WATERWAYS CONSULTING, INC.
Ecological Restoration Design ~ Civil Engineering ~ Natural Resource Management

TECHNICAL MEMORANDUM

To: Yakama Nations Fisheries Department

From: Waterways Consulting, Inc.

Date: March 2024

Re: Toppenish Creek above Olney Dam Floodplain Reconnection and Fish Passage Improvement: Initial Analysis and Concept Alternatives

Yakama Nations Fisheries (YNF) hired Waterways to assess existing conditions and identify and prioritize fisheries habitat restoration opportunities in 23 miles of Toppenish, Simcoe, Agency, and Wahtum Creeks (referred to as the "Assessment"; Waterways, 2024). Following the completion of the draft Assessment, YNF requested that Waterways perform hydraulic, sediment transport, and engineering analyses in support of one of the prioritized projects in the Assessment. This project would restore floodplain connectivity and improve fish passage in lower Toppenish Canyon, just above the head of the Toppenish Fan. The site is immediately upstream of the Olney Irrigation Diversion, where flow from Toppenish Creek is diverted into the Toppenish Feeder Canal **(Figure 1)**.

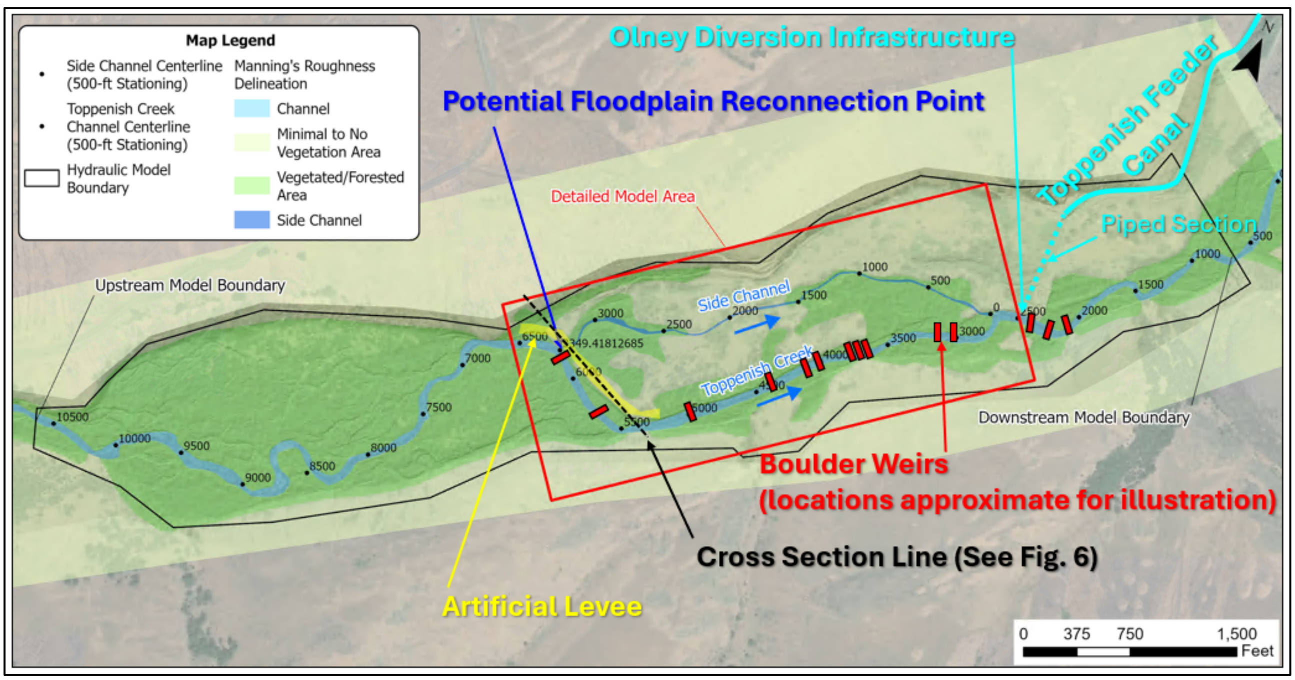


Figure 1. *Existing Conditions in the Potential Project Area and Modeling Extent.*

About a mile upstream of the Olney Diversion, an artificial levee was built in the 1970s to confine Toppenish Creek to the southern (river-right) side of the valley, presumably to facilitate livestock grazing on the north side of the valley (Reichmuth, 2007). The concentration of flows against the southern valley wall caused the creek to incise several feet, resulting in disconnection and dewatering of the floodplain, instability and simplification of the channel, and impaired steelhead habitat (**Figure 2A**).

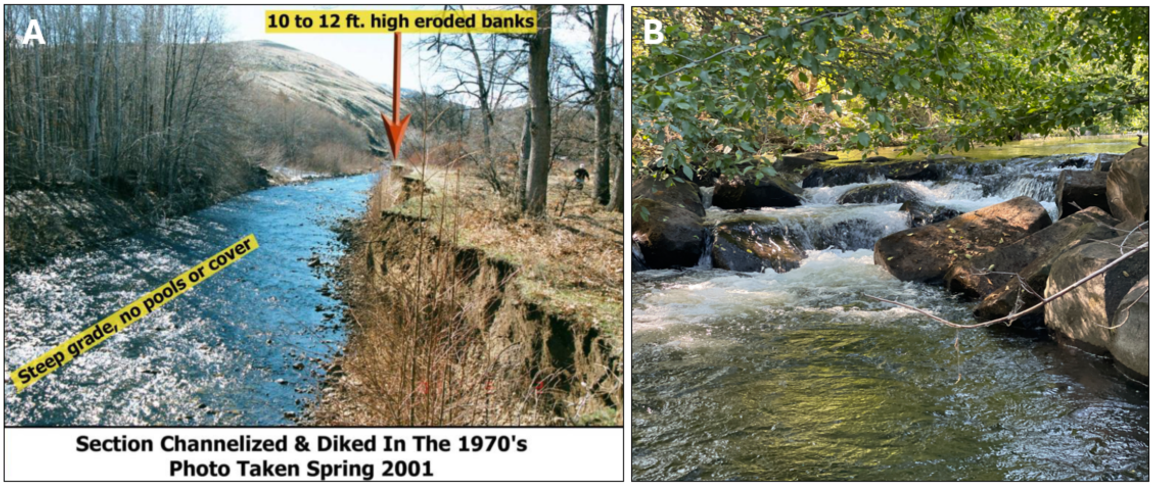


Figure 2. *Photos of Potential Project Reach: (A) Simplified Channel Confined Against Valley Wall (from Reichmuth, 2007); (B) Example of One of 15 Boulder Weir Grade Control Structures Built in 2000s*

In the early 2000s, a series of about 15 boulder weirs were built within the confined channel reach to stabilize the base level (**Figure 2B)**. Some of these may present partial fish passage barriers. Although adult steelhead can probably pass these weirs, collectively they may inhibit juvenile steelhead access to high quality habitat immediately upstream of the leveed reach (T. Resseguie, YNF, personal communication, 2023). In addition, the project included building a rock lined notch in the artificial dike to try to reconnect the floodplain, along with a “training channel” to help water enter the floodplain. However, as shown below, flow still does not enter the floodplain except during rare high flow events.

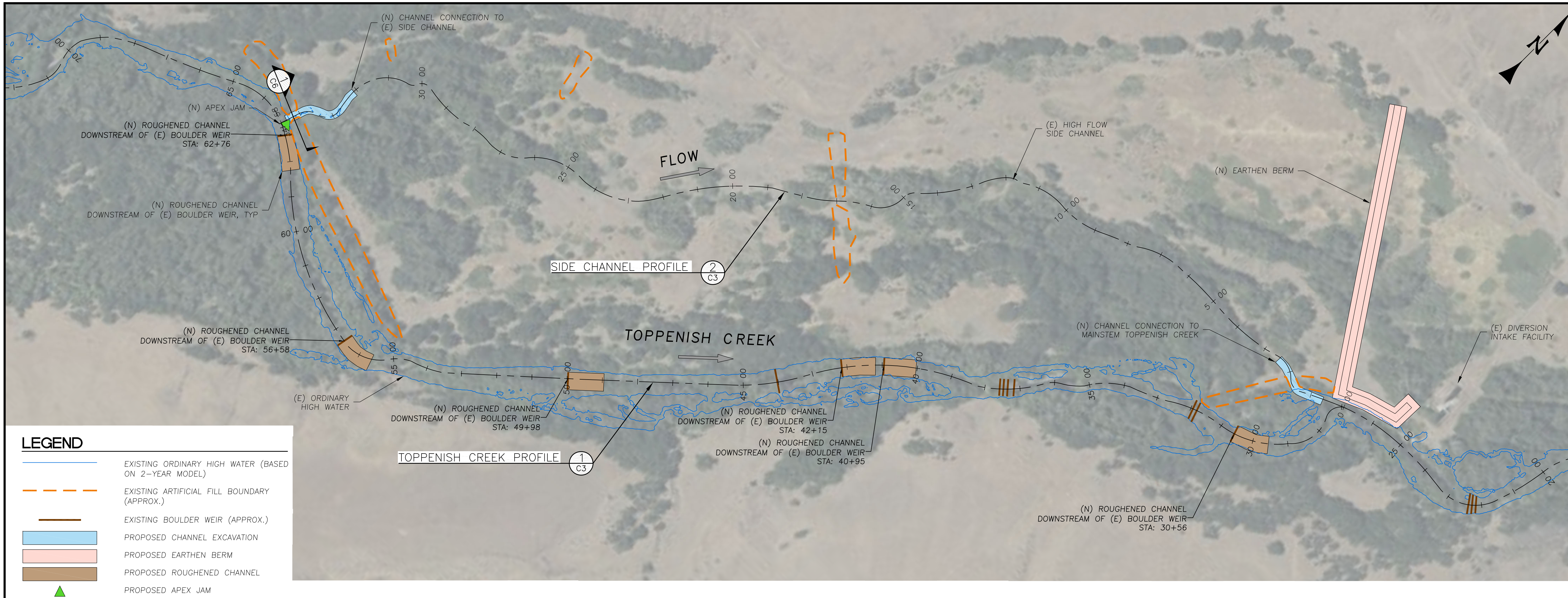
Alternatives

The potential restoration project would aim to restore connectivity between the channel and floodplain. The necessary elements to accomplish this goal include breaching/removing the levee, excavation to reconnect former channel threads, and constructing a berm or levee to return the floodplain flows to the main channel to protect the Olney diversion and canal infrastructure. In addition, the project would improve fish passage at some of the larger boulder drop structures by creating several fish-passable constructed riffles. This memo and accompanying Appendices presents and evaluates three potential alternative project scenarios.

Three alternatives were developed and evaluated to better understand the hydraulic and engineering opportunities and constraints of reconnecting the floodplain. The alternatives are shown in the Conceptual Alternatives Sketches (**Appendix A**), and summarized below:

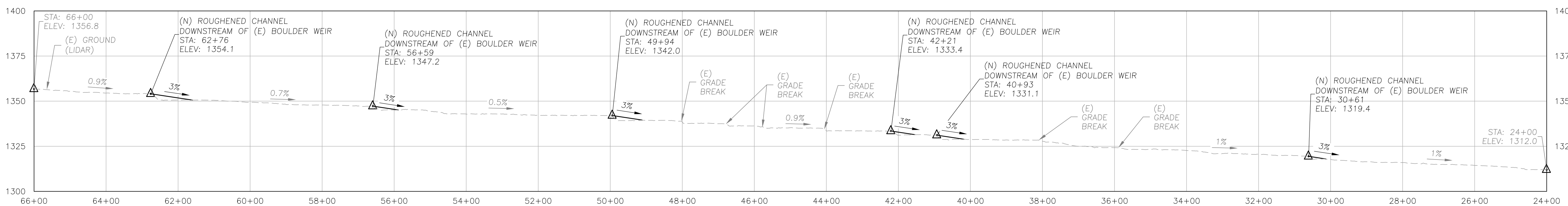
- <u>Alternative 1</u> includes the minimum of earthwork possible to hydraulically reconnect the floodplain, including a levee breach, excavating pilot channels, and building a cross-valley berm that is as short as possible (**Figure 3**).
- <u>Alternative 2</u> would include removal of the artificial levees and more aggressive excavation to activate more of the remnant distributary channels, with a cross-valley berm (**Figure 4**).
- <u>Alternative 3</u> would be equivalent to Alternative 2, but with a longer berm that follows the main side channel to avoid artificial ponding of water (**Figure 5**).

All three Alternatives include installation of six constructed riffles at a subset of the boulder weir structures to improve fish passage. All three alternatives also include installation of a single apex jam at the flow split location along the levee.



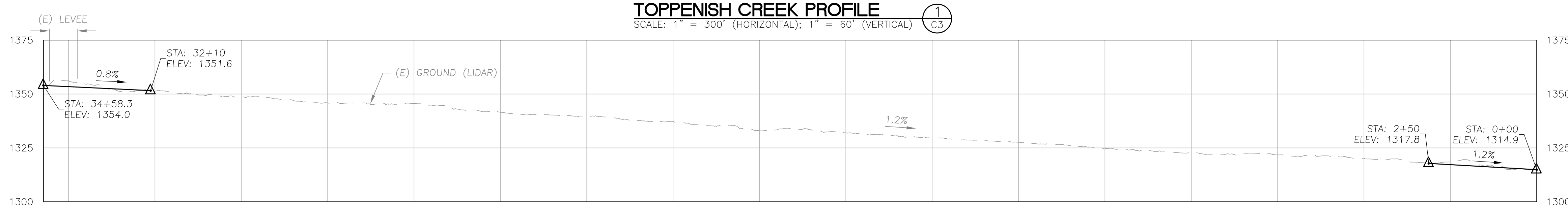
ALTERNATIVE 1 SITE PLAN

SCALE: 1" = 300'



TOPPENISH CREEK PROFILE (1/C3)

SCALE: 1" = 300' (HORIZONTAL); 1" = 60' (VERTICAL)



SIDE CHANNEL PROFILE (2/C3)

SCALE: 1" = 300' (HORIZONTAL); 1" = 60' (VERTICAL)

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ALTERNATIVE CONCEPT 1 - MINIMIZE THE AMOUNT OF EARTHWORK TO RECONNECT FLOODPLAIN

BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS

FIGURE 3

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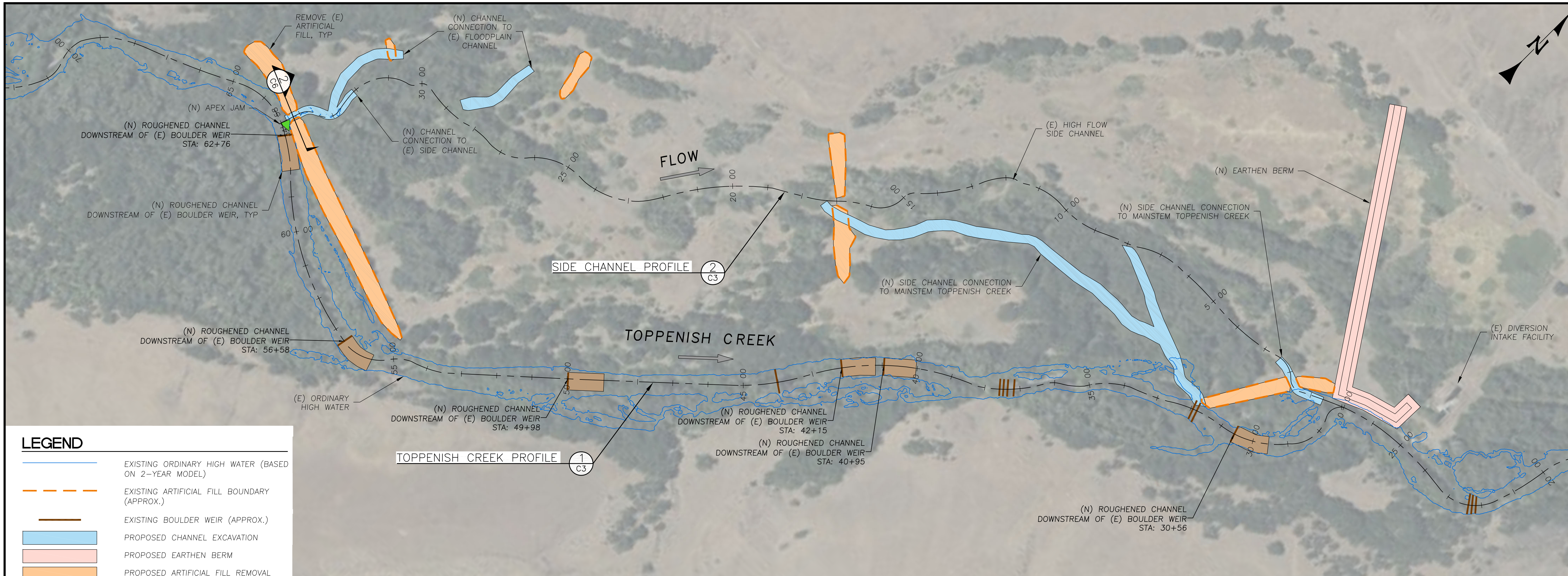

LEGEND

- EXISTING ORDINARY HIGH WATER (BASED ON 2-YEAR MODEL)
- EXISTING ARTIFICIAL FILL BOUNDARY (APPROX.)
- EXISTING BOULDER WEIR (APPROX.)
- PROPOSED CHANNEL EXCAVATION
- PROPOSED EARTHEN BERM
- PROPOSED ARTIFICIAL FILL REMOVAL
- PROPOSED ROUGHENED CHANNEL
- PROPOSED APEX JAM

ALTERNATIVE 2 SITE PLAN

SCALE: 1" = 300'

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ALTERNATIVE 2 -
ADDITIONAL EARTHWORK TO REMOVE FILL
AND CONNECT MORE CHANNELS

BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS
0 1"

FIGURE
4

ALTERNATIVE 3 SITE PLAN

SCALE: 1" = 300'

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ALTERNATIVE 3 -
ALTERNATIVE 2 WITH CURVED BERM TO AVOID PONDING

BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALES FOR REDUCED PLOTS

0 1"

FIGURE

5

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Additional habitat enhancement elements– such as adding large wood structures, revegetation, and excavation of alcoves – can be added to any of the alternatives to further enhance the habitat benefits of the project (Some of these opportunities are identified in the Assessment; see Figure 53 from the main Assessment report). However, these enhancements are not evaluated in this memo. The focus of this study was on identifying the possible approaches, costs, and feasibility of the main project elements needed to reconnect the floodplain.

The primary element of this project will be breaching or removing the artificial levee that currently confines Toppenish Creek to the south valley wall. **Figure 6** shows a cross section across the valley at the location of the main levee (See **Figure 1** for cross section location). Under current conditions, the entrance to the former side channel consists of a boulder-lined low point in the levee four to five feet above the modern channel bed. In Alternative 1, the levee would be breached at this location and the entrance of the side channel lowered closer to the elevation of the channel bed of Toppenish Creek. A small pilot channel would be required to connect this entrance section to the floodplain channel further downstream. In Alternatives 2 and 3, the breach location and entrance to the side channel would be similar, but these options would also include removing the existing levee along its entire length (about 900 feet).

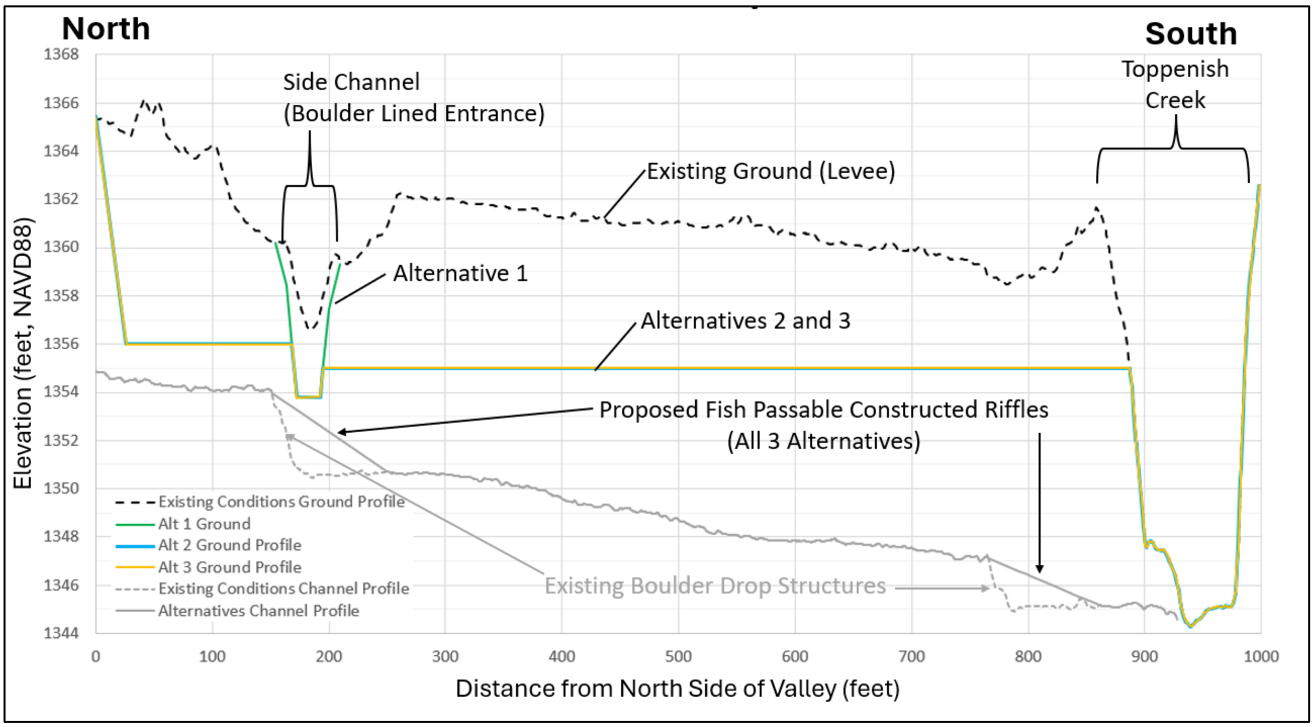

Figure 6. *Cross Section Through Levee (see Figure 1 for Location) and Profile of Toppenish Creek Projected Onto the Toe of the Levee*

Hydraulic and Sediment Analysis

Waterways developed a 2-D hydraulic model of the reach and analyzed both Existing Conditions and Proposed Conditions hydraulics for the three proposed alternatives. **Appendix B** provides a slide set containing a comprehensive presentation of results of the hydraulic model runs for Existing Conditions and all 3 alternatives, for a full range of flows (summer low flow, spring high flows, 2-year, 10-year, and 100-year recurrence interval floods). In addition, Appendix B provides an explanation of the model set up, along with bedload sediment mobility calculations to show locations of potential sedimentation and erosion. The slides are meant to provide a reference for selecting a preferred alternative and for further evaluating and refining the designs. The following discussion describes some of the key results and findings of the analysis.

Existing Conditions

Figure 8 shows the modeled flood extents and water velocities in the potential project area under Existing Conditions.

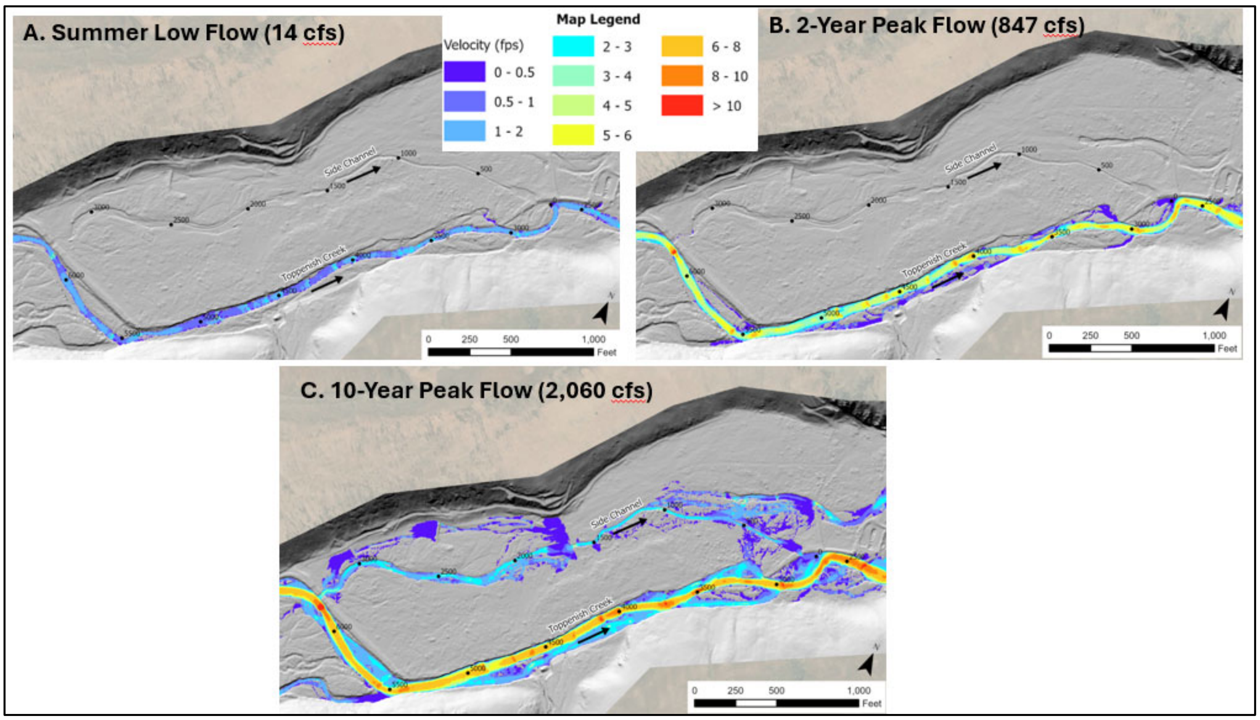

Figure 8. *Existing Conditions Modeled Water Velocities During (A) Summer Low Flows, (B) Small Flood (2-Year Recurrence Interval), and (C) Flood Flow (10-Year Recurrence Interval)*

The following bullet points summarize hydraulic and geomorphic interpretations of the existing conditions in the project reach based on **Figure 8**:

- The modeling confirms that the reach lacks hydraulic and habitat diversity due to artificial confinement and channel incision.
- All the flow is confined to within the straightened channel throughout the year: low flows, moderate flows, and even moderate high flows including a 2-year peak flow event. The model predicts that some of the high flow enters the floodplain channel through the boulder lined entrance section during a 10-year peak flow. The artificially leveed floodplain therefore contains

flow only a few days every decade, on average. This artificial situation is extremely different from the reach immediately upstream of the levee, which has complex flow patterns including multiple channel threads throughout much of the year and provides some of the highest quality steelhead habitat in Toppenish Creek.

- During a 2-year peak flow, there are only limited areas where velocities are below 3 or 4 feet per second within the reach. The reach provides little to no velocity refuge for juvenile fish, who must migrate out of the reach, contending with the boulder weirs, to find protected lower velocity zones.
- The lack of lower velocity zones during floods explains the predominance of cobble and boulder bedload, and the lack of spawning-size gravel, within this reach.

Alternative 1

Figure 9 shows the modeled flood extents and water velocities for Alternative 1.

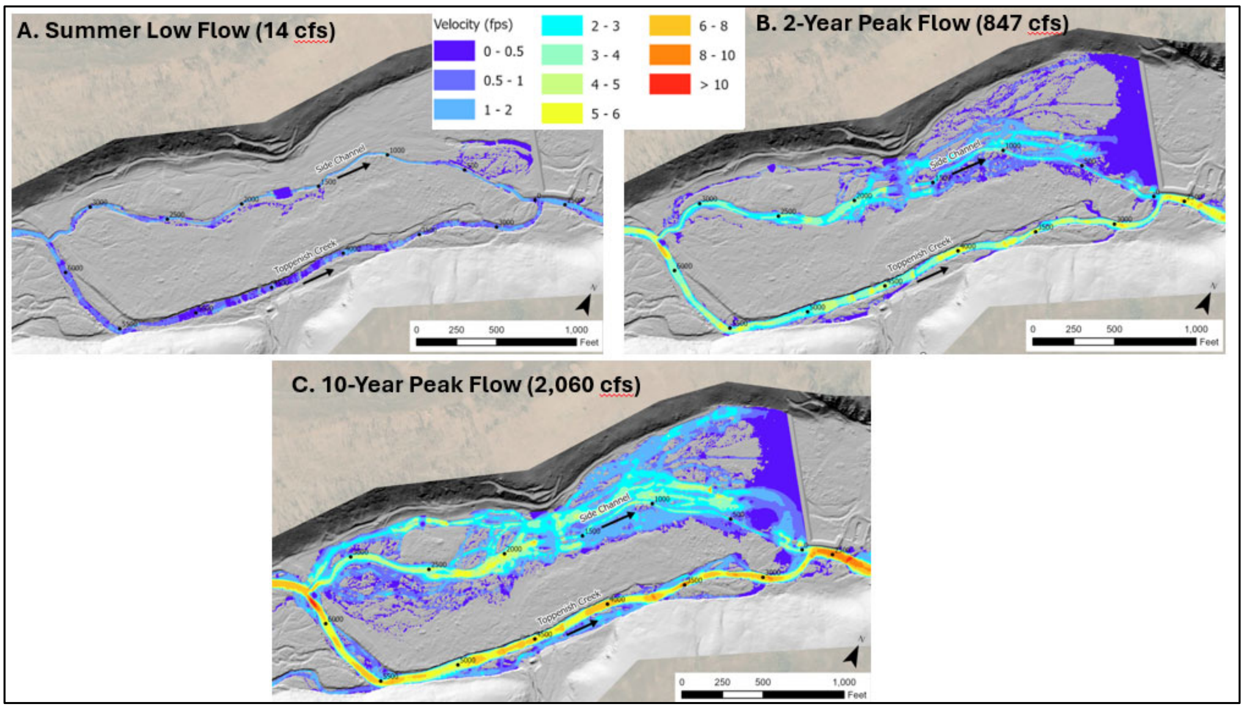

Figure 9. *Modeled Water Velocities for Alternative 1 During (A) Summer Low Flows, (B) Small Flood (2-Year Recurrence Interval), and (C) Moderate Flood (10-Year Recurrence Interval)*

The following bullet points summarize interpretations of the hydraulic and geomorphic performance of Alternative 1:

- By breaching the levee, some flow would enter the side channel throughout the year, even during the summer low flow period.
- A substantial fraction of flow would enter during floods, which reduces flow velocities in the mainstem for the 2-year and 10-year recurrence interval flows.
- Artificial ponding would occur over a large area of the floodplain due to the proposed cross-valley dike. This could help to recharge the groundwater aquifer and could provide rearing

opportunities for fish. However, it would artificially change the hydraulic and habitat characteristics of the area and could lead to losses in surface flows. YNF and other stakeholders would need to decide whether this is appropriate or desirable.

- It is debatable whether it is desirable to split the flow during low flow period. On one hand, this could reduce water depths and velocities and potentially increase stream temperature. On the other hand, the multiple-thread channels raise the groundwater level, helping to support riparian forest, and offer better and more complex in-channel habitat, and potentially increase hyporheic exchange with the mainstem channel.
- The reach immediately upstream of the artificial levee provides a possible “reference reach” for the type of complex, forested channel and floodplain that would be the long-term target outcome of the project.

Alternative 2

Figure 10 shows the modeled flood extents and water velocities for Alternative 2.

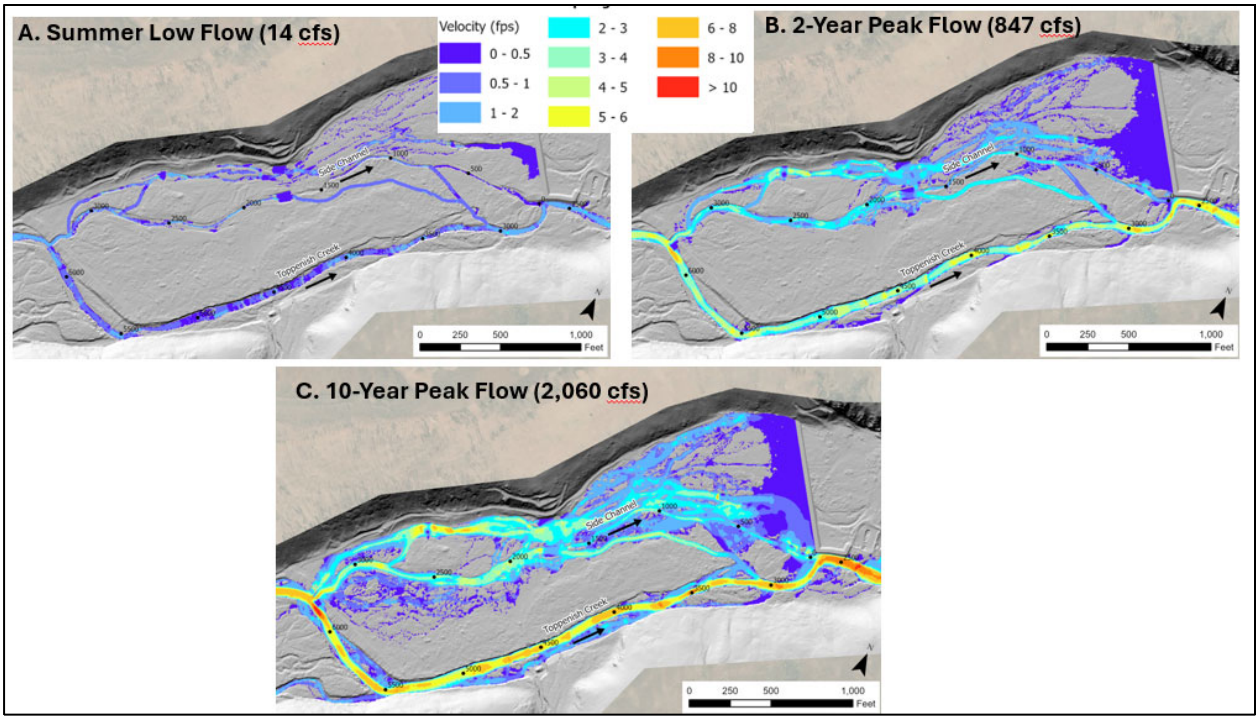

Figure 10. *Modeled Water Velocities for Alternative 2 During (A) Summer Low Flows, (B) Small Flood (2-Year Recurrence Interval), and (C) Moderate Flood (10-Year Recurrence Interval)*

The following bullet points summarize interpretations of the hydraulic and geomorphic performance of Alternative 2:

- The volume of flow into the floodplain is the same as for Alternative 1, but flow is more spread out through more complex flow pathways connecting more of the floodplain.
- There is less ponding at the cross-valley berm than in Alternative 1 because there are more pathways that allow some of flow to get back to Toppenish Creek upstream of the berm.

- Even so, there would still be a significant amount of artificial ponding behind the berm throughout most of the year.

Alternative 3

Figure 11 shows the modeled flood extents and water velocities for Alternative 3.

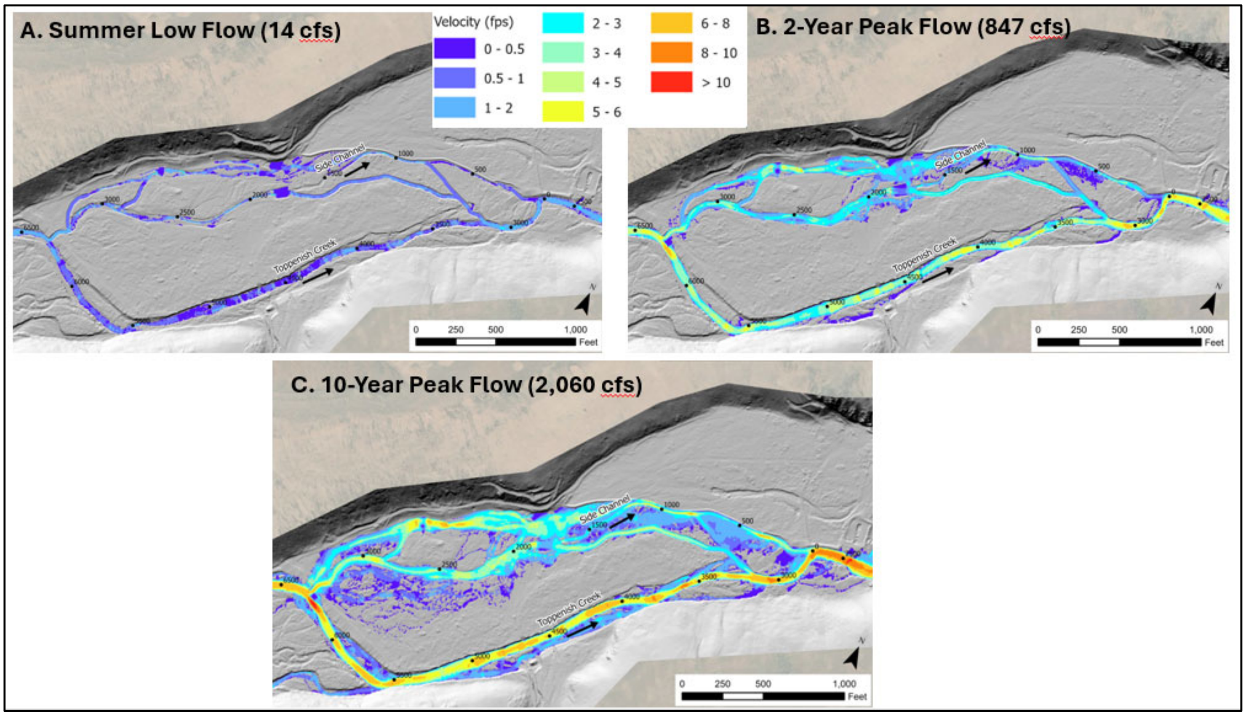

Figure 11. *Modeled Water Velocities for Alternative 3 During (A) Summer Low Flows, (B) Small Flood (2-Year Recurrence Interval), and (C) Moderate Flood (10-Year Recurrence Interval)*

The following bullet points summarize interpretations of the hydraulic and geomorphic performance of Alternative 2:

- The berm successfully returns water to Toppenish Creek and avoids ponding at all flows
- The berm cuts off potential side channel pathways in the floodplain, so there is a net reduction in the complexity of flow pathways and the residence time of water in the floodplain relative to Alternative 2.

Bedload Deposition and Habitat Creation

Upper Toppenish Creek is a bedload-dominated stream in that the movement and deposition of bedload, not suspended load, is the primary control on the geomorphology and substrates in the stream. The size of bed material sediment that deposits in a given location will directly determine the type of fish habitat that will form – for example, pools that do not fill in with fine sediment, riffles with spawning-size gravels, or sand deposits that allow for rearing of lamprey. Generally speaking, deposition of bedload over time leads to more channel dynamics and complexity, whereas erosion of bedload causes channel incision and simplification.

The size of sediment that will deposit is primarily determined by the local basal shear stress (the shear stress exerted on the particles on the channel bed) during a bedload-mobilizing event. The Shields' formula (Shields, 1936) expresses the relationship between basal shear stress and the size of bedload that can be moved. For this analysis, the Shields equation was rearranged to estimate the maximum mobile grain size as a function of shear stress and applied to the gridded hydraulic model results to produce maps of maximum mobile grain size in a given flood event (**Figure 9**)[1]. In theory, the maximum grain size that can move in a moderate to high flow should be similar to the grain sizes that would be expected to be found in the channel bed. For this analysis, the 10-year flood is used to estimate bed material grain sizes (similar results for the 2-year flood are provided in **Appendix B**). **Figure 9** can be considered as a map of predicted grain sizes expected in the channel for different scenarios.

The following points summarize the interpretations of this sediment transport analysis:

- The Existing Conditions model accurately predicts that the main channel of Toppenish Creek is dominated by cobble-size sediment, with smaller amounts of spawning-size gravel (**Figure 9A**). This is consistent with field observations and suggests that in general the model provides reasonable and realistic predictions.
- All three Alternatives would set the invert elevation of the entrance to the side channel at the same elevation as the bed of Toppenish Creek (see **Figure 6**). This would allow bedload to enter the newly opened side channel system. The model suggests that once the supply of bedload is restored, and following several large flood cycles, a more complex patchwork of grain sizes should develop within the side channels. Cobble size sediments are predicted near the entrance to the side channel, and gravel size sediments will predominate throughout the rest of side channel system (**Figure 9B** and **9C**). This could create more gravel spawning sites in the side channels, a feature that is currently a limiting factor in this reach.
- In Alternatives 1 and 2, deposition of fine sediment will occur upstream of the cross-valley berm (**Figure 9B**). The model predicts that a prograding delta, with its typical pattern of grain sizes, would form upstream of the impoundment: a gravel and sand delta transitioning to fines (mud) deposition near the berm. Although it would be artificial, this could create a complex wetland with a variety of beneficial depositional environments, similar to a large beaver pond. These deposits could potentially provide rearing areas for lamprey.
- In Alternative 3, gravel deposition would be expected throughout much of the side channel complex, creating more spawning sites (**Figure 9C**).
- Alternative 2 would provide the greatest variety of grain sizes and habitat types among the 3 alternatives. That alternative would include artificially ponding water against a berm, which will have both positive and negative impacts.

[1] For this calculation we assumed a dimensionless critical shear stress (τ^*) value of 0.06, a typical value for gravel bed streams (Montgomery and Buffington, 1999)eams (Montgomery and Buffington, 1999)

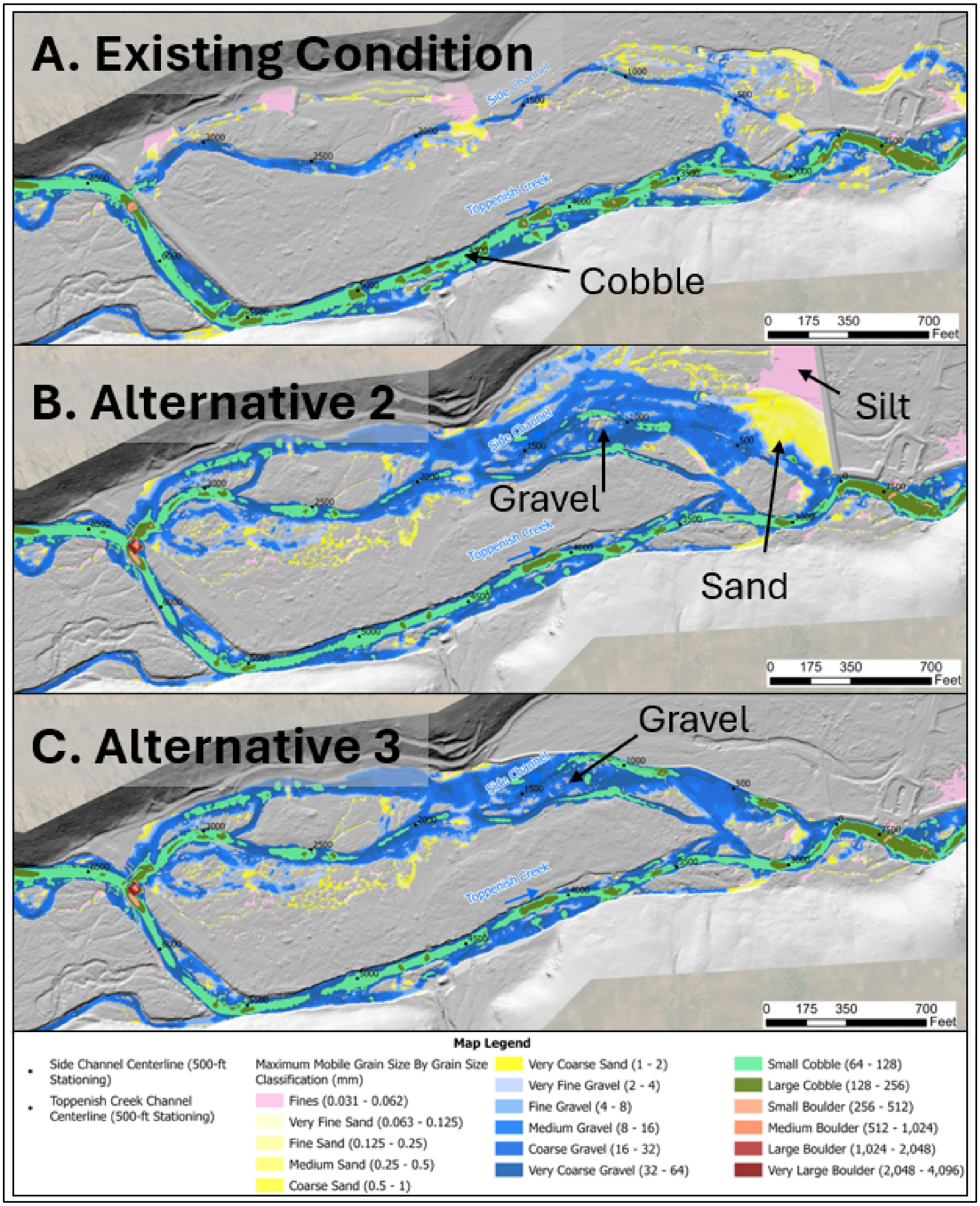

Figure 9. *Modeled Pattern of Maximum Mobile Grain Size in a 10-Year Recurrence Interval Peak Flow, Considered to be a Proxy for the Predicted Bed Grain Size. (A) Existing Conditions, (B) Alternative 2 Scenario, (C) Alternative 3 Scenario. (Note: the bed material map for Alternative 1 is not shown here to allow more space for the other maps, but can be found in the* ***Appendix B****)*

Estimated Project Costs and Cost Drivers

A rough "order-of-magnitude" construction cost estimate was developed for each of the alternatives for the purpose of comparing relative costs and for beginning to develop an idea of the absolute costs of the project (**Table 1**). At the current level of project development, these cost estimates are not considered accurate; instead, they are intended to provide order-of-magnitude construction costs. Note that the cost estimates are for construction of the elements in Appendix B only, and do not include the following additional parts of the project that will likely be needed or desired by YNF:

- Survey and design costs
- Geotechnical engineering for the constructed berm
- Permitting costs
- Construction oversight and management
- Additional potential project features that were not considered in these alternatives but that will be beneficial to include in the project, including addition of large wood, excavation of alcoves, and revegetation

Table 1. *Rough "Order-of-Magnitude" Costs for 3 Alternatives*

ITEM NO.	ITEM	TOTAL		
		ALT 1	ALT 2	ALT 3
1	MOBILIZATION	$175,000	$190,000.00	$180,000
2	TEMPORARY EROSION CONTROL	$50,000	$50,000	$50,000
3	CLEARING AND GRUBBING	$40,000	$40,000	$40,000
4	DEWATERING	$100,000	$100,000	$100,000
5	UNCLASSIFIED EXCAVATION	$10,000	$150,000	$150,000
6	ENGINEERED FILL	$575,000	$575,000	$500,000
7	ENGINEERED STREAMBED MATERIAL	$600,000	$600,000	$600,000
8	APEX JAM	$45,000	$45,000	$45,000
9	SEEDING	$25,000	$35,000	$35,000
	SUBTOTAL	$1,620,000	$1,785,000	$1,700,000
	CONTINGENCY (30%)	$486,000	$535,500	$510,000
	TOTAL	$2,106,000	$2,320,500	$2,210,000

NOTES:

1. These are rough order of magnitude construction costs for concept alternatives based on 2024 prices.

The main cost drivers are similar for all three versions:

- All three alternatives include fish passage improvements on Toppenish Creek. The main cost drivers for the fish passage improvements include dewatering and construction of roughened channels, which are built using engineered streambed material. The cost estimate assumes that this is imported material. The cost of this work is ~$700k (excluding mobilization, demobilization, and temporary erosion control), assuming that there will be 6 roughened channel sections. This number would change if more or fewer rock riffles are needed.

- All three concept alternatives include an earthen berm that would prevent flows up to the 100-year event from flooding the existing diversion intake structure. The berm for Alternative 1 and Alternative 2 would be perpendicular to the floodplain, whereas Alternative 3 has a longer, curved earthen berm to prevent ponding. Due to floodplain ponding upstream of the cross-valley berm, the berm in Alternatives 1 and 2 would need to be higher than the berm in Alternative 3. As a result, the cost of the engineered fill for the different earthen berm alternatives is similar, even though the berm in Alternative 3 is longer: ~$575k for Alternatives 1 and 2 and ~$500k for Alternative 3 (excluding mobilization, demobilization, and temporary erosion control).

- The main difference in cost between the alternatives is the quantity of excavation to create floodplain channels and remove artificial fill. Alternative 1 has the least excavation and the lowest cost for excavation: ~$10k. Alternatives 2 and 3 have significantly larger quantities of excavation, resulting in higher costs (~$150k). However, the three alternatives are fairly similar in cost, despite the significant differences in the amount of excavation. That is because excavation is a relatively low cost compared to the main cost drivers, construction of the berm and the engineered riffles. Therefore, the differences between the three alternatives do not result in significantly different overall costs.

References

Shields, A. 1936. Application of similarity principles and turbulence research to bed-load movement: Mitt. Preuss. Verschanst., Berlin, Wasserbau Shiffbau, in Ott, W.P., and uchelen, J.C. (translators), California Institute of Technology, Pasadena, California, Report no. 167, 43 p.

Buffington, J.M. and Montgomery, D.R., 1997. A systematic analysis of eight decades of incipient motion studies, with special reference to gravel-bedded rivers. Water resources research, 33(8), pp.1993-2029.

Reichmuth, D.R., Potter, A.S., Reichmuth, M.G. 2007. Toppenish Basin Geomorphology. Report prepared by Geomax P.C., April 2007. 195 p.

Waterways Consulting, Inc. 2024. Toppenish and Simcoe Creeks Habitat Assessment and Restoration Prioritization – Final Report, prepared for Yakama Nations Fisheries, 109 p. plus 9 Appendices.