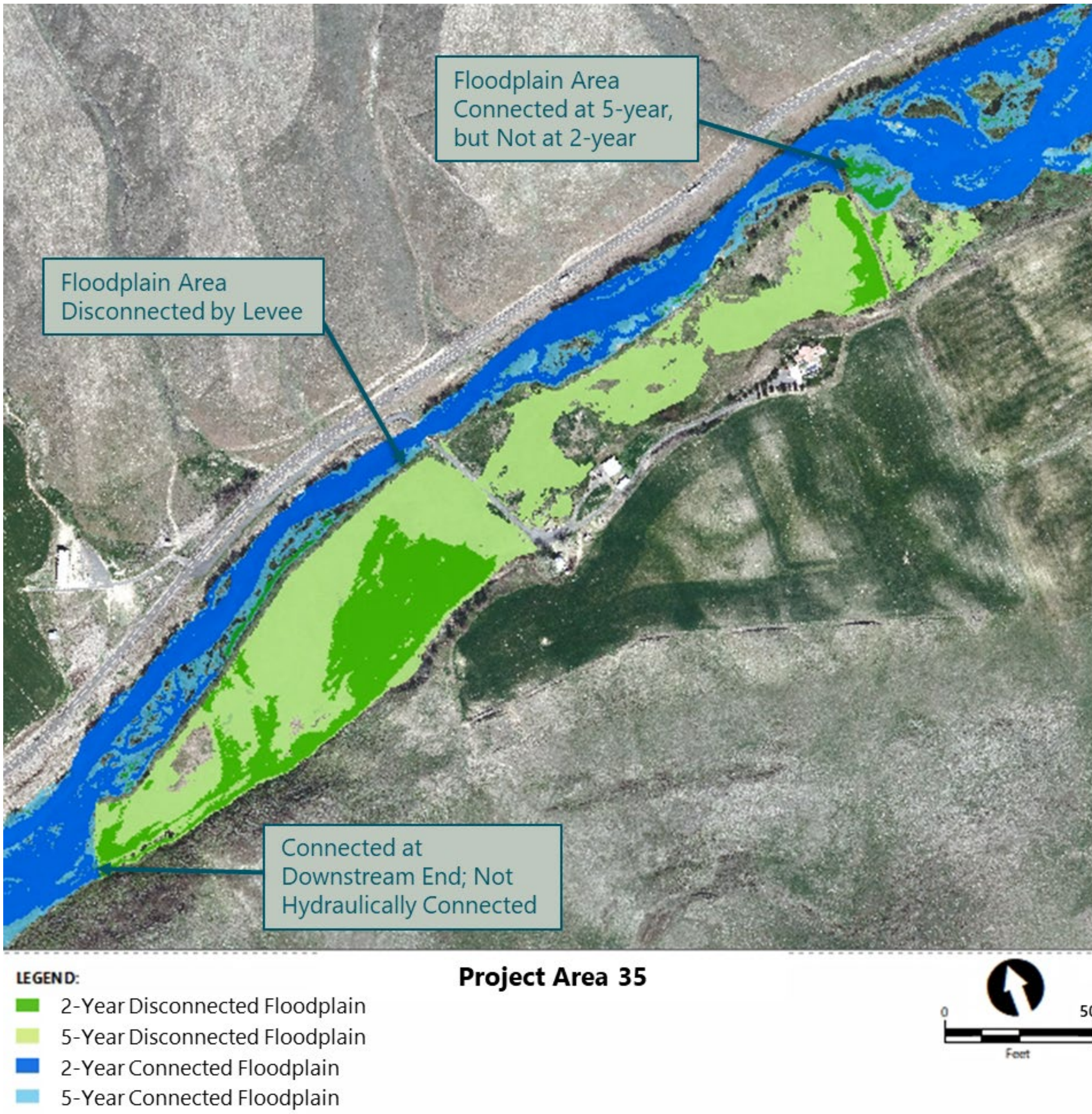


Figure F-3
Connected vs. Disconnected Floodplain for the 2-year and 5-year Events



Based on the assumption that the area inundated at the 5-year flow event represents the approximate maximum possible potential for the 2-year floodplain connection, the different areas of inundated floodplain can be assigned a conceptual significance greater than what they directly represent. These modeled inundated areas and the conceptual areas they represent are explained in

Table F-1. This analysis focuses on four of these areas in particular, examined as a percent of the total potential area that could be inundated (represented by the 5-year available floodplain):

- The area currently inundated at the 2-year flow, shown in Figure F-1 as the "Existing Floodplain"
- The additional area that could be inundated given channel bed aggradation, shown in Figure F-1 as the "Channel Aggradation Potential"
- The additional area that could be inundated given removal of encroaching features, shown in Figure F-1 as the "Encroachment Removal Potential"
- The additional area that could be inundated given both channel bed aggradation and removal of encroaching features, shown in Figure F-1 as both the "Encroachment Removal Potential" and Channel Aggradation Potential" combined

Table F-1
Modeled Floodplain Areas and Conceptual Significance

Floodplain Area	Description	Conceptual Significance	Use in Final Analysis
2C	2-year connected floodplain	The currently connected floodplain at the 2-year event.	None
2D	2-year disconnected floodplain	The floodplain disconnected by levee or other encroaching feature at the 2-year event.	None
2A	2-year available floodplain	The total floodplain area with elevation low enough to be accessed by the 2-year event, connected or not.	None
5C	5-year connected floodplain	The area of floodplain that could potentially be connected at the 2-year event with sufficient channel bed aggradation or other rise in water surface elevation.	None
5D	5-year disconnected floodplain	Not used. [1.]	None
5A	5-year available floodplain	The total area potentially connected at the 2-year event given channel bed aggradation and removal of encroaching features.	None
$\frac{2C}{5A}$	2-year connected divided by 5-year available floodplain	The percent of the potentially available area that is <u>currently inundated at the 2-year flow.</u> Used as an analysis result for connectivity (Figures F-4 and F-5).	Existing Connected Floodplain
$\frac{(5C-2C)}{5A}$	5-year connected minus 2-year connected divided by 5-year available floodplain	The percent of the potentially available area <u>gained via channel bed aggradation.</u> Used as an analysis result for connectivity (Figure F-6).	Channel Aggradation Potential

Floodplain Area	Description	Conceptual Significance	Use in Final Analysis
$\frac{2D}{5A}$	2-year disconnected divided by 5-year available floodplain	The percent of the potentially available area gained via removal of encroaching features. Used as an analysis result for connectivity (Figure F-7).	Encroachment Removal Potential
$\frac{(5A-2C)}{5A}$	5-year available minus 2-year connected divided by 5-year available floodplain	The percent of the potentially available area gained via simultaneous removal of encroaching features and channel bed aggradation.[2] Used as an analysis result for connectivity (Figure F-8).	Total Floodplain Potential

Notes:

1. The 5-year disconnected area cannot be conceptually accessed without both channel bed aggradation and removal of encroaching features; therefore, modeling just the removal of encroaching features at the 5-year event is not useful for this analysis.
2. This includes removing features that encroach on both the 2-year and 5-year inundation area.

This analysis therefore produces four distinct results: Existing Connected Floodplain, Channel Aggradation Potential, Encroachment Removal Potential, and Total Floodplain Potential. The concepts behind these results are shown in Table F-2. How an individual project area scores in each one of these analysis results can provide insight into what restoration actions will be most effective for that project area. Because all of the analysis results are measured as a percent of the total available floodplain, if a project area scores highly in the Existing Connected analysis result it can be due to two different scenarios.

In the ideal scenario represented in Figure F-4, the existing connected floodplain (2C), is similar to the potential connected floodplain (5C) in that both are already well-connected floodplains and therefore do not have a large amount of potential for restoration. However, the scenario represented in Figure F-5 would also score very similarly to Figure F-4, but in this case the channel is so incised or confined that the potentially available floodplain, as defined for this assessment, is not much larger than the existing connected floodplain. Even though both score highly in the Existing Connected Floodplain analysis result, the two are at the opposite ends of the spectrum for floodplain connection. While this may seem like a drawback to this method, it is actually very useful for prioritization and conceptual restoration. For prioritizing restoration work, reaches with a high amount of potential area available to be reconnected via restoration actions are desirable for restoration work and should be prioritized highly, and conversely project areas with a small amount of potential area are not desirable for restoration work and should not be prioritized. The scenarios in Figures F-4 and F-5 are opposite ends of the connected floodplain spectrum, but both represent scenarios where there is little potential floodplain area to be gained from restoration work. Therefore, project areas similar to these scenarios with high scores in the Existing Connected analysis result can be sorted to the bottom of a prioritization.

Figure F-4
High Existing Connected Floodplain – Ideal Scenario

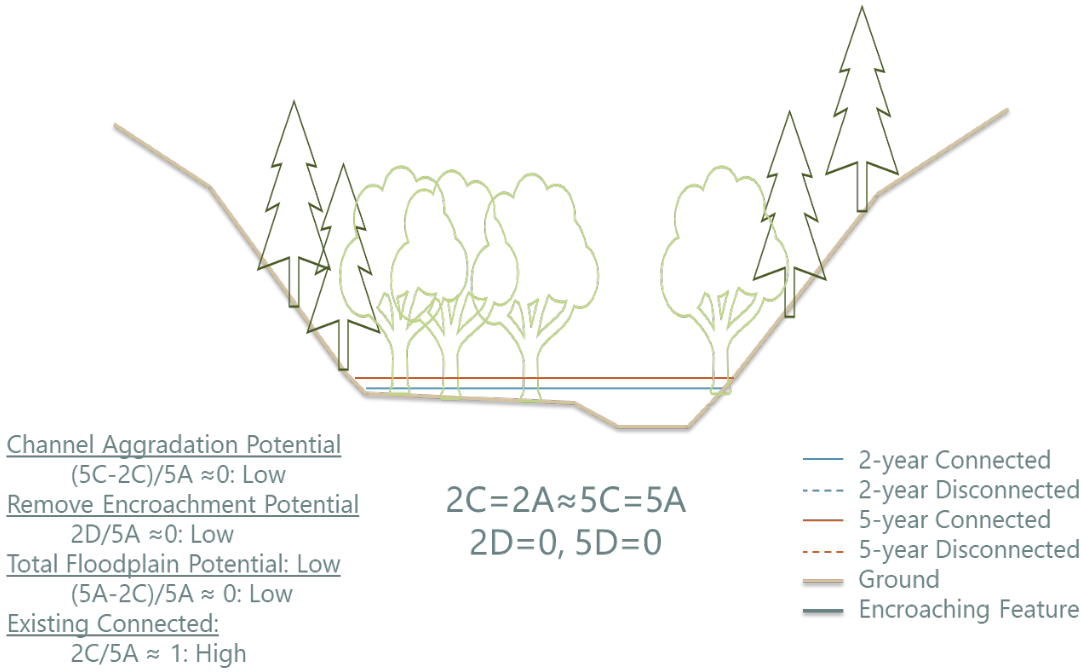
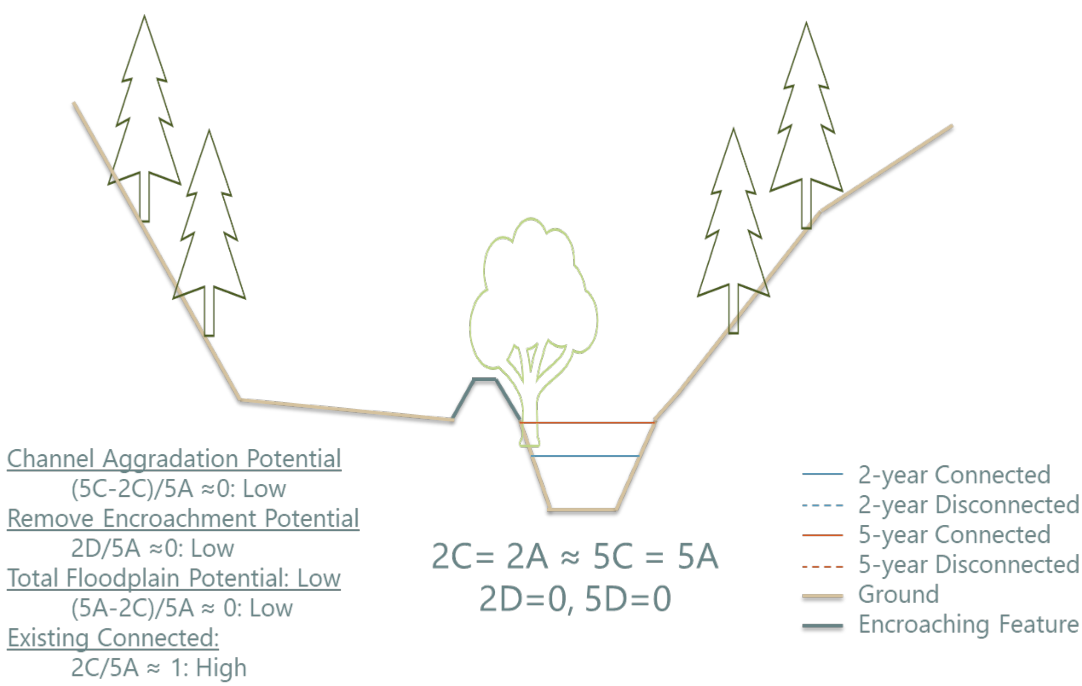


Figure F-5
High Existing Connected Floodplain – Highly Confined Scenario



Several scenarios related to the analysis results indicate that these reaches have floodplain area that is not currently connected but could potentially be connected with restoration work. Figure F-6 shows a scenario where the 2-year connected floodplain connection area is low, but if the channel bed were to aggrade and the water surface elevation raise to a level similar to the current 5-year connected floodplain, a significantly larger area would be connected. This scenario represents a reach that would score highly in the Channel Aggradation potential analysis result. Project areas that score highly in this analysis result will be ranked highly in the prioritization and will have restoration strategies recommended that can help to aggrade the channel bed and reconnect some of this potential area.

Figure F-7 shows a scenario where the 2-year connected floodplain connection area is low, but if an encroachment such as a levee, high bank, or structure were removed a significantly larger area would be connected. This scenario represents a reach that would score highly in the Encroachment Removal potential analysis result. Project areas that score highly in this analysis result will be ranked highly in the prioritization and will have restoration strategies recommended that can reconnect disconnected floodplain.

Finally, a scenario exists where there is some area that could potentially be connected at a 2-year event but is not currently, and neither Encroachment Removal nor Channel Aggradation on their own would be enough to connect these areas. Figure F-8 shows a scenario where, should the encroachment be removed, not much area would be gained, and if the channel bed elevation were raised and the water surface elevation rise to the 5-year level still not much area would be gained. However, if both actions were to occur, a large amount of floodplain area could be connected at the 2-year event. This scenario is represented by the Total Floodplain Potential analysis result and these project areas will be ranked more moderately in the prioritization because they have potential, but more effort is required to connect it.

All of these scenarios represent an idealized condition; in reality, most, if not all, project areas will have some combination of the above scenarios and will be more similar to the scenario shown in Figure F-1.

Figure F-6
High Channel Aggradation Potential

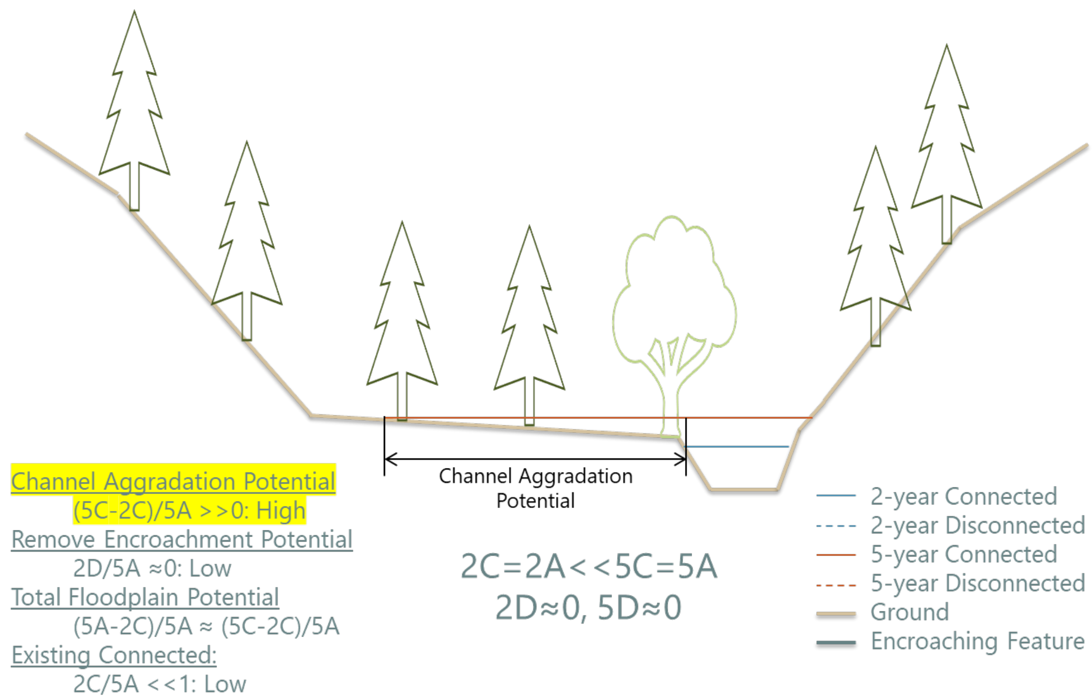


Figure F-7
High Encroachment Removal Potential

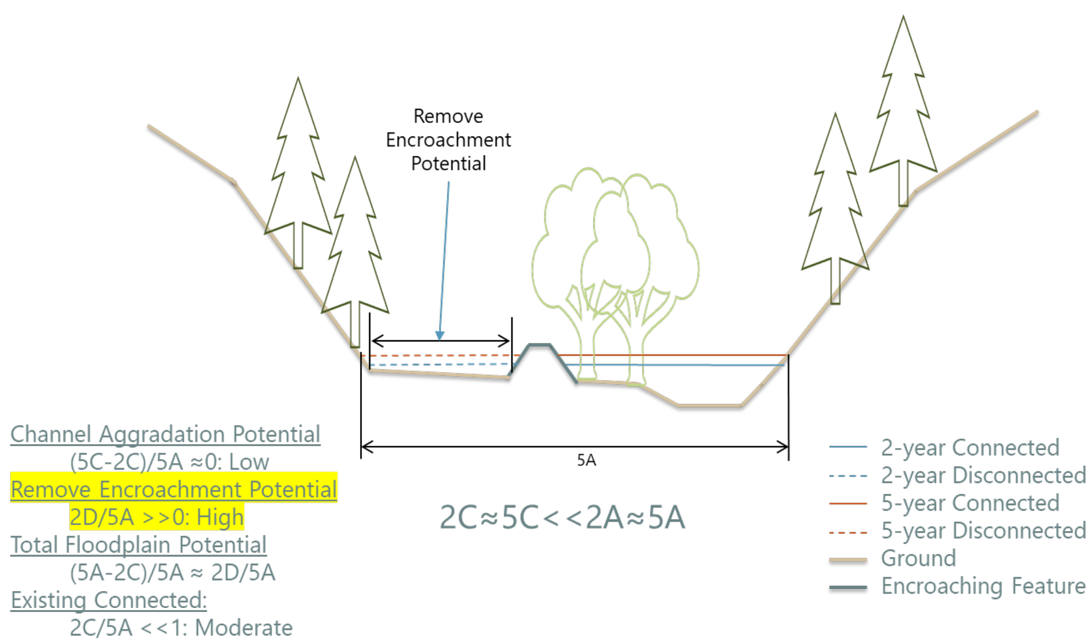
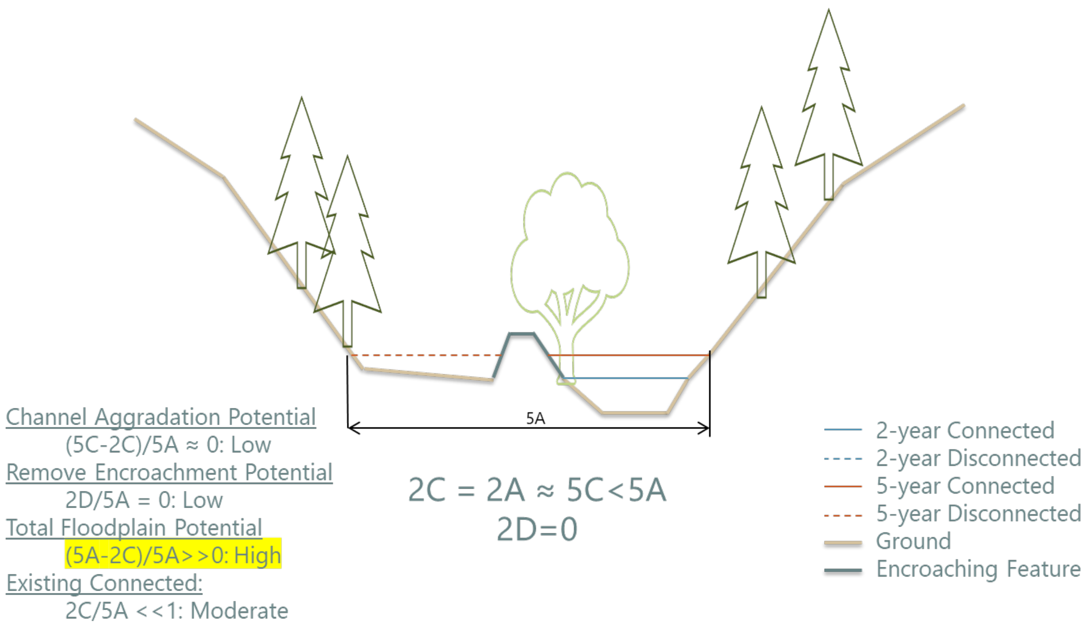


Figure F-8
Total Floodplain Potential – Both Channel Aggradation and Encroachment Removal are Necessary



Connectivity Trends and Patterns

This section briefly describes some of the basin-wide trends that result from the Connectivity analysis. A more detailed breakdown of how this analysis applies to individual project areas is discussed in the Project Area Cut sheets in Appendix J. This section references figures and tables that are provided at the end of this appendix and also heavily references terms defined and explain in the previous section.

The 2-year connected area per valley mile shown in Figure F-12 is the most direct measurement of the current connection of the floodplain. As shown in Figure F-11, the 2-year connected area is expressed as a percentage the total 5-year floodplain area. Similarly, Figures F-13, F-14, F-15, and F-16 show the same information but for potential floodplain area per the two potential restoration actions: channel bed aggradation (i.e., reversing channel incision) and removal of encroaching features (i.e., levees).

Figure F-9 combines the existing floodplain area and "potential floodplain area through restoration actions" expressed as a percentage of the total potential floodplain area. In an ideal situation, these three percentages would total 100%. However, there are several situations where this is not the case, and understanding those situations provides insight into how this analysis and metric is useful.

The difference between the totals and 100% is the same as the difference in the "5-year disconnected area percentage" and the "2-year disconnected area percentage." For most of the project areas, the "currently connected area percentage" and both individual "restoration action area percentages" total less than 100%. This is because the two restoration actions are viewed as if they were done individually, either channel bed aggradation or removing encroaching features but not both, so they will discount the additional area from the "5-year disconnected area percentage" over the "2-year disconnected area percentage" shown in Equation F-2.

Equation F-2

$$100\% = C_2 + P_{RL} + P_{RB} + (D_5 - D_2)$$

and

$$P_B = P_{RL} + P_{RB} + (D_5 - D_2)$$

where:

C_2	=	currently connected area at 2-year, as a percentage of the total available
P_{RL}	=	potential area by removal of encroaching features restoration action, as a percent
P_{RB}	=	potential area by channel bed aggradation restoration action, as a percent
D_5	=	disconnected area at 5-year, as a percentage of the total available
D_2	=	disconnected area at 2-year, as a percentage of the total available
P_B	=	potential area by doing both restoration actions together

Figure F-10 shows the third potential restoration metric ("Total Floodplain Potential"), which considers both channel bed aggradation and removal of encroaching features. The "Total Floodplain Potential" metric counts the difference in 5-year and 2-year disconnected percentage, which explains the difference between the "Total Floodplain Potential" restoration action and the sum of the two individual restoration actions alone.

When the total is greater than 100%, as shown in Figure F-9, this indicates that the difference in 5-year to 2-year disconnected area is negative. Physically, this means the 2-year disconnected area is reconnected as water surface elevation increases to the 5-year level, thus making the 5-year disconnected area smaller than the 2-year disconnected area. This is shown in Figure F-10 where the "Total Floodplain Potential" restoration action is smaller than the sum of the two individual restoration actions. This simply indicates that the individual actions are "double counting" the difference between the 2-year and 5-year disconnected area, because either removing encroaching features or raising the water surface elevation would reconnect that area.

There are several interesting trends that should be noted to understand how connectivity is occurring across the basin. The connected area per valley mile (Figure F-11) shows a clear trend towards the lower end of the basin. However, when looking at connected area per valley mile per available area (as a percentage), no relevant trend is discernable. This indicates that, while there is technically more connected floodplain in the downstream reaches, this is likely due to natural river processes of increased deposition and spreading out while moving downstream into these lower energy reaches. So, the connected area as a factor of its potential remains similar throughout the basin.

The two potential areas obtained via restoration actions in Figures F-14 and F-16 show only a slight trend towards the lower reaches of the basin and show no correlation when expressed as a percentage of the total potential in Figures F-13 and F-15.

It is also interesting that channel bed aggradation shows at least some benefit for all of the project areas except Project Area 43 (see Figure F-13). All other project areas show a benefit of more than 5% and most more than 15%. By comparison, removing encroaching features (see Figure F-15) shows a large benefit for some project areas but also many others that show almost no benefit (less than 5%). The restoration option for removing encroaching features has a few outliers that make physical sense as well: Project Areas 5 and 6 include the large Camp Wooten levee, and Project Areas 13 and 14.1 include the Rainbow Lake and Hatchery levees.

Finally, it should be noted that in Figure F-11, which shows the percentage of currently connected area, the majority (49/60) of project areas are already above 50%. While this is a good indication for the basin, it does not necessarily mean most reaches are connected to at least 50% of their optimal level. The metric used as 100% in this analysis is the 5-year available floodplain; it is very likely that much of the basin has been incised or confined beyond this point, making the "100%" level less than the potentially optimal level. This assessment chose to use the 5-year available as the "100%" level because it seemed like a reasonable goal for floodplain connection. With future iterations of assessment, this may be adjusted to expand as opportunities arise or decrease as others are deemed impossible based on anthropomorphic demands on the river and basin and balanced with the benefit to fish and aquatic species.

Scoring for Prioritization

In order to combine the Connectivity analysis results of Channel Aggradation, Encroachment Removal, and Total Floodplain Potential into one Connectivity value to be used as a metric in the prioritization, weights were assigned to each Connectivity analysis result, which were then summed to produce the final metric value. Table F-2 provides the weights chosen to combine these results. The Channel Aggradation Floodplain Potential and Encroachment Removal Floodplain Potential are favored in the weighting over the Total Floodplain Potential. The Total Floodplain Potential represents the areas where benefit can be gained only by performing both floodplain connection restoration actions; while these areas still have value, they would require more restoration effort for similar benefits and therefore are weighted lower.

Table F-2
Complexity and Connectivity Weighting

Connectivity Weighting	
Analysis Result	**Percent Weight**
Channel Aggradation Floodplain Potential	40%
Encroachment Removal Floodplain Potential	40%
Total Floodplain Potential	20%

The next step in the prioritization process is to rank, classify, and score each project area in each of the three metrics (Complexity, Connectivity, and Excess Transport Capacity). Project areas are ranked in the Connectivity metric from best to worst by the scores determined using the weightings described in Table F-2. Each project area is then ranked for the Connectivity prioritization metric and can be classified and scored according to the system outlined in Table F-3.

The Connectivity analysis results, and therefore the Connectivity prioritization metric, already inherently measures the potential of the project areas to reconnect the floodplain at the 2-year event. Therefore, the project areas that would gain the most benefits from reconnecting floodplain with the least amount of effort will already be ranked at the top, and as such receive the highest scores. It should be noted that the floodplain connectivity metric reflects the potential for each project area as they currently stand. Should events occur, such as channel bed aggradation that opens more floodplain potential, or land ownership change that makes floodplain area designated "unobtainable" become available, the potential of a project area could change drastically. Table F-3 describes the concepts behind the classifications and scoring for connectivity.

Table F-3
Floodplain Connectivity Potential Classification and Scoring

Percentile Rank	Class	Class Score	Metric Score Threshold[1]	Class Conceptualization
75th to Top	1	5	0.235	Project areas in this class have the most floodplain potential, indicating that restoration efforts have the potential to raise the percentage of connected area to the highest potential based on current conditions. These should be the primary target of floodplain reconnection restoration actions.
50th to 75th	2	3	0.204	Project areas in this class score above average for floodplain connection potential and should be a secondary target for floodplain reconnection restoration actions.
25th to 50th	3	1	0.155	Project areas in this class have below average floodplain connection potential and should be the last group of project areas targeted for floodplain reconnection restoration.
Bottom to 25th	4	0	0	Project areas in this class have the least floodplain connection potential. This can either indicate that the project area is not well connected and has little room for improvement, or it is very well connected and there is little else to be connected via restoration efforts. In either case, these should not be targeted for floodplain reconnection actions, based on their current conditions.

Notes:

1. This is the score that defines the lower limit for the corresponding classification for this metric. These data can be used to track progression of project areas and compare to how they would rank according to the levels of this assessment, as new restoration projects are completed and new data become available.

Detailed Instructions for Performing This Analysis

Part of the purpose of this assessment is to define repeatable and data driven methods for assessing project areas and how they have progressed in relation to their goals. This section provides the detailed steps taken to perform the Connectivity analysis of the Tucannon River so that these analyses can be repeated in the future for additional analyses and evaluation of progress. Table F-4 provides the data that will need to be collected to reassess the project areas for complexity.

Table F-4
Raw Data Needed to Perform Connectivity Analysis

Data Needed	Used For	Source
Topography Digital Elevation Model	1D hydraulic modeling	LiDAR, preferably blue-green and 0.5-meter horizontal accuracy or greater
Hydrology	Flows used in hydraulic modeling	Hydrologic gage data[2]
Water surface inundation boundaries[1]	Calculation of island count and island perimeters	1D hydraulic modeling results
Levees and encroachments	Delineation of disconnected area	Aerial photographs or field data
Relative elevation map	Calculation of inundated area	LiDAR, preferably blue-green and 0.5-meter horizontal accuracy or greater
Project area delineations	Calculation of all metrics per project area	Project area shapefiles from this assessment

Notes:

1. Water surface boundaries should be for the flows desired for the analysis: in this assessment, the 2-year (1,436 cfs), and 5-year (2,530 cfs).
2. See Appendix C for a description of gage locations on the Tucannon River and methods used to interpret those data.

The following steps will assume the user has adequate GIS knowledge and access to the same data sources as those produced in this report.

1. This analysis uses HEC-RAS 1D model results for the 2-year and 5-year flow events as a base layer. See the main report and Appendix C for details on how the modeling was done, and how the hydrologic flow events were determined.
2. Water surface elevation raster's (produced in HEC-RAS) were imported into GIS.
3. A REM was created based on the steps outlined in Ecology 2014 using the water surface elevation rasters as the base digital elevation model (DEM) (as opposed to the terrain raster described in Ecology 2014). The REM was created relative to the river centerline, which was manually digitized.
4. All results from the resulting relative elevation raster with a value of 0 or less will be under the water surface at that flow event. These areas were isolated from the REM and the bounding areas were exported as simple polygons.
5. These polygon shapefiles were then manually edited to delete areas not relevant to this analysis. These areas include areas within lakes or standing bodies of water, areas behind well-established levees or roads, such as in the town of Starbuck, and areas on the opposite side of the Tucannon River valley that are not realistically reconnectable. The resulting polygon shapefiles form the total available floodplain area for the 2-year and 5-year event described in Table F-5.

6. The water surface break line shapefile, obtained as a data file from the LiDAR survey, was imported into GIS. Any areas of the total available polygons not directly connected to the low-winter flow were labeled as "disconnected areas." Additionally, areas that were only connected on the downstream side or were behind known levees were manually separated and counted as disconnected areas as shown in Figure F-3. This produces four distinct floodplain shapefiles: 2-year Available, 2-year Disconnected, 5-year Available, and 5-year Disconnected.
7. These four shapefiles were broken up by project area and summed for each project area to produce the disconnected areas and available areas described in Table F-5.
8. The disconnected area was subtracted from the total area to produce the connected area described in Table F-5. Each of these metrics was also differenced between the 2-year and 5-year areas to obtain the available difference, disconnected difference, and connected difference.
9. All nine of these areas shown in Table F-5 were divided by the valley length, which was manually digitized, to obtain the area per valley mile of each of the floodplain areas shown in Table F-6.
10. These values of area per valley mile were used to calculate the restoration actions in Table F-6:
    a. Raise bed: 5-year connected minus 2-year connected divided by the 5-year available (5C-2C)/5A
    b. Remove levee: 2-year disconnected divided by 5-year available (2D/5A)
    c. Doing both: 5-year available minus 2-year connected divided by 5-year available (5A-2C)/5A
    d. Existing: 2-year connected divided by 5-year available 2C/5A

References

Ecology (Washington State Department of Ecology), 2014. "A Methodology for Delineating Planning-Level Channel Migration Zones." Pub. No. 14-06-025. Shorelands and Environmental Assistance. Olympia, Washington. July 2014. Available at: https://fortress.wa.gov/ecy/publications/SummaryPages/1406025.html.

Tables

Table F-5

Connectivity Analysis Floodplain Area Results

Project Area	Restoration Status	River Mile Start	Valley Mile Start	Floodplain Area (acres)								
				Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference
1.1	Treated	49.6	44.0	6.10	9.21	3.11	0.60	1.42	0.82	5.50	7.80	2.30
1.2	Untreated	49.2	43.7	2.66	3.52	0.85	0.39	0.84	0.45	2.27	2.68	0.41
2	Untreated	48.6	43.1	6.82	8.86	2.04	1.25	1.68	0.43	5.57	7.18	1.61
3.1	Untreated	48.2	42.7	3.04	4.25	1.21	0.63	1.02	0.39	2.40	3.23	0.82
3.2	Treated	46.8	41.4	17.44	23.60	6.16	0.39	0.34	-0.05	17.05	23.27	6.21
4	Untreated	46.5	41.2	2.56	3.02	0.46	0.20	0.29	0.09	2.36	2.73	0.37
5	Untreated	46.1	40.8	10.71	13.83	3.12	6.18	8.30	2.11	4.53	5.53	1.00
6	Treated	45.4	40.2	11.61	15.02	3.42	4.12	5.76	1.64	7.48	9.26	1.78
7	Untreated	44.9	39.7	4.28	5.28	1.00	0.47	1.01	0.53	3.80	4.27	0.47
8	Treated	44.4	39.3	5.68	7.82	2.14	0.22	0.71	0.49	5.46	7.11	1.65
9	Treated	44.0	38.9	8.47	11.64	3.17	3.08	5.02	1.94	5.38	6.62	1.24
10.1	Treated	43.6	38.5	9.20	11.44	2.24	0.50	0.78	0.28	8.70	10.66	1.96
10.2	Treated	42.9	37.9	9.36	11.55	2.20	0.17	0.40	0.23	9.19	11.16	1.97
10.3	Treated	42.4	37.5	6.43	8.67	2.23	0.10	0.34	0.24	6.33	8.32	1.99
11.1	Treated	41.7	36.9	8.67	11.06	2.38	0.41	0.25	-0.16	8.26	10.81	2.55
11.2	Treated	40.7	36.0	20.53	25.71	5.18	1.94	1.90	-0.04	18.59	23.81	5.22
12	Untreated	40.1	35.5	10.01	13.03	3.03	0.52	0.65	0.13	9.48	12.38	2.90
13	Untreated	39.3	34.8	5.08	5.73	0.65	0.11	0.24	0.13	4.97	5.50	0.52
14.1	Treated	38.7	34.3	7.36	9.97	2.61	0.26	1.02	0.77	7.10	8.94	1.84
14.2	Treated	37.9	33.6	5.71	7.47	1.76	0.31	0.54	0.23	5.40	6.93	1.53
14.3	Untreated	37.2	33.0	10.59	15.35	4.77	1.84	2.04	0.20	8.74	13.31	4.57
15.1	Treated	36.8	32.7	4.63	6.13	1.51	0.17	0.40	0.23	4.45	5.73	1.28
15.2	Treated	36.4	32.3	4.31	6.09	1.78	0.46	0.29	-0.16	3.86	5.80	1.94
16	Untreated	35.0	31.1	16.92	24.42	7.51	5.40	6.52	1.12	11.51	17.90	6.39
17.1	Untreated	34.6	30.7	5.30	7.94	2.65	0.40	0.62	0.22	4.90	7.32	2.42
17.2	Untreated	34.3	30.4	7.38	10.35	2.97	0.81	1.13	0.31	6.57	9.22	2.65
18.1	Treated	33.2	29.5	20.22	28.94	8.73	0.48	0.74	0.26	19.73	28.21	8.47
18.2	Untreated	32.5	28.8	10.74	15.47	4.73	1.41	2.46	1.04	9.33	13.02	3.69
19	Untreated	31.9	28.3	7.77	9.89	2.12	0.25	0.04	-0.20	7.52	9.85	2.33
20	Untreated	31.5	27.9	7.13	10.04	2.91	0.47	0.94	0.47	6.66	9.10	2.45
21	Untreated	30.4	26.9	9.75	12.28	2.54	0.47	0.89	0.41	9.27	11.39	2.12
22	Treated	29.3	25.9	8.46	10.02	1.56	0.04	0.31	0.27	8.42	9.71	1.29
23	Treated	28.3	25.1	9.37	16.31	6.95	1.00	3.39	2.39	8.37	12.92	4.56
24	Treated	27.5	24.3	7.70	8.73	1.03	0.17	0.48	0.32	7.53	8.24	0.71
25	Untreated	27.0	23.9	5.66	9.66	4.00	1.05	3.51	2.45	4.61	6.15	1.55
26	Treated	24.0	21.1	54.67	68.76	14.09	2.83	2.42	-0.41	51.84	66.34	14.50
27	Untreated	22.9	20.2	19.33	31.27	11.94	7.48	11.25	3.76	11.85	20.02	8.18
28.1	Untreated	22.1	19.4	23.93	31.88	7.95	4.20	6.25	2.05	19.72	25.63	5.90
28.2	Treated	20.9	18.4	28.82	48.09	19.27	5.07	8.52	3.46	23.75	39.57	15.81
28.3	Treated	19.7	17.4	19.94	31.20	11.25	0.41	0.44	0.02	19.53	30.76	11.23
29	Treated	18.6	16.4	11.70	20.79	9.09	1.44	8.32	6.89	10.26	12.47	2.20
30	Untreated	17.6	15.5	17.18	22.98	5.80	1.70	0.82	-0.88	15.49	22.16	6.68
31	Untreated	16.1	14.1	23.57	32.84	9.27	3.79	7.98	4.19	19.78	24.86	5.08
32.1	Untreated	15.3	13.4	18.04	25.29	7.26	9.48	7.28	-2.20	8.56	18.02	9.46
32.2	Untreated	14.6	12.8	9.74	14.82	5.09	1.23	0.41	-0.83	8.50	14.42	5.92

Table F-5
Connectivity Analysis Floodplain Area Results

Project Area	Restoration Status	River Mile Start	Valley Mile Start	Floodplain Area (acres)								
				Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference
33	Untreated	13.4	11.7	8.83	10.80	1.97	0.12	0.18	0.05	8.71	10.62	1.92
34.1	Untreated	12.3	10.5	35.75	49.64	13.89	8.39	14.99	6.61	27.36	34.65	7.29
34.2	Untreated	11.5	9.9	21.14	28.26	7.12	3.66	5.67	2.01	17.48	22.58	5.10
35	Untreated	10.8	9.3	15.37	35.00	19.62	6.67	22.47	15.80	8.70	12.52	3.83
36	Untreated	9.1	7.8	51.72	76.84	25.12	3.08	0.65	-2.43	48.63	76.19	27.56
37	Untreated	8.0	6.9	10.68	13.52	2.84	0.17	0.54	0.37	10.51	12.98	2.47
38	Untreated	5.0	4.1	41.21	61.27	20.06	4.40	6.30	1.90	36.81	54.97	18.16
39.1	Untreated	4.9	4.0	1.88	2.22	0.34	0.00	0.00	0.00	1.87	2.22	0.34
39.2	Untreated	4.6	3.7	3.22	4.01	0.79	0.00	0.01	0.01	3.22	3.99	0.78
40	Treated	4.0	3.2	18.42	27.47	9.05	2.48	3.17	0.69	15.94	24.30	8.36
41	Untreated	3.7	2.9	13.72	22.95	9.23	2.18	5.11	2.93	11.53	17.84	6.30
42	Untreated	3.3	2.6	7.85	12.16	4.31	0.78	3.67	2.89	7.08	8.49	1.42
43	Untreated	2.9	2.3	16.04	27.58	11.54	6.31	8.54	2.24	9.73	19.04	9.31
44	Untreated	2.5	2.0	6.90	20.42	13.52	0.34	5.01	4.68	6.56	15.40	8.84
45	Untreated	2.0	1.6	12.43	16.43	4.00	1.75	4.08	2.34	10.68	12.35	1.67

Table F-6

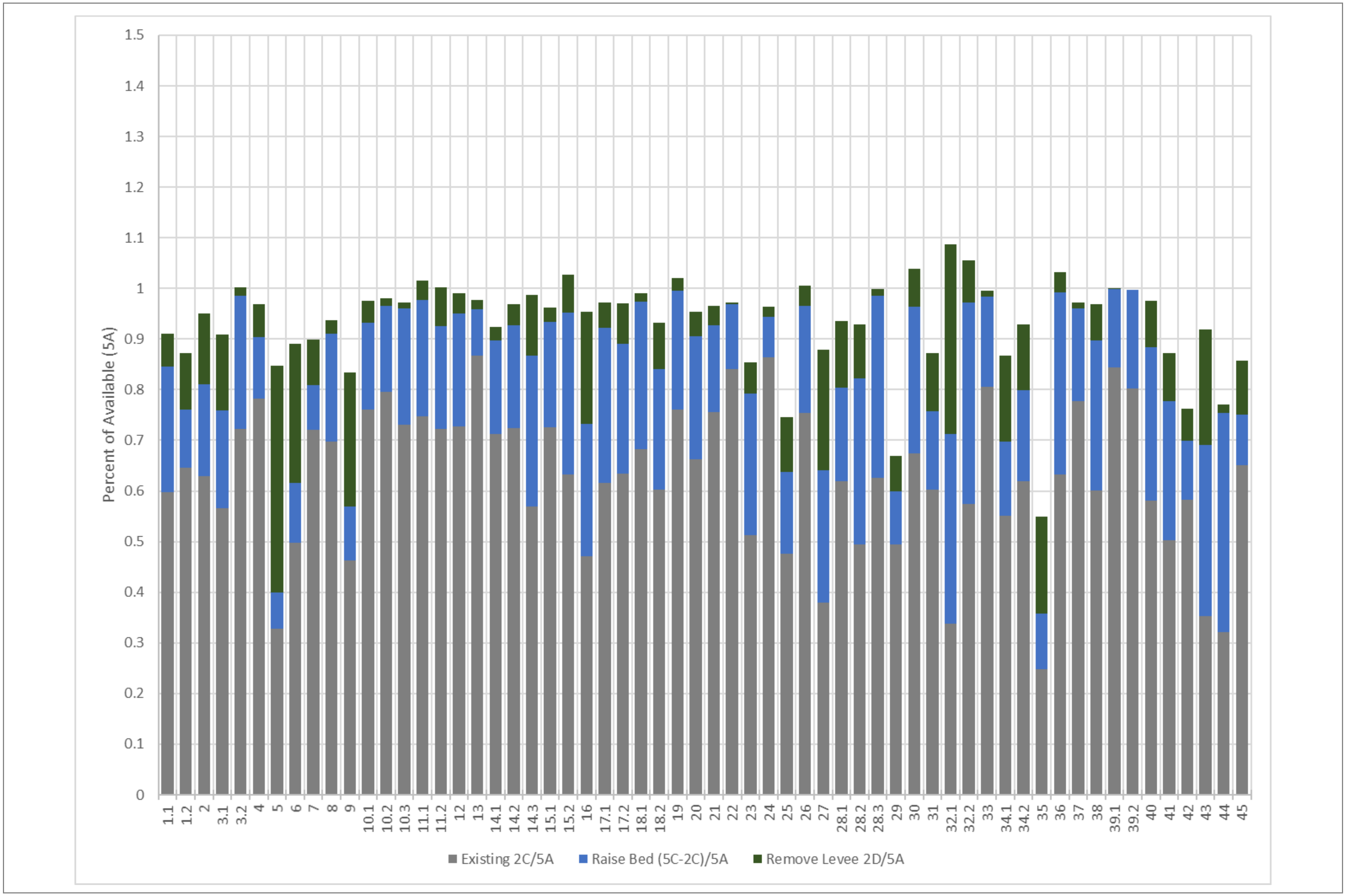
Connectivity Analysis Restoration Action Results

			Area Per Valley Length (acres per mile)									Restoration Actions			
Project Area	**River Length (miles)**	**Valley Length (miles)**	**Available 2-year**	**Available 5-year**	**Available Difference**	**Disconnected 2-year**	**Disconnected 5-year**	**Disconnected Difference**	**Connected 2-year**	**Connected 5-year**	**Connected Difference**	**Raise Bed (5C-2C)/5A**	**Remove Levee 2D/5A**	**Do Both (5A-2C)/5A**	**Existing 2C/5A**
1.1	0.55	0.50	12.21	18.44	6.23	1.20	2.83	1.63	11.01	15.61	4.60	25%	7%	40%	60%
1.2	0.39	0.36	7.38	9.75	2.37	1.09	2.33	1.24	6.29	7.42	1.13	12%	11%	35%	65%
2.0	0.64	0.56	12.09	15.71	3.62	2.22	2.98	0.77	9.87	12.72	2.85	18%	14%	37%	63%
3.1	0.37	0.37	8.27	11.56	3.30	1.73	2.79	1.06	6.54	8.78	2.24	19%	15%	43%	57%
3.2	1.44	1.29	13.51	18.29	4.77	0.30	0.26	-0.04	13.21	18.03	4.81	26%	2%	28%	72%
4.0	0.24	0.21	11.92	14.06	2.14	0.92	1.36	0.44	11.00	12.70	1.70	12%	7%	22%	78%
5.0	0.45	0.43	25.10	32.40	7.30	14.49	19.44	4.95	10.61	12.96	2.35	7%	45%	67%	33%
6.0	0.74	0.64	18.24	23.61	5.37	6.48	9.06	2.58	11.76	14.55	2.80	12%	27%	50%	50%
7.0	0.45	0.42	10.16	12.53	2.37	1.12	2.39	1.26	9.03	10.14	1.11	9%	9%	28%	72%
8.0	0.45	0.41	13.76	18.94	5.19	0.53	1.71	1.18	13.23	17.24	4.01	21%	3%	30%	70%
9.0	0.40	0.41	20.76	28.54	7.78	7.56	12.31	4.75	13.20	16.23	3.03	11%	26%	54%	46%
10.1	0.47	0.41	22.63	28.13	5.50	1.24	1.92	0.68	21.40	26.21	4.82	17%	4%	24%	76%
10.2	0.72	0.63	14.87	18.36	3.49	0.26	0.63	0.37	14.61	17.73	3.13	17%	1%	20%	80%
10.3	0.41	0.38	16.89	22.76	5.87	0.27	0.90	0.63	16.62	21.85	5.23	23%	1%	27%	73%
11.1	0.75	0.62	13.96	17.80	3.84	0.66	0.40	-0.26	13.30	17.40	4.10	23%	4%	25%	75%
11.2	0.96	0.89	23.16	29.01	5.85	2.19	2.15	-0.04	20.98	26.86	5.89	20%	8%	28%	72%
12.0	0.65	0.52	19.25	25.07	5.82	1.01	1.25	0.24	18.24	23.82	5.58	22%	4%	27%	73%
13.0	0.77	0.67	7.62	8.59	0.98	0.16	0.35	0.19	7.45	8.24	0.79	9%	2%	13%	87%
14.1	0.61	0.56	13.23	17.92	4.69	0.46	1.84	1.38	12.77	16.08	3.31	18%	3%	29%	71%
14.2	0.82	0.61	9.31	12.18	2.86	0.51	0.88	0.37	8.81	11.30	2.49	20%	4%	28%	72%
14.3	0.72	0.64	16.57	24.04	7.46	2.89	3.19	0.31	13.69	20.84	7.16	30%	12%	43%	57%
15.1	0.38	0.32	14.44	19.14	4.71	0.54	1.26	0.72	13.90	17.89	3.99	21%	3%	27%	73%
15.2	0.42	0.39	10.99	15.52	4.53	1.17	0.75	-0.42	9.83	14.77	4.94	32%	8%	37%	63%
16.0	1.39	1.24	13.66	19.73	6.06	4.36	5.27	0.90	9.30	14.46	5.16	26%	22%	53%	47%
17.1	0.34	0.34	15.61	23.42	7.81	1.17	1.83	0.66	14.44	21.58	7.14	31%	5%	38%	62%
17.2	0.31	0.27	27.78	38.95	11.17	3.06	4.24	1.18	24.72	34.71	9.99	26%	8%	37%	63%
18.1	1.08	0.96	20.95	30.00	9.04	0.50	0.77	0.27	20.45	29.23	8.78	29%	2%	32%	68%
18.2	0.78	0.70	15.39	22.17	6.78	2.02	3.52	1.50	13.36	18.64	5.28	24%	9%	40%	60%
19.0	0.56	0.47	16.56	21.08	4.52	0.53	0.09	-0.44	16.03	20.98	4.96	24%	3%	24%	76%
20.0	0.44	0.40	17.72	24.97	7.25	1.17	2.34	1.17	16.55	22.63	6.08	24%	5%	34%	66%
21.0	1.05	1.06	9.18	11.57	2.39	0.45	0.84	0.39	8.73	10.73	2.00	17%	4%	25%	75%
22.0	1.08	0.98	8.65	10.24	1.59	0.04	0.32	0.28	8.61	9.92	1.31	13%	0%	16%	84%
23.0	1.05	0.81	11.51	20.04	8.53	1.23	4.16	2.93	10.28	15.88	5.60	28%	6%	49%	51%
24.0	0.76	0.71	10.83	12.28	1.45	0.23	0.68	0.45	10.60	11.59	1.00	8%	2%	14%	86%
25.0	0.54	0.45	12.54	21.42	8.87	2.33	7.77	5.44	10.21	13.64	3.43	16%	11%	52%	48%
26.0	2.99	2.79	19.62	24.68	5.06	1.02	0.87	-0.15	18.61	23.81	5.20	21%	4%	25%	75%
27.0	1.05	0.90	21.52	34.81	13.29	8.33	12.52	4.19	13.19	22.29	9.10	26%	24%	62%	38%
28.1	0.87	0.79	30.16	40.19	10.02	5.30	7.88	2.58	24.87	32.31	7.44	19%	13%	38%	62%
28.2	1.17	1.01	28.55	47.64	19.09	5.02	8.44	3.43	23.53	39.20	15.67	33%	11%	51%	49%
28.3	1.16	1.03	19.32	30.23	10.90	0.40	0.42	0.02	18.92	29.80	10.88	36%	1%	37%	63%
29.0	1.12	1.01	11.63	20.68	9.04	1.43	8.28	6.85	10.21	12.40	2.19	11%	7%	51%	49%
30.0	1.01	0.83	20.75	27.76	7.01	2.05	0.99	-1.06	18.70	26.77	8.06	29%	7%	33%	67%
31.0	1.49	1.44	16.42	22.87	6.46	2.64	5.56	2.92	13.78	17.32	3.54	15%	12%	40%	60%
32.1	0.79	0.69	26.14	36.66	10.52	13.74	10.55	-3.19	12.40	26.12	13.72	37%	37%	66%	34%
32.2	0.69	0.58	16.72	25.46	8.74	2.12	0.70	-1.42	14.60	24.76	10.16	40%	8%	43%	57%
33.0	1.22	1.12	7.87	9.63	1.76	0.11	0.16	0.05	7.76	9.47	1.71	18%	1%	19%	81%
34.1	1.14	1.17	30.62	42.52	11.90	7.18	12.84	5.66	23.44	29.68	6.24	15%	17%	45%	55%
34.2	0.78	0.63	33.77	45.13	11.36	5.85	9.06	3.21	27.92	36.07	8.15	18%	13%	38%	62%
35.0	0.69	0.65	23.50	53.51	30.00	10.20	34.36	24.15	13.30	19.15	5.85	11%	19%	75%	25%

Table F-6
Connectivity Analysis Restoration Action Results

Project Area	River Length (miles)	Valley Length (miles)	Area Per Valley Length (acres per mile)									Restoration Actions			
			Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference	Raise Bed (5C-2C)/5A	Remove Levee 2D/5A	Do Both (5A-2C)/5A	Existing 2C/5A
36.0	1.70	1.44	35.93	53.38	17.45	2.14	0.45	-1.69	33.79	52.93	19.14	36%	4%	37%	63%
37.0	1.10	0.97	11.03	13.96	2.93	0.18	0.56	0.38	10.85	13.40	2.55	18%	1%	22%	78%
38.0	2.97	2.77	14.88	22.12	7.24	1.59	2.28	0.69	13.29	19.85	6.56	30%	7%	40%	60%
39.1	0.10	0.09	20.82	24.63	3.81	0.03	0.03	0.01	20.80	24.60	3.80	15%	0%	16%	84%
39.2	0.33	0.31	10.22	12.74	2.52	0.00	0.04	0.04	10.22	12.70	2.48	19%	0%	20%	80%
40.0	0.57	0.52	35.38	52.75	17.38	4.76	6.08	1.32	30.61	46.67	16.06	30%	9%	42%	58%
41.0	0.35	0.31	44.48	74.40	29.93	7.08	16.57	9.49	37.40	57.84	20.44	27%	10%	50%	50%
42.0	0.33	0.26	30.45	47.14	16.70	3.01	14.21	11.20	27.44	32.93	5.50	12%	6%	42%	58%
43.0	0.43	0.28	56.98	97.98	41.00	22.40	30.34	7.94	34.58	67.64	33.06	34%	23%	65%	35%
44.0	0.43	0.31	22.23	65.80	43.57	1.08	16.16	15.08	21.15	49.64	28.50	43%	2%	68%	32%
45.0	0.52	0.43	29.14	38.53	9.38	4.10	9.57	5.48	25.05	28.96	3.91	10%	11%	35%	65%

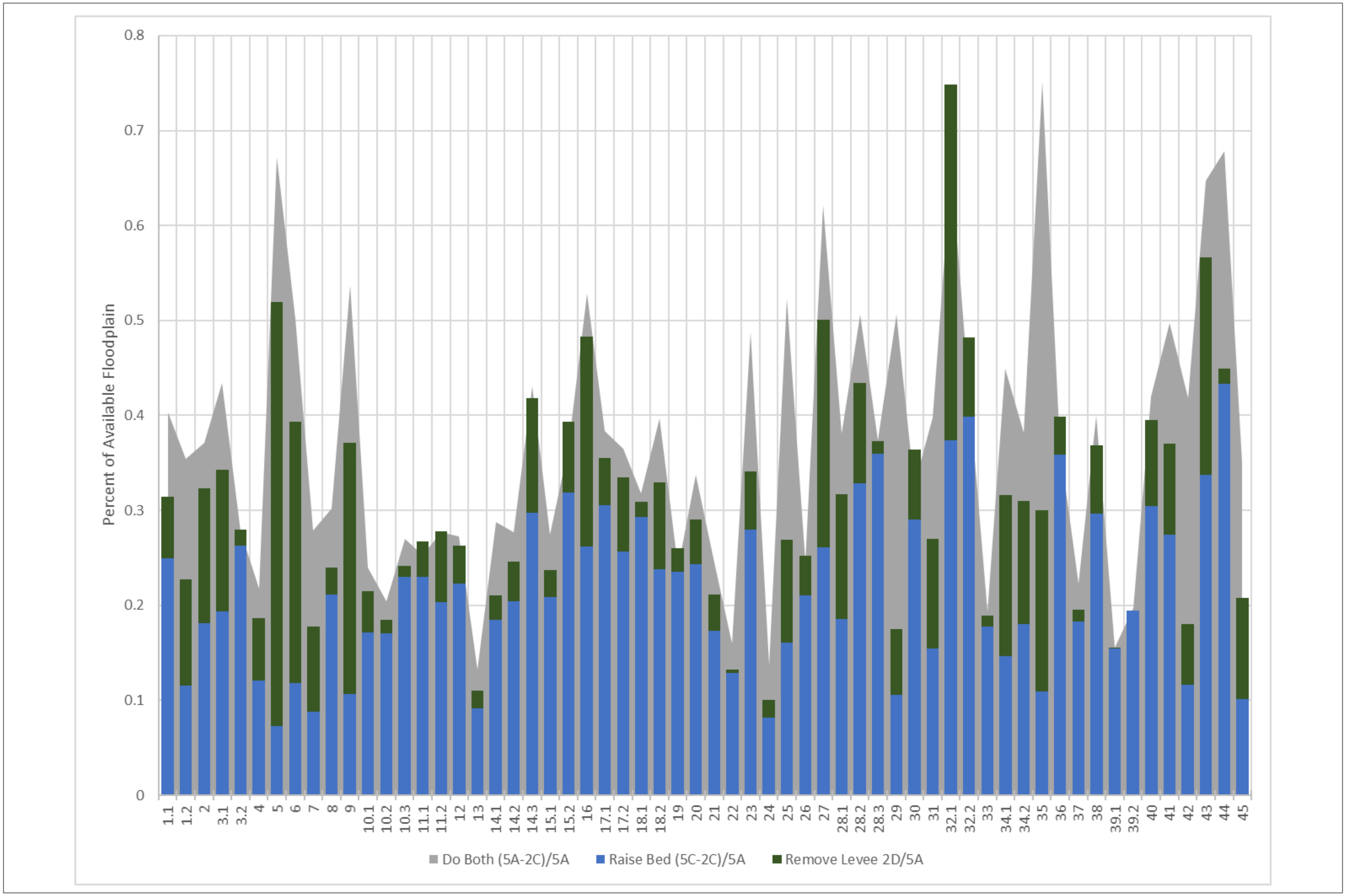
Figures



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-9.docx

ANCHOR QEA

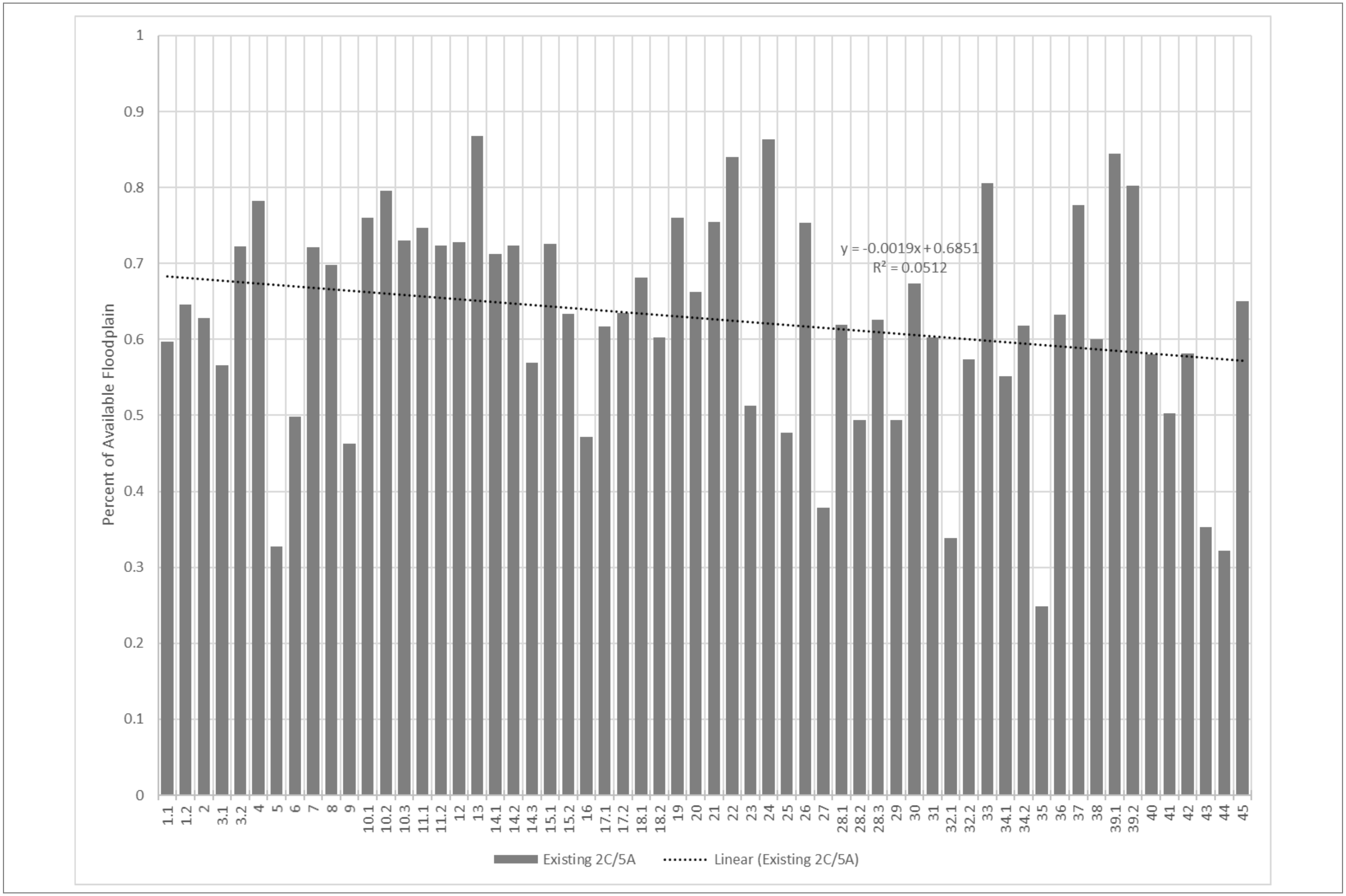
Figure F-9
Existing and Potential Floodplain as Percent of Available Floodplain
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-10.docx

ANCHOR QEA

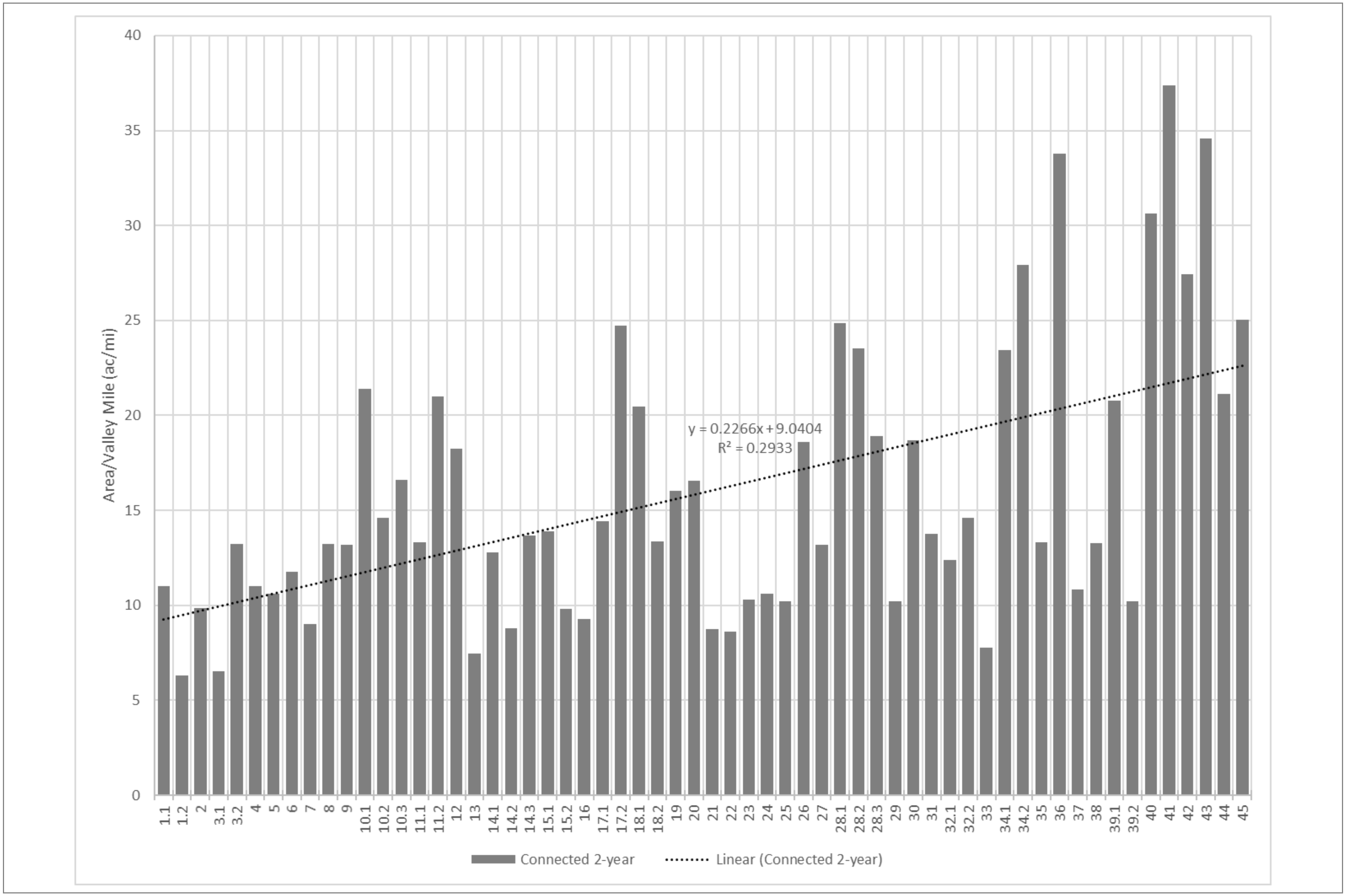
Figure F-10
Select Restoration Action Benefits as Percent of Available Floodplain
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-11.docx

ANCHOR QEA

Figure F-11
Existing Connected 2-Year Floodplain as a Percentage of Total Available Floodplain (2C/5A)

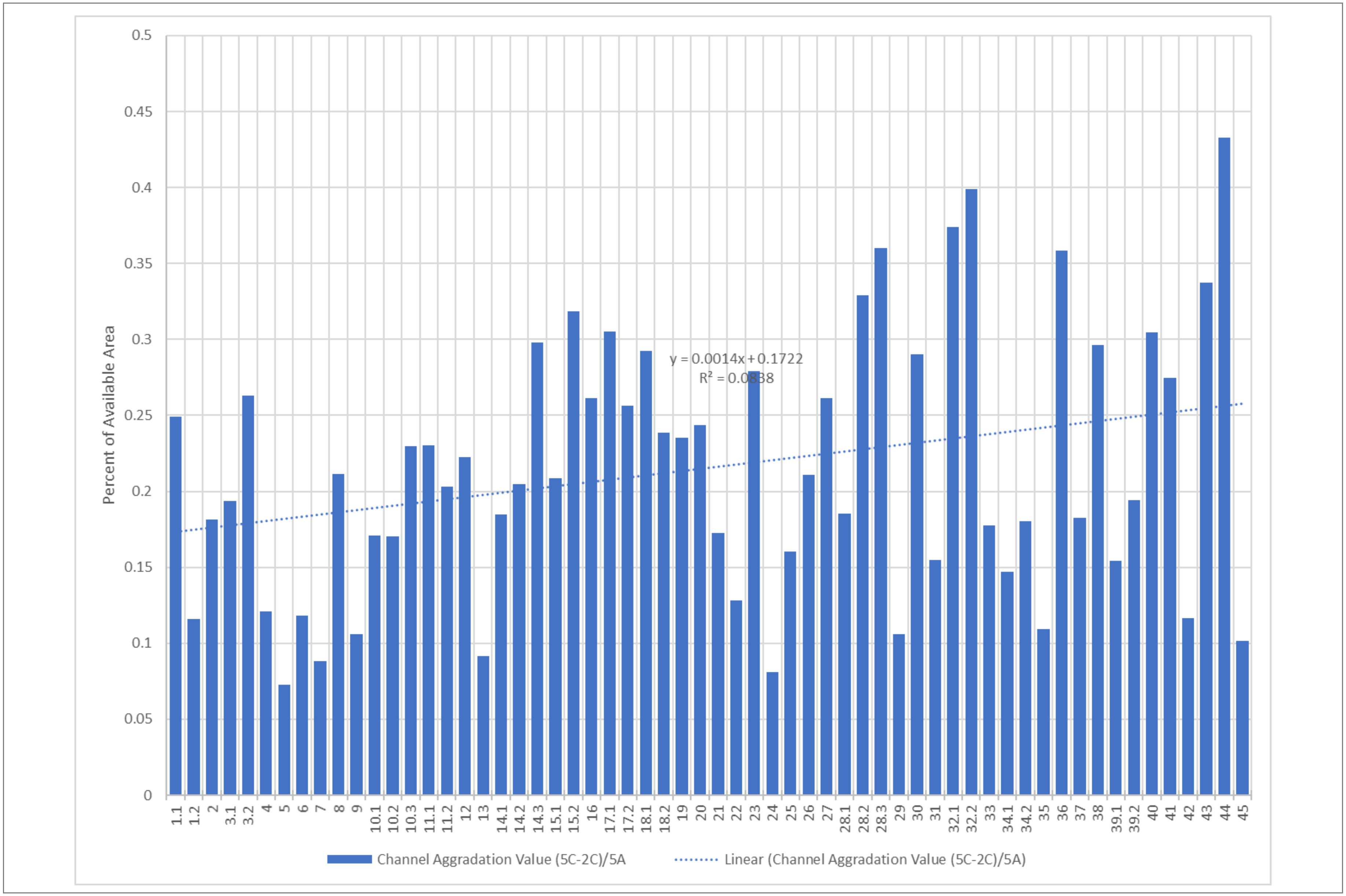


Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-12.docx

ANCHOR QEA

Figure F-12
Existing Connected 2-Year Floodplain Area per Valley Mile

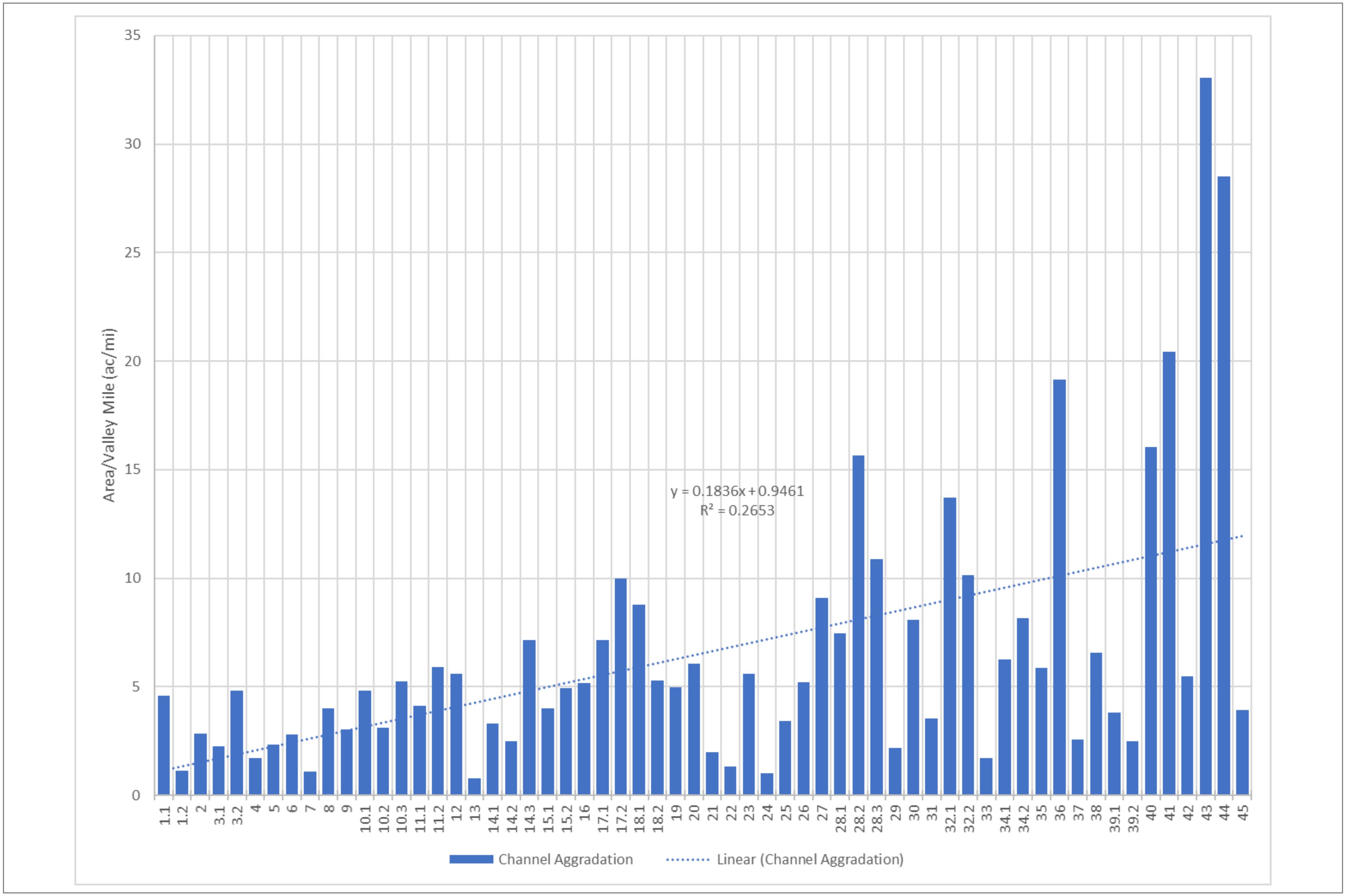
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-13.docx

ANCHOR QEA

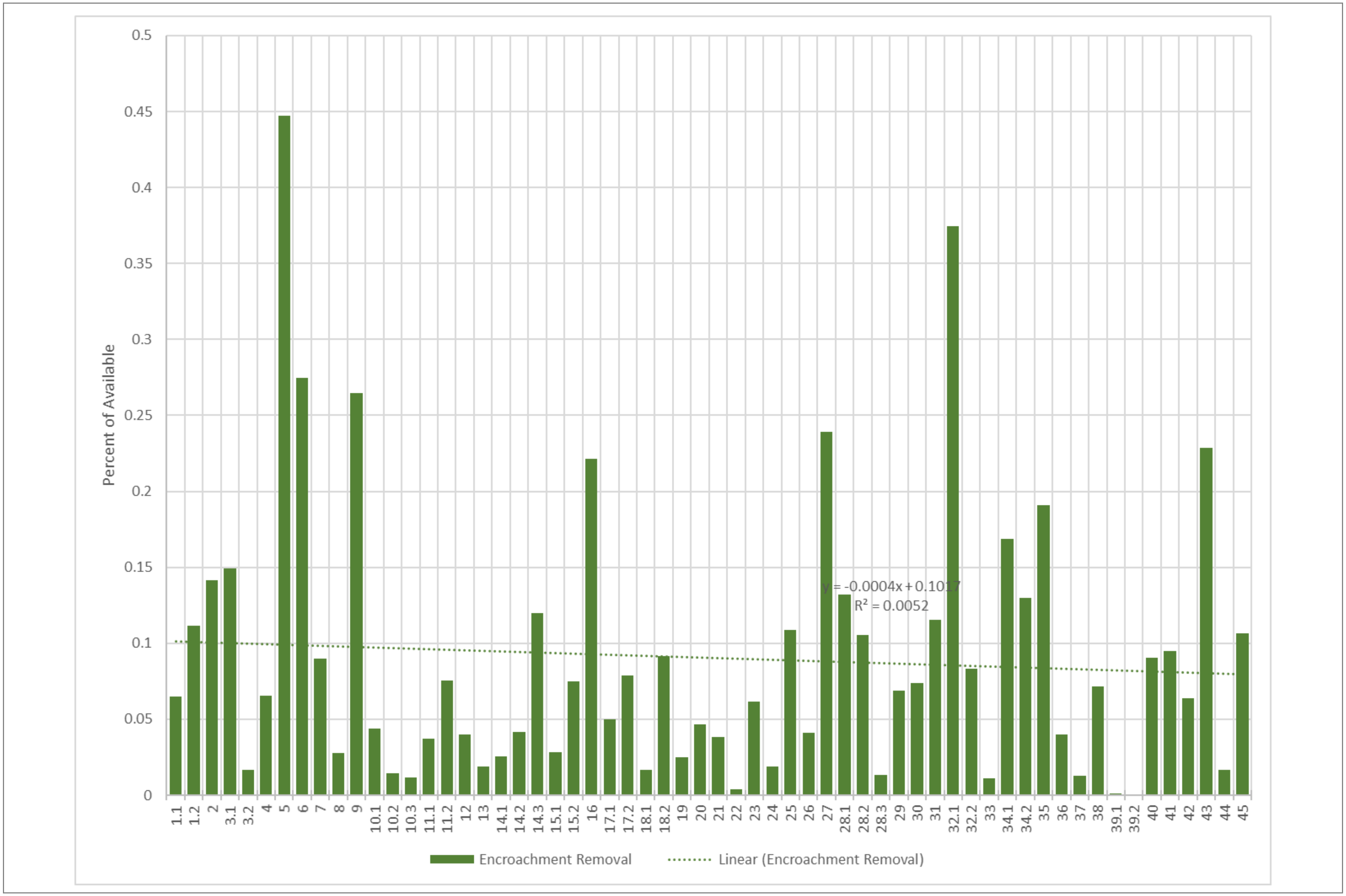
Figure F-13
Potential Benefit of Channel Aggradation as Percent of Available Area (5C-2C)/5A
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-14.docx

ANCHOR QEA

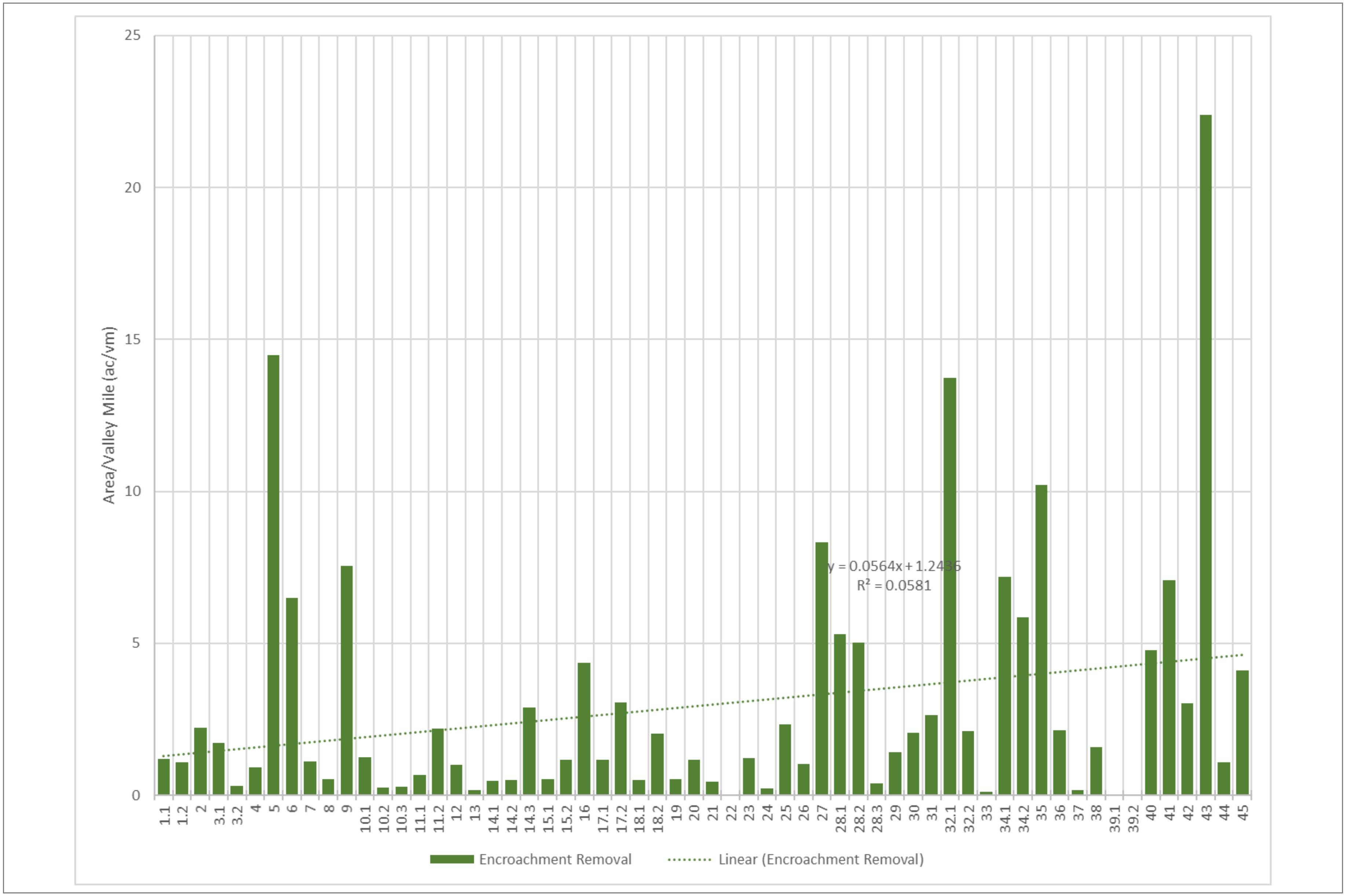
Figure F-14
Benefit of Channel Aggradation Area per Valley Mile (5C-2C)
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-15.docx

ANCHOR QEA

Figure F-15
Potential Benefit of Encroachment Removal as a Percent of Available Area 2D/5A



Filepath: \\fuji\bellingham\Projects\Columbia Conservation District\2018 Tucannon River Restoration\Reports and Deliverables\2020 Deliverables\Main Report\Appendices\Full Page Figures\Figure F-16.docx

ANCHOR QEA

Figure F-16
Benefit of Encroachment Removal Area per Valley Mile (2D)

Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration