FINAL

IMPLEMENTATION PLANNING FOR RESTORATION OF COASTAL STREAMS AND EMBAYMENTS ALONG THE RAILROAD CORRIDOR ON THE PUGET SOUND SHORELINE

Programmatic Restoration Recommendations and Conceptual Design at Three Priority Sites

Prepared for

Tulalip Tribes Natural Resources Department

6406 Marine Drive

Tulalip, WA 98271

December 2022

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement EPA 16-05251 through the Washington Department of Fish and Wildlife. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the Washington Department of Fish and Wildlife, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FINAL

IMPLEMENTATION PLANNING FOR RESTORATION OF COASTAL STREAMS AND EMBAYMENTS ALONG THE RAILROAD CORRIDOR ON THE PUGET SOUND SHORELINE

Programmatic Restoration Recommendations and Conceptual Design at Three Priority Sites

Prepared for **December 2022**

Tulalip Tribes Natural Resources Department
6406 Marine Drive
Tulalip, WA 98271

Project Team:
ESA | Environmental Science Associates
Confluence Environmental Company
Hanson Professional Services, Inc.
Shannon & Wilson
Tulalip Tribes Natural Resources Department

2801 Alaskan Way
Suite 200
Seattle, WA 98121
206.789.9658
esassoc.com

D202001337.00

Suggested citation: ESA (Environmental Science Associates), Confluence Environmental Company, Hanson Professional Services, Shannon & Wilson, and Tulalip Tribes Natural Resources. 2022. Implementation Planning for Restoration of Coastal Streams and Embayments Along the Railroad Corridor on the Puget Sound Shoreline – Programmatic Restoration Recommendations and Conceptual Design at Three Priority Sites. Prepared for the Washington Department of Fish and Wildlife, Olympia, Washington.

EXECUTIVE SUMMARY

Along the eastern shoreline of Puget Sound, 73 miles of existing railroad is a prominent feature affecting the shoreline habitats and coastal streams in the area. This programmatic analysis was prepared to enhance collaboration among the BNSF Railway and salmon habitat restoration partners to implement restoration projects in coastal estuaries and embayments, with a focus on replacing existing railroad drainage crossings to improve fish passage and rearing conditions for salmonids. The restoration at these crossings will improve fish passage conditions as well as the quality and quantity of estuary and embayment habitats.

The current work presented in this report is Phase 2 of the project, which is beginning the implementation of restoration actions at priority sites identified in Phase 1. Phase 1 entailed conducting an inventory and prioritization of coastal stream mouths and embayments along the railroad were replacing the railroad drainage crossings would benefit Puget Sound Chinook salmon, which are listed as threatened under the Endangered Species Act. An advisory group convened in Phase 1 was integral to initiating a collaborative dialogue for working toward habitat restoration along the railroad. In addition to the Tulalip Tribes who were part of the project team, the advisory group participants included representatives from BNSF, Washington Department of Fish and Wildlife (WDFW), WDFW Estuary and Salmon Restoration Program, Washington Department of Ecology, Snohomish County, and the South Puget Sound Salmon Enhancement Group. The prioritization completed in Phase 1 identified 17 highest priority sites and 27 high priority sites among the 196 coastal streams that were evaluated (Confluence et al. 2019). In addition, seven out of 13 embayments evaluated had high scores for likelihood of Chinook salmon use and habitat quality.

This report presents the information examined during Phase 2, which focuses on planning for restoration of the highest and high priority sites from Phase 1, now referred to collectively as "priority sites." Phase 2 included the development of **programmatic recommendations** for restoring coastal estuaries along the railroad and the development of restoration design concepts for three of the priority sites identified in Phase 1.

The programmatic recommendations presented here entail identifying design standards, site characteristics affecting design and constructability, and potential grant funding opportunities for the design and construction. The programmatic recommendations were developed through discussions with BNSF, engagement with restoration partners throughout the region, the experience of the project team in working on projects along this railroad corridor, and best practices for coastal estuary restoration considering fish passage and natural processes. The Puget Sound Partnership (PSP) has recognized the importance of this effort by identifying "*funding and coordinated partner engagement with BNSF to reduce impacts to nearshore habitat from railroad infrastructure*" as part of its Action Agenda for Puget Sound recovery (PSP 2022).

Stream crossing sizing standards used in the railroad industry and those used in Washington State to provide fish passage at freshwater sites are described in this report (Chapter 2). Statewide guidance for tidal crossings, which are the focus of this project, are not established at this time, and instead the crossing size is evaluated on a case-by-case basis.

Page

Chapter 3 identifies railroad and site characteristics that affect the design and ability to construct replacement railroad drainage crossing structures. The railroad characteristics identified are embankment height, embankment materials, number and width of trackway, geometry of the track alignment, additional railroad infrastructure, and proximity to grade crossings. Additional site characteristics are site access and staging, stream alignment and elevation, and stream gradient. In the interest of identifying where priority sites based on benefits to Chinook salmon align with BNSF priorities, additional BNSF considerations for selecting sites and minimizing operational impacts during construction are described. The railroad and site characteristics of each of the priority coastal stream mouths and embayments are listed in Chapter 4.

A case study for the Meadowdale Beach Park restoration project, the first habitat restoration project on the Puget Sound shoreline that entailed replacing the railroad drainage crossing and excavating a large estuary, is presented in Chapter 5. The case study describes the funding sources compiled to complete the project. In addition, several "keys to success" are identified that are applicable to all future shoreline restoration projects along the railroad.

Potential grant funding opportunities are described in Chapter 6. These include federal and state salmon recovery and fish passage funding, federal funding specific to railroads, and new funding opportunities that are being developed. The grant funding opportunities support the development of a funding strategy, which also identifies non-grant funding contributions.

The programmatic recommendations were applied during the development of design concepts for three priority sites described in Chapter 7. The three sites were chosen based on the geographic distribution throughout the project area, the apparent differences in the engineering complexities associated with each site, the differences in anticipated crossing structures needed at each site, and the willingness of the landowners to partner on the restoration work. The three sites demonstrate the range of complexities and solutions that may apply to the full list of priority sites. The three priority sites are Squalicum Creek estuary in Bellingham, Japanese Gulch Creek estuary in Mukilteo, and an unnamed creek estuary on Joint Base Lewis-McChord (JBLM).

The Squalicum Creek estuary railroad crossing is comprised of six box culverts located on a railroad spur, not the railroad mainline. The railroad crossing is one of three crossing structures located in an approximately 250-foot-long reach of the creek and all are downstream of river mile 0.1. The other crossings are Roeder Avenue owned by the City of Bellingham and a private truck bridge owned by the Port of Bellingham. Restoration of the three crossings would address partial fish passage barriers at the mouth of the largest creek in the City of Bellingham and allow for restoration to enlarge and enhance the constrained estuary. In this way, the restoration would benefit all anadromous salmonids throughout the Squalicum Creek watershed and amplify the benefits of substantial habitat restoration work that has been completed upstream by restoring full passage into the creek system. The proposed restoration includes three long bridges, which allows for widening of the estuary. Several challenges associated with estuary restoration in this constrained site are described. Site restoration will require close coordination among the City of Bellingham, the Port of Bellingham, and BNSF.

Page

The Japanese Gulch Creek estuary railroad crossing is upstream of a proposed estuary restoration project for which the City of Mukilteo has 100% designs and downstream of four recent phases of creek restoration to improve fish passage and habitat conditions. Currently, the creek flows under the railroad in three culverts. The proposed restoration is in two side-by-side box culverts. The restoration options at the site are limited due to the low embankment height of the railroad tracks. Close coordination will be needed with the City of Mukilteo to ensure the proposed railroad crossing connects seamlessly with the downstream restoration project.

The unnamed creek estuary on JBLM currently flows through the railroad corridor in a round pipe. The pipe is perched at its outlet and largely buried by riprap protecting the railroad embankment. The proposed restoration at the site is to replace the existing culvert with an 8-foot diameter round pipe. The site is on a remote section of the shoreline, and JBLM has indicated the site is in an area that they do not use for training and therefore would be unlikely to be impacted by their training.

The report concludes with a summary and recommended next steps. One of the recommended next steps is to complete the site analysis and conceptual design development of the priority sites identified in Phase 1. This step informs discussions with BNSF, adjacent landowners, and other stakeholders. It also provides information on the willingness of local adjacent landowners, and potentially gets their required planning processes underway. For example, this happened at the Squalicum Creek estuary site as the City of Bellingham and Port of Bellingham are now actively planning for their parts of the restoration. Another recommended step is the development of a Regional Implementation Plan through a collaborative process to ensure that a coordinated and actionable plan is produced. The Implementation Plan should include a funding strategy, targeted schedule, permitting strategy, and the roles and responsibilities of BNSF, adjacent landowners, and key stakeholders.

TABLE OF CONTENTS

Implementation Planning for Restoration of Coastal Streams and Embayments Along the Railroad Corridor on the Puget Sound Shoreline – Programmatic Restoration Recommendations and Conceptual Design of Three Priority Sites

Page

Page

List of Figures

List of Tables

Page

IMPLEMENTATION PLANNING FOR RESTORATION OF COASTAL STREAMS AND EMBAYMENTS ALONG THE RAILROAD CORRIDOR ON THE PUGET SOUND SHORELINE

Programmatic Restoration Recommendations and Conceptual Design of Three Priority Sites

1.0 Introduction and Project Background

For long stretches of the eastern shoreline of Puget Sound, the adjacent railroad is a prominent feature affecting the shoreline habitats and coastal streams in the area. This project aims to work collaboratively with BNSF Railway[1] (BNSF), tribes, agencies, and salmon habitat restoration partners to implement restoration projects in coastal estuaries and embayments, with a focus on replacing or improving existing railroad drainage crossings[2] – herein referred to as crossings – to improve fish passage and rearing conditions for salmonids. The restoration at these crossings will improve fish passage conditions as well as the quality and quantity of estuary and embayment habitats. Successful enhancement projects will meet goals for providing fish passage, providing access to rearing and migration habitat for juvenile salmonids, supporting natural stream functions including sediment and large wood debris transport, supporting railroad right-of-way integrity, and minimizing ongoing maintenance needs associated with railroad drainage crossings.

The ecological significance of such restoration is based on the importance of coastal streams, estuaries, and shallow shoreline habitats of Puget Sound for anadromous salmonids. The term anadromous describes a salmonid life cycle in which the fish hatch and spend their early lives in freshwater before migrating to the ocean to mature; then as adults returning to the river or stream where they were hatched to spawn. Puget Sound and its contributing watersheds support eight species of anadromous salmonids, including five species of Pacific salmon and three species of trout. The watersheds draining into Puget Sound include several large rivers, as well as hundreds of smaller coastal stream systems that flow directly into Puget Sound. The estuaries of rivers and coastal streams provide a vital link for anadromous salmonids moving to and from freshwater and saltwater habitats. In this way, fish passage in estuaries is essential for anadromous salmonids to complete their lifecycle. In addition, estuaries and shallow shoreline habitats, including embayments and stream mouths, provide important rearing habitat for young (juvenile) anadromous salmonids entering saltwater for the first time. Recent research has documented the importance of coastal estuaries and streams as rearing habitat for non-natal populations of Chinook salmon (Beamer et al. 2003, 2005, 2006, 2013; Hirschi et al. 2003).

While coastal streams in Puget Sound have been modified by development and transportation, the railroad embankment along the shoreline is an especially prominent modification that is located right at the outlet

[1] Burlington Northern Santa Fe shortened its name to BNSF Railway in 2005.

[2] Railroad drainage crossings include stream, wetland, stormwater, and estuary drainages that cross the railroad. These may cross in culverts or under trestles and bridges.

or mouth of many coastal streams. The BNSF railroad embankment is adjacent to 73 miles of the Puget Sound shoreline between Olympia and the U.S.-Canada border (**Figure 1**; Confluence et al. 2019). BNSF's predecessor railroad companies have operated along Puget Sound since the late 1800s. Most of the railroad lines along the shoreline were initially constructed on trestles, a series of cross-braced wood frames with open spaces in between, along the shoreline to elevate the railroad above the water. More recently, the trestles were backfilled and hardened with ballast and riprap to form a solid embankment or causeway for the railroad line to reduce maintenance costs. **Figure 2** shows examples of a historic trestle and a current embankment. When a trestle line was converted to an embankment, as was common in the early 20th century, through streams were routed into crossing structures, typically round or box culverts and occasionally bridges. In many instances, these embankments were installed where coastal estuaries would have naturally occurred. An unintended consequence of these embankments is that they interrupt the natural connection between the watershed and Puget Sound. According to the Puget Sound Partnership (PSP) 2022-2026 Action Agenda for Puget Sound, the BNSF railroad infrastructure impairs and impedes essential nearshore habitat along 52 miles Washington's shoreline (with another 21 miles of railroad within 200 feet of the shoreline) (PSP 2022).

By working with BNSF, tribes, agencies, and regional restoration partners, this project aims to restore coastal estuaries and embayment habitats and improve site resiliency along the railroad embankments on the eastern shoreline of Puget Sound by replacing existing crossing structures with larger structures that are sized appropriately for the stream and tidal conditions of each site. This report presents project background information, describes habitat and fish passage impediments, presents specific justification for considering habitat and fish passage improvements, and encourages continued dialogue between the project team and BNSF regarding project coordination and planning for multiple sites along BNSF's Bellingham, Scenic, and Seattle Subdivisions between the U.S.-Canada border and Olympia, Washington.

The current work presented in this report is Phase 2 of the project, which is beginning the implementation of restoration actions at priority sites identified in Phase 1. In Phase 1, the project began with an inventory of the number and location of stream and embayment[3] crossings along the railroad on the Puget Sound shoreline between Olympia and the U.S.-Canada border. Next, we conducted a field investigation to characterize each crossing structure and the habitats upstream and downstream of each structure. This information was applied in an evaluation framework to prioritize coastal streams for restoration based on anticipated benefits to Chinook salmon. The Phase 1 work was guided by a technical advisory group who convened to review methods, results, and recommendations of the evaluation. Advisory group participants included representatives from BNSF, Washington Department of Fish and Wildlife (WDFW), WDFW Estuary and Salmon Restoration Program, Washington Department of Ecology (Ecology), Snohomish County, and the South Puget Sound Salmon Enhancement Group. The prioritization identified 17 highest priority sites and 27 high priority sites among the 196 coastal streams that were evaluated (Confluence et al. 2019). A map of the priority streams is provided in **Figure 3**. Seven additional embayment sites were identified as being a high priority for restoration. The final report from Phase 1 is available at: https://nr.tulaliptribes.com/Topics/HabitatMonitoringAndResearch/RailroadStreamCrossing.

[3] The embayments of interest were those sites where the railroad embankment cuts off a portion of the nearshore habitats which creates a partially or completely isolated embayment landward of the railroad tracks.

Figure 1. Map of BNSF Railroad Along Puget Sound Shoreline between Olympia and U.S.-Canada border

Figure 2. Historic railroad trestle south of Bellingham, WA (top; note visible openings in the railroad line running over the water) and current railroad embankment (bottom)

Top photo source: Historylink.org, courtesy Paul Dorpat, https://www.historylink.org/File/10904.

Figure 3. Prioritization Tiers of Stream Mouths Evaluated Along the BNSF Railroad on Shoreline of Puget Sound

(Interactive map also available at: bit.ly/3Po5naM)

This report presents the information gained during Phase 2, which focuses on planning for restoration of the highest and high priority sites from Phase 1, now referred to collectively as "priority sites." One additional site was added to the list of priority stream mouths based on more recent information to bring the total number of priority stream sites to 45. Phase 2 included the development of programmatic recommendations for restoring coastal estuaries along the railroad and the development of restoration design concepts for three of the priority sites identified in Phase 1. The programmatic recommendations presented here entail identifying design standards, site characteristics affecting design and constructability, keys to success of a completed restoration along the railroad, and potential grant funding opportunities for the design and construction. The programmatic recommendations were developed through discussions with BNSF; engagement with tribes, agencies, and restoration partners throughout the region; the experience of the project team in working on projects along this railroad corridor; and best practices for coastal estuary restoration considering fish passage and natural processes. Puget Sound Partnership has recognized the importance of this effort by identifying "*Funding and coordinated partner engagement with BNSF to reduce impacts to nearshore habitat from railroad infrastructure*" as part of its Action Agenda for Puget Sound recovery (PSP 2022). The programmatic recommendations were applied during the development of design concepts for three priority sites. The three priority sites are Squalicum Creek estuary in Bellingham, Japanese Gulch Creek estuary in Mukilteo, and an unnamed creek estuary on Joint Base Lewis-McChord (JBLM). The report concludes with a summary of recommendations and recommended next steps. The three sites were chosen based on the geographic distribution along the shoreline railroad corridor, the apparent differences in the engineering complexities associated with each site, the differences in anticipated crossing structures needed at each site, and the willingness of the landowner to partner on the restoration work.

A story map was prepared to communicate this work to a broader audience. The story map is available here. Select "View Story" after following the link.

2.0 Existing Stream and Embayment Crossing Structures and Sizing Standards

2.1 Types of Crossing Structures

This chapter summarizes observations for the 196 stream crossings inventoried in Confluence et al. (2019). Existing crossing structures include **bridges** (multi-span trestles and single span), **box culverts**, and round/oval **pipe culverts**. Bridges include concrete or creosote wood pilings supporting the railroad girders with rails above. Although the surveyed trestle bridges include characteristics such as pilings in the stream channel and bank hardening that adversely affect fish habitat, bridges tend to be the structure type that appeared least restrictive to streamflow, natural stream/shoreline processes, and fish passage.

Existing box culverts are four-sided structures. They are constructed with reinforced concrete and tend to be large enough to contain streambed materials. Another type of culvert used along the BNSF railroad embankment is arch culverts that are constructed with a combination of concrete and corrugated metal. Arch culverts also allow for streambed material within the structure, but arch culverts are not preferred by BNSF. Box and arch culverts tend to be more restrictive to streamflow and associated processes than bridges, but they typically allow for a wetted channel underlain by natural substrate.

Pipe culverts are comprised of concrete, corrugated metal, or high-density polyethylene (HDPE) plastic. These features are the most restrictive structure type and typically include a pipe that passes through the railroad embankment. The pipe culvert outlet may be at grade or severely perched above the downstream grade. Of the 196 sites inventoried, more than 80 had culverts that were perched at low tide. These structures effectively disconnect the upstream and downstream areas and result in a barrier to fish movement. These structures may also fail to pass streamflows at peak flows, may cause either excessive downstream erosion or sedimentation, and may prevent the transport of sediment or woody debris. A small number of the observed pipe culverts had been modified since they were initially installed, either to repair a failing structure or to extend the serviceable life of the crossing structure (e.g., slip-lining a new pipe inside an older one).

In several locations, multiple culverts are used for the same stream crossing. Where multiple culverts occur, there are two general configurations: (1) culverts may be side-by-side so the cumulative area of the culverts provides sufficient area for passing streamflow; or (2) culverts may have different inlet elevations so that one culvert supports the low-flow stream channel and other culverts function during high or flood flow. Such side-by-side culverts often fail to function as intended, with one culvert becoming dominant over time and disconnecting the floodway from the stream. For these reasons, WDFW does not support these types of structure installations (D. Small, personal communication 2022).

2.2 Sizing Standards for Stream and Embayment Crossings

Railroad stream and drainage structures have been installed and maintained since the railroad began construction along Puget Sound shorelines in the late 19th century. Over time, various standards have been developed for these structures based on federal safety, streamflow or flood conditions, fish passage, and tidal conditions. Standards have evolved over time if their application indicated that they did not adequately meet their stated goals. This chapter summarizes the established railroad design guidance as well as Washington State standards for design focused on fish passage characteristics and additional considerations for structures affected by tidal conditions.

2.2.1 Railroad Standards

Railroads maintain specialized infrastructure as part of the national transportation network and fill an important role in freight and passenger transportation. This infrastructure supports heavy live axle loads up to 80,000 pounds from regular use by railcars. BNSF uses a combination of industry guidance and corporate policies to guide the design and development of stream crossing structures (AREMA 2008; UPRR and BNSF 2016; BNSF 2018). Inspection criteria for culverts focus on identifying any structural deficiencies that require immediate strengthening or that undermine structural elements comprise critical deficiency requiring immediate response, whereas debris in stream crossing waterways that affect hydraulic capacity comprise an important, but not urgent deficiency (AREMA 2008).

For the design of new culverts, AREMA (2008) characterizes the design process as relying on a combination of pure fluid mechanics and practical considerations. At a minimum, culverts shall be designed to discharge a 25-year flood without static head at the culvert entrance and a 100-year flood to 2 feet below the base of rail. The approach for railroad culvert design is consistent with minimum requirements from the Federal Highway Administration guidance (FHWA 2012) and focuses on requirements to maintain structural support for the trackway while minimizing long-term maintenance needs for culverts (**Table 1**). Some criteria have been adjusted to promote structure maintenance; for example, BNSF identifies that the minimum diameter for all culverts installed under tracks maintained by BNSF be 36 inches in order to accommodate regular inspection and cleaning (BNSF 2018).

TABLE 1.
SUMMARY OF RAILROAD CULVERT DESIGN CRITERIA

Design Factor	AREMA Guidance	Notes
Culvert Location	The best alignment is a straight entrance and direct exit. Coincide as nearly as possible with stream alignment and maintain stream gradient.	Railroad guidance shows a preference for 90-degree intercept with railroad. Limit intercept to 54 to 126 degrees when alignments are skewed.
Culvert Material/Type	Circular, oval, and pipe arches considered that maintain uniform barrel cross section.	Arch culverts are not preferred by BNSF.
Inlet Entrance Design	Lesser value of 2 feet below base of rail or headwater = 1.5 x structure diameter.	Wingwalls may be required.
Outlet Design	Defined for controlled outlets only.	General goal is to use materials that minimize scour.
Diameter	Minimum of 24 inches for main track.	BNSF criterion is minimum of 36 inches.
Length	As needed.	Some guidance includes additional culvert length to accommodate additional fill.
Cover	2.5 feet from bottom ties	

Source: AREMA (2008)

These design approaches led to crossing structure types ranging from round pipes (that often lack streambed substrates within the structure) to box or arch culverts (that can simulate stream and floodplain characteristics within the structure). The final type of structure is single or multi-span bridges. Depending on structure design, these structures may have similar impacts on streams as culverts or, as is preferred, can fully span the stream, estuary, and floodplain (**Table 2**). Multiple bridge spans may be constructed next to each other to provide the desired total crossing width. Likewise, multiple box culverts can be constructed next to each other to provide the desired total crossing width. This may be necessary in locations where other site conditions (e.g., low embankment height) prevent installation of a bridge.

TABLE 2.
COMPARISON OF CROSSING STRUCTURE TYPES THROUGH RAILROAD EMBANKMENT

Structure Parameter	Round Culvert	Box Culvert	Arch Culvert	Bridge
Configuration	Round pipe through right-of-way embankment	3- or 4-sided culvert structure (top, sides, and with or without bottom)	Arch-shaped culvert with or without bottom	Structure that spans stream, estuary, and floodplain. May include intermediate supports in the stream channel or estuary
Material	Concrete, corrugated metal with cathodic protection, HDPE plastic	Concrete reinforced with rebar	Concrete and corrugated metal with cathodic protection	concrete, steel, railroad girders
Potential Restriction to Streamflow	Severe	Moderate to Severe	Moderate to Severe	Minimal
Function for Fish and Stream Habitat	Lowest	Medium	Medium	Highest
Longitudinal Dimension	3 to 8 feet diameter	up to 12 feet wide for railroad structures	up to 12 feet wide for railroad structures	14 to 34 feet opening per bridge span
Construction Costs	Low	Medium	Medium	High
Installation Methods	Multiple, including jack and bore, directional drilling, and open cut*	Jack and bore and open cut*	Jack and bore and open cut*	Open cut*
Construction Duration	Short	Short to Medium	Short to Medium	Longest
Channel Maintenance Needs	High, typically associated with sediment and wood debris	Low to Medium	Low	Low
Drainage Structure Maintenance Costs	Low	Low	Low	Medium to High
Embankment Height	Low	Medium	Medium	Medium to High

* Open-cut installation is not a preferred method due to impacts on track bed and operations. This approach is only valid when rail traffic is very light, such as on spur or branch lines without daily traffic.

2.2.2 Washington State Standards

While culvert sizing is driven by hydraulic needs to convey water arriving at the structure to the other side, in Washington State, the sizing of stream crossings is also driven by requirements to provide fish passage (Greene et al. 2017). The Stevens Treaties signed between Indian tribes in the Pacific Northwest and the Governor of the Washington Territory in 1854-55 included as part of the treaties the right for tribes to engage in off-reservation fishing. Washington State law (Revised Code of Washington [RCW] 77.57.030) reinforces that treaty obligation and states that water crossings must "freely pass fish" to allow efficient fish passage. Washington Administrative Code (WAC) 220-110-070 states that bridges are preferred *"in order to ensure free and unimpeded fish passage for adult and juvenile fishes and preserve spawning and rearing habitat."* Other water crossing structures are allowed as long as maximum water velocity, minimum water depth, and maximum hydraulic drop criteria for fish passage are met. Federal courts have found that building and maintaining barrier culverts violate the obligations to tribes under the treaties (United States v. Washington 2017). Public agencies and tribes in Washington State are working to identify and improve fish passage at public and private passage barrier culverts.

Fish passage design in Washington State is informed by technical guidance developed by WDFW (WDFW Guidelines; Barnard et al. 2013). The WDFW Guidelines are primarily developed for freshwater (non-tidal) portions of streams. The WDFW Guidelines describe four **design approaches** that are applicable for consideration along the railroad embankment. Each of the four is described below, with information on the settings for which the design approach may be suitable (Barnard et al. 2013). The descriptions in the WDFW Guidelines are for non-tidal sites; we have added notes on tidal applicability.

- **No-slope culvert** – Small, countersunk culverts laid on a flat grade for simple installations on small streams.

- **Stream simulation culvert –** Culverts placed at the same grade as the stream. Appropriate for more complex sites on low-gradient streams and most projects on higher gradient streams. Design approach focuses on creating a structure sufficiently large to allow for a semi-natural stream channel and floodplain to occur within the structure. While guidance has been developed and tested for stream systems, tidal environments are generally considered complex sites due to additional water and tidal processes acting on the sites, and designs need to be developed and reviewed on a site-by-site basis.

- **Bridge** – A structure that spans the waterway with or without structures in the stream channel. Designed to accommodate natural processes and provide better habitat and connectivity than culverts.

- **Hydraulic design culvert** – Limited application in exceptional cases where constraints prevent the use of other design approaches. Design techniques include baffles and roughened channels to reduce velocities within the culvert to allow for upstream fish passage.

The hydraulic design approach is frequently used as a retrofit for existing culverts to reduce velocities, but has drawbacks for fish passage, especially in tidal settings. Therefore, it is only applicable in unusual cases, such as exceptionally long culverts, which prevent the use of the other approaches. Although once a standard approach for culvert design, many culverts designed with this design approach fail to provide fish passage due to velocities, overly shallow flow over the culvert bottom, lack of resting pool below the culvert, or a drop that exceeds fish jumping abilities. In Washington State, the hydraulic design option is now a limited option that WDFW typically permits only for situations where bridges or stream simulation culverts are not possible. The hydraulic design approach is not considered applicable to restoration of estuaries along the railroad and is therefore not described further in this report.

The WDFW Guidelines identify a suite of geomorphic factors to inform the selection of a design approach. The geomorphic factors include channel width, channel slope, floodplain utilization (considered here as wetlands in the floodplain immediately upstream of crossing), channel stability, debris prone, and constraints. A summary of the design approach suitability based on these geomorphic factors if provided in **Table 3.**

TABLE 3.
DESIGN APPROACH SUITABILITY BASED ON GEOMORPHIC FACTORS

Geomorphic Factors	No-slope Culvert	Stream Simulation Culvert	Bridge
Channel Width	small (<10 feet bankfull width bankfull width*)	small and medium (up to 15 feet bankfull width)	large (>15 feet bankfull width)
Channel Slope	low slope (<2%)	up to 10% (beyond 10% will likely require instream structures to provide fish passage)	up to 10% (beyond 10% will likely require instream structures to provide fish passage)
Upstream Wetland Present (adapted from Floodplain Utilization)	not appropriate	unlikely to be large enough	preferred
Channel Stability	stable	stable or moderately stable	any stability
Capacity to Transport Sediment and Large Woody Debris	light	light or medium	any debris amount
Constraints from Adjacent Infrastructure or Land Ownership	few	few or some	any level of constraints

*Bankfull width is the channel width during *"the most effective channel-forming flood with a recurrence interval seldom greater than the 2-year flood in undisturbed channels*" (Ecology 2016).

2.2.3 Sizing of Tidal Crossings in Washington

The WDFW Guidelines described above are primarily developed for freshwater (non-tidal) portions of streams and state that tidally influenced crossing design is more complex and requires a different approach. The complexity of designing an appropriately sized water crossing structure is due to there being more water in estuaries during high tides – both freshwater from streams and saltwater from Puget Sound – coupled with freshwater and tidal processes acting on estuaries.

While the WDFW Guidelines provide a formula for sizing structures in freshwater, no such formula is developed for tidal settings. In practice, WDFW evaluates tidal sites on a case-by-case basis, which allows for factoring in coastal and fluvial geomorphology conditions. For the purposes of this evaluation of conceptual recommendations of priority sites, we apply the design philosophy promoted by the WDFW Guidelines. For estuarine crossings, the WDFW Guidelines state that the main tool for restoring ecosystem functions is to avoid creating a hydraulic constriction, considering stream and tidal water movement through the water crossing structure. Further, the WDFW Guidelines "*promote a water* *crossing selection and design process intended to have the least effect on the natural processes that create and support the [habitat] structure."* Put simply, the wider the opening, the less the effect on ecosystem processes. While WDFW has not established guidance specific to tidally influenced structures, the state guidance defaults to the Washington Administrative Code (WAC), which indicates that free fish passage should be provided for all species and life stages (WAC 220-660-200).

To provide a working estimate of suitable crossing sizing at tidally influenced stream mouths, we used two times bankfull width. For sites with large and wide wetlands immediately upstream (i.e., not narrow, linear wetlands), we interpret the wetlands as an indication that the site would naturally support a larger estuary. For these sites, larger structures may be recommended following site evaluation and conceptual design to maintain and create estuary wetland habitat in addition to stream/estuary conditions that support fish passage. This preliminary approach and any assumptions will need to be discussed and evaluated with WDFW and BNSF before finalizing a crossing design width. These design criteria are starting points for conceptual design through rapid assessment; however, final design may need to incorporate detailed information about the relationship between the structure and tidal waters, which may affect final structure sizing.

3.0 Railroad and Site Characteristics Affecting Constructability

3.1 Embankment Height

Embankment height informs the maximum potential crossing structure height and therefore potential crossing structure types, as well as possible installation techniques. Railroads require a minimum amount of cover over culverts (see **Table 4**), which may limit options for installing structures of sufficient size to allow for debris to pass through the culvert and for regular maintenance inspections. Tall embankments with stream structures near the bottom may require excavation of large amounts of material to facilitate installing the replacement structure.

Rail embankments along the Puget Sound nearshore are mostly low-gradient (flat) embankments that are approximately 10 to 20 feet tall. The trackway elevation gradually increases from south to north, reaching peak heights just north of the Tacoma Narrows Bridge before returning to lower heights north of Seattle and rising again near Chuckanut Drive before becoming lower as it approaches Bellingham. In taller embankment segments, the embankment is 30 to 50 feet tall. Many of the adjacent uplands are bluffs, with some streams and embayments forming larger valleys. Stream segments upstream of the railroad embankment may be highly incised, which limits construction alignments. In some cases, the stream segment is heavily impacted by development and may be piped or otherwise modified upstream of the railroad embankment, which may limit alignment options to provide for fish passage. Furthermore, since the railroad embankment effectively sits on a narrow shelf with a bluff on one side and the Puget Sound shoreline on the other, the streambed elevation for some streams may be only a couple of feet below the tracks on the upstream side of the embankment.

3.2 Embankment Materials

Some segments of the railroad embankments were originally constructed as trestles that were subsequently backfilled to form the earthen and rock embankments currently lining Puget Sound (see Figure 2). Embankment materials can range from bedrock to rock and gravel to timber piles overlain with rock and gravel backfill. In some locations, the embankment fill is armored with large boulders or retaining walls to protect the embankment from erosion, while in other areas the embankment fill is not armored. The legacy embankment construction along the Puget Sound shoreline consists of a variety of embankment materials covered with a veneer of rock. These material variations require a complete geotechnical investigation to develop an understanding of the embankment materials and the underlying geology. The underlying geology of the embankment may drive the selection of a replacement stream crossing structure. Construction of stream crossing structures will need to consider how to limit disruption to existing armoring and retaining walls and restore their function after construction. Given the proximity of the embankment to marine waters and the presence of stream crossings, there may also be voids within the embankment due to past erosion.

3.3 Number and Width of Trackways

The length of culverts through railroad embankments depends on the width of the trackway. Track widths vary along the railroad embankment, from a single track to as many as four tracks, and may also include maintenance and signal laydown areas and access roads. Most existing culverts cross under two tracks and have a typical top of embankment width of 30 to 45 feet. Narrower segments occur where the track is on bridges or trestles or where vertical walls are used to support one side of the embankment. Where the number of tracks increases to three or four, there is typically a gap between the mainline tracks and the other secondary tracks. In these areas, the width at the top of the embankment may expand to 70 to 100 feet.

Crossing structure replacement projects will need to be compatible with existing and future railroad operations planned for the next 20+ years and consider any necessary track upgrades to comply with current railroad engineering and mainline design requirements, such as increasing track centerline distances. The intent is for designs to anticipate future conditions and to incorporate known projections for changes in natural conditions and railroad infrastructure. In some instances, BNSF or other regional railroad interests (e.g., Sound Transit) may be interested in widening the proposed embankment to accommodate a new ballast walkway or a future track.

3.4 Railroad Track Geometry

Railroad geometry informs construction options; earthwork and perpendicular drainage crossing structure construction are more efficient on tangent track geometry. However, the presence of track curvature poses additional complications. For example, railroad curves may not follow the surrounding terrain and may complicate identifying a stream alignment that crosses the railroad efficiently. Proposed projects located along a curving portion of the track may have limited options for maintaining railroad operations during construction using a shoo-fly (a temporary bypass route).

3.5 Railroad Control Points, Signals, and Switches

Railroad control points, signals, switches, and cross-overs are critical parts of the railroad infrastructure that often involve sensitive electronic components, extensive railroad components that may be required to move, and critical safety areas where trains are held. Impacts on control points and switches can create challenges for traffic management along the railroad, which may affect project scheduling. For culvert projects, these components may create additional logistical challenges and project costs for any culvert replacements. It will require evaluation of options for relocating the affected railroad infrastructure and potentially repositioning the proposed culvert replacement. Such railroad infrastructure may also require additional construction staging and coordination and/or temporary relocation of signals or switches.

3.6 Proximity to Grade Crossings

Grade crossings, including roadways and multi-use trails that cross rail lines, may include utilities or signals that need to be considered during design and construction. Upgrading drainage crossings near grade crossings to box culverts is the preferred approach due to limited low embankment heights. There may also be opportunities to consolidate grade crossings within a corridor to increase the drainage structure's opening and improve traffic channelization. Crossings also require internal coordination among different departments within BNSF (e.g., Engineering, Public Projects, Track, Maintenance of Way, and Signals) as well as the municipal roadway authority to determine how to minimize impacts on crossing signal systems and potentially rerouting traffic during construction.

3.7 Site Access and Staging

The railroad embankment resides in a variety of site conditions, from urban to rural, with some sites being isolated from both roadway and marine access. Site access for excavation equipment, staging, and installation of replacement structures is an important consideration. In many locations, access is possible using the surrounding road network. In other instances, if BNSF is doing the construction, limited access by rail may be possible. Marine access may be possible at some sites, such as using barges to deliver equipment and materials. However, depending on the railroad location relative to the shoreline and the site configuration, marine access may impact aquatic habitats, which may not be permitted or may require mitigation.

Culvert replacement projects will require substantial upstream and downstream staging areas for materials and equipment. The staging space required depends on the type and size of the structure, the installation method, and the necessary stabilization/shoring of the railroad and surrounding areas. In more densely populated areas and areas with other infrastructure in close proximity, providing the needed staging areas may be challenging. This needs to be considered and planned for throughout the design process. In some cases, site access and staging may be a driver for grouping or batching groups of drainage crossing projects. For example, a single landowner, JBLM, is adjacent to a portion of the BNSF railway where several priority stream crossings are located. Coordination with JBLM for grouped culvert projects may create a more efficient and effective process than developing restoration plans for each site individually.

3.8 Stream Alignment and Elevation

Stream alignment is an important consideration in designing a replacement structure. In most instances, the structures under the railroad are approximately perpendicular to the track. However, some culverts may include bends or turns that are difficult to replicate in natural systems. Furthermore, in some instances it may be desirable to construct the replacement structure while maintaining streamflow through the existing structures. In those instances, stream channels may to be realigned to support flow through the replacement structure. In many instances, the upstream or downstream habitats may be channelized or manipulated.

The stream elevation relative to the track is an important characteristic in defining the replacement structure options. Some streams are more than 30 feet below the trackway, while others appear to be as little as approximately 5 feet below the track. Streams that are near the track elevation may require different structural designs and may have limited interior vertical dimensions.

3.9 Stream Gradient and Hydraulic Drops

Stream gradient affects the stream crossing design approach that can be used to provide fish passage (see Table 1). Stream gradient, in combination with other site characteristics identified above, may affect the constructability of a replacement structure. For example, a stream crossing located at the base of a steep bluff may limit site access and the availability of proper staging areas.

3.10 Additional BNSF Considerations for Selecting Sites and Minimizing Operational Impacts of Construction

Through a series of discussions with BNSF, the project team developed the following understanding of BNSF's preferences for selecting among the priority sites and constructing the restoration:

1. Replacing damaged drainage structures.
2. Improving public safety (i.e., reduce occurrences of trespassing; consolidate at grade railroad crossings).
3. Improving operational reliability (i.e., the existing feature is undersized and susceptible to track overtopping during certain flood events). Understanding the capacity of existing water crossings to convey 100-year flows (Q_{100} flows) is an initial step in evaluating operational reliability.
4. Replacing drainage structures that are at or approaching their routine life-cycle replacement schedule.
5. Addressing debris buildup parallel to the right-of-way or upstream.

We understand that minimizing operational impacts to BNSF must be prioritized during planning. Operational details to consider include:

1. Bundling two or more sites within close proximity that could be constructed within the same track protection work limits.
2. Bundling two or more sites within a BNSF signal block (e.g., between two BNSF control points).
3. Bundling two or more sites within one BNSF subdivision.
4. Bundling projects of similar construction duration and complexity (e.g., construct multiple box culverts simultaneously).

4.0 Characterization of Railroad and Site Characteristics at Priority Sites

The 2019 study that prioritized stream crossings based on benefits of restoration to juvenile Chinook salmon included field inventories of each stream crossing that was evaluated (Confluence et al. 2019). The study is available at:

https://pugetsoundestuary.wa.gov/wp-content/uploads/2021/03/2016_0198_Technical-Report.pdf.

Forty-five stream crossings and seven embayments were categorized as a priority for restoration (i.e., high and highest priority tiers). **Table 4** describes the existing site conditions affecting the constructability, design, and sizing of replacement stream crossings at the priority sites. These factors include conditions related to characteristics of the railroad embankment and adjacent infrastructure, as well as stream characteristics. Embayment structure sizes represent the observed conditions, in most cases the embayment opening has been narrowed significantly by a rip-rap embankment to a limited bridge opening.

The anticipated replacement structures to address any undersized crossings will be based on the necessary width of the opening (see Table 2). The possible structure type, as well as the constructability information for each site, will be considered when determining the structure type and sizing to advance to engineering design. Due to the desired drainage opening size, large structure widths associated with many of the priority sites may require bridges or similar large span structures. For embayments, additional bridge structures or extension of bridges coupled with removal of rip-rap embankments may be necessary to restore historic tidal exchange.

Table 4
Existing Conditions Affecting Constructability, Design, and Sizing of Priority Sites

ID#	Stream Name	Approximate Railroad Embankment Height (feet)	Number of Tracks	Track Alignment	Other Railroad Infrastructure Nearby	Other Non-Railroad Infrastructure Nearby	Type of Existing Structure (number)	Diameter of Existing Structure(s) (feet)	Bankfull Width Upstream (feet)	Structure Length (feet)	Channel Slope (%)	Presence of Wetland	Estimated Width Based on Two times Bankfull Width (feet)
1	Pipers Creek	15-20	2	curve	pedestrian overpass	park	round culvert (2)	5.0	15.0	n/d	0	upstream	30.0
2	Padden Creek	15-20	1	tangent	switch, crossover	boat ramp, business	bridge (1)	148.0	14.5	20	0	upstream (embayment)	29.0
6	Oyster Creek, near Samish	15-20	1	slight curve	no	no	bridge (1)	54.0	22.2	59	1	downstream	44.4
7	Pigeon Creek #1	15-20	3	curve	switch, crossover	City of Everett lift station	round culvert (2)	3.2	4.0	n/d	1	no	8.0
18	Merrill & Ring Creek	15-20	2	tangent	no	no	round culvert (3)	3.8	11.8	72	4	no	23.6
33	unnamed, Nakeeta Beach Ravine	15-20	2	tangent	no	houses immediately downstream	round culvert (1)	4.3	12.8	144	4.5	no	25.6
38	Big Gulch Creek	15-20	2	tangent	no	City of Mukilteo wastewater treatment plant	round culvert (1)	4.7	9.0	92	1	no	18.0
39	Upper Chennault Beach Creek	15-20	2	tangent	signal, unidentified box	no	round culvert (1)	2.0	7.8	60	3	no	15.6
60	unnamed, north of Samish	50+	1	tangent	no	no	round culvert (2)	3.0	7.6	56	2	no	15.2
66	Cain Creek, outside of Drayton Harbor	15-20	2	tangent	road crossing	two-lane road perpendicular to railroad	round culvert (1)	2.5	6.6	n/d	n/d	downstream	13.2
67	unnamed, Blaine Harbor	15-20	2	tangent	no	no	round culvert (1)	2.5	8.0	n/d	0	downstream	16.0
70	Dakota Creek, Drayton Harbor	15-20	1	tangent	no	two-lane road running parallel upstream	bridge (1)	n/d	n/d	n/d	n/d	upstream, downstream	n/a
89	Maulsby Swamp	15-20	2	tangent		four-lane road running parallel downstream	round culvert (1)	3.0	22.0	185	2	upstream	44.0
90	unnamed, Port of Everett	20-30	3	tangent	switch, crossover	port	n/d	n/d	n/d	n/d	n/d	no	n/d
96	Edgewater Creek	15-20	2	tangent	signal	no	round culvert (1)	4.0	8.6	n/d	n/d	maybe? dead trees	17.2
98	Japanese Gulch Creek (mainline)	15-20	3	tangent	switch, crossover	roads upstream and downstream	round culvert (2)	4.0	14.7	n/d	n/d	no	29.4
99	Japanese Gulch Creek (spur)	30-50	1	curve	no	no	round culvert (1)	4.8	*	148	n/d	no	n/d
103	unnamed, Stillaguamish River estuary near Miller Rd and Pioneer Hwy	15-20	1	tangent	no	no	round culvert (1)	n/d	n/d	n/d	n/d	upstream, downstream	n/d
104	Maddox Creek, Skagit River estuary near Pioneer Hwy and Milltown Rd	15-20	1	tangent	no	two-lane road running parallel upstream	round culvert (1)	n/d	n/d	n/d	n/d	downstream	n/d
134	Fragrance Creek	30-50	1	slight curve	no	two-lane road running parallel downstream	round culvert (1)	3.0	13.2	n/d	n/d	downstream	26.4

ID#	Stream Name	Approximate Railroad Embankment Height (feet)	Number of Tracks	Track Alignment	Other Railroad Infrastructure Nearby	Other Non-Railroad Infrastructure Nearby	Type of Existing Structure (number)	Diameter of Existing Structure(s) (feet)	Bankfull Width Upstream (feet)	Structure Length (feet)	Channel Slope (%)	Presence of Wetland	Estimated Width Based on Two times Bankfull Width (feet)
137	unnamed, Samish Bay north of Colony Creek	15-20	1	tangent	no	no	round culvert (1)	2.5	2.0	65	n/d	downstream	4.0
142	Picnic Point Creek	15-20	2	slight curve	pedestrian overpass	park	round culvert (2)	3.5	12.8	54	2	no	25.6
149	unnamed, at Norma Beach Rd and Sunset Bay Wharf	15-20	2	slight curve	no	wharf, at-grade pedestrian crossing	round culvert (1)	3.0	12.0	163	8	no	24.0
150	Lunds Gulch Creek (Meadowdale Beach Park; pre-restoration)	15-20	2	slight curve	no	park	bridge (1)	4.5	17.4	250	0	no	34.8
157	Perrinville Creek	15-20	2	curve	no	houses immediately upstream	round culvert (2)	3.0	10.0	53	2	no	20.0
189	Chambers Creek	15-20	2	straight	bridge superstructure; unidentified boxes	marina, storage business	bridge (1)	160	n/d	n/d	n/d	upstream (embayment)	n/a
210	unnamed, just south of Richmond Beach Park	15-20	2	tangent	no	no	round culvert (1)	2.9	3.5	63	2.9	no	7.0
220	Boeing Creek	15-20	2	curve	no	no	box culvert (1)	7.0	8.0	65	3	no	16.0
228	Shellabarger/Willow Creek	15-20	1	tangent	no	park, port	box culvert (2)	3.0	n/d	n/d	n/d	upstream	n/d
232	Sequalitchew Creek	30-50	2	tangent	no	no	box culvert	3.0	11.5	190	n/d	upstream	22.5
235	unnamed, JBLM	20-30	2	curve	no	no	round culvert (1)	8.5	n/d	22	n/d	no	n/d
240	unnamed, JBLM	15-20	2	tangent	no	no	round culvert (1)	1.5	6.0	n/d	n/d	no	12.0
242	unnamed, JBLM	15-20	2	tangent	no	no	round culvert (1)	3.3	6.0	90	2	no	12.0
244	unnamed, JBLM	15-20	2	slight curve	no	no	round culvert (1)	2.5	4.0	120	4	no	8.0
245	unnamed, JBLM	15-20	2	slight curve	no	no	round culvert (1)	3.0	6.5	n/d	n/d	no	13.0
246	unnamed, JBLM	15-20	2	tangent	no	no	round culvert (1)	2.0	n/d	72	4	no	n/d
247	unnamed, JBLM	15-20	2	tangent	no	no	round culvert (1)	3.0	4.0	66	4	no	8.0
248	unnamed, JBLM	15-20	2	slight curve	no	no	round culvert (1)	n/d	n/d	n/d	n/d	no	n/d
249	unnamed, JBLM	15-20	2	tangent	no	no	round culvert (1)	2.0	6.0	82	4	no	12.0
250	unnamed, north end of JBLM	15-20	2	slight curve	no	no	round culvert (1)	3.0	6.0	60	6	no	12.0
254	unnamed, north of JBLM	15-20	2	tangent	unidentified boxes nearby	no	bridge (1)	90.0	10.0	12	2	upstream (embayment)	20

ID#	Stream Name	Approximate Railroad Embankment Height (feet)	Number of Tracks	Track Alignment	Other Railroad Infrastructure Nearby	Other Non-Railroad Infrastructure Nearby	Type of Existing Structure (number)	Diameter of Existing Structure(s) (feet)	Bankfull Width Upstream (feet)	Structure Length (feet)	Channel Slope (%)	Presence of Wetland	Estimated Width Based on Two times Bankfull Width (feet)
255	unnamed, Saltar's Point Beach	15-20	2	tangent	no	no	bridge (1)	240.0	n/d	40	n/d	upstream (embayment)	n/a
257	Little Squalicum Creek	15-20	1	tangent	no	park	bridge (1)	36.0	2.7	112	19	no	5.4
258	Squalicum Creek	15-20	1	slight curve	no	port, bridges upstream and downstream, sewer	bridge (1)	58.0	60.0	62	1	no	120
259	Shell Creek	15-20	2	slight curve	no	no		n/d	n/d	n/d	n/d	upstream	n/d
Estuary/Embayment Crossings													
	Chuckanut Bay	15-20	1	Tangent (existing trestle)	Rip-rap embankment along embayment	No.	Bridge (1)	230	Tidal	20	n/d	yes	n/a
	Titlow Lagoon	15-20	2	Tangent (existing trestle)	Rip-rap embankment along embayment	Lagoons are managed as a park.	Round culvert (2)	n/d	Tidal	120	n/d	yes	n/a
	Colony Creek	15-20	1	Slight curve	Rip-rap embankment along embayment	Chuckanut Drive Bridge	Bridge (1)	150	Tidal	16	n/d	yes	n/a
	Steilacoom Lagoon	20-30	2	Slight curve	Rip-rap embankment along embayment	No	Bridge (1)	180	Tidal	36	n/d	yes	n/a
	Shelleberger Creek	15-20	1	Slight curve	Rip-rap embankment along historic embayment	Marina, local streets, additional culverts.	Round culvert (2)	3	Tidal	>200	n/d	yes	n/a
	Chambers Creek	20-30	1	Tangent	Lift bridge and rip-rap embankment along embayment	Marina, Chambers Creek Rd.	Lift Bridge	240	Tidal	30	n/d	yes	n/a
	Sequalitchew Creek	30-50	1	Tangent	Rip-rap embankment along embayment.	No	Box culvert (1)	5	Tidal	60	n/d	yes	n/a

Notes: n/d means no data are available (site not accessed during field survey)

5.0 Meadowdale Beach Park Restoration Case Study

The stream-mouth restoration project at Meadowdale Beach Park in Snohomish County was completed in 2022 and included the types of restoration options possible at other priority crossing sites identified in the Phase 1 Confluence et al. (2019) report. The restoration project is the first habitat restoration project on the Puget Sound shoreline that entailed replacing the railroad drainage crossing and excavating a large estuary. This case study describes the project and the funding sources that funded the project's construction. In addition, several "keys to success" are identified that are applicable to all future shoreline restoration projects along the railroad

5.1 Restoration Project Overview

Snohomish County Parks and Recreation Division (Snohomish County Parks) led the project and worked closely with BNSF throughout planning, design, and construction. The project includes not only the improvement of fish passage by replacing an undersized culvert with a railroad bridge, but also restores a small estuary, restores sediment transport to the beach, allows safe access to the beach, and improves park amenities. A pre-construction (existing) box culvert was structurally sound, and its replacement was for the benefits listed. The railroad portion of the project entailed replacing an undersized box culvert at the mouth of Lunds Gulch Creek with a 128-foot, five-span bridge (**Figure 4**). The bridge provided a 90-foot-wide corridor for estuary aquatic habitat and a pedestrian trail along one side for park visitors to access the Puget Sound shoreline. The new railroad bridge also allowed for substantial habitat restoration upstream and downstream in the estuary, as well as farther upstream in the creek. A large embayment estuary was excavated upstream of the railroad, and the outlet channel across the stream delta was directed in a northerly direction to protect estuary habitats (**Figure 5)**. These restoration elements provide highly beneficial habitats for non-natal juvenile Chinook salmon as well as other salmon, trout, and nearshore fish. The estuary portion of the restoration project was a high priority action in the Salmon Recovery Plan of the Lake Washington, Cedar/Sammamish watershed (WRIA 8 2017, 2019).

The new railroad bridge also improved park safety by providing safe, year-round access to the beach. Previously, the undersized culvert was intended to convey both the creek and people to the beach. The culvert was closed to pedestrians in the winter for salmon spawning and high streamflows. Some park users illegally crossed the railroad track or walked along a narrow ledge in the culvert to access the beach. Prior to safe passage provided by the restoration project, this presented a serious safety hazard.

5.2 Restoration Funding

The Meadowdale Beach Park restoration required numerous grants and a funding strategy. Based on 2020 data, the project construction costs were estimated at $16 million. Snohomish County Parks commissioned a cost-benefit analysis for the restoration project, which determined that the community would receive more than $4 in public benefits for every $1 invested in park restoration (Earth Economics 2018). Given the project's multiple benefits, including habitat restoration, park improvements, and railroad safety, Snohomish County was able to apply for a wide range of grants. Grant applications for funding were largely successful and accounted for 45% of the total project cost. Snohomish County contributed the remaining 55% of the construction costs. The following summarizes the funding sources for the $14,750,000 construction project (Snohomish County Parks 2022).

- Total grants received: $6,704,078
  - Washington Wildlife Recreation Program (WWRP) - Water Access Grant - $604,078
  - Aquatic Lands Enhancement Account (ALEA) Grant - $500,000
  - Salmon Recovery Funding Board (SRFB) Grant - $800,000
  - Estuary and Salmon and Restoration Program (ESRP) grant - $1,000,000
  - Federal Railroad Administration/Consolidated Rail Infrastructure Safety Improvement (FRA/CRISI) Grant - $3,500,000
  - National Oceanic and Atmospheric Administration (NOAA) Coastal and Marine Habitat Restoration Grant - $300,000
  - Snohomish County (Parks [Real Estate Excise Tax]/ Surface Water Management/ Councilmatic Bonds) - $8,046,000

5.3 Keys to Success

The following keys to success are derived from a presentation that Logan Daniels, the Snohomish County Parks Project Manager, made to the Puget Sound Salmon Recovery Council in September 2020, as well as subsequent conversations with this project team. These keys to success address local sponsor needs and keys for working with BNSF.

- Ensure that the local sponsor is committed. Substantial resources need to be dedicated to the project during a prolonged process that includes a feasibility study, design, public outreach, securing funding, managing funding, updating organizational leadership, running the bid process, and construction.
- Hire a design consultant team with qualified experts in railroad engineering, geotechnical engineering, civil engineering, wetland science, fisheries biology, archaeology, permitting, appraisals, and legal issues (attorneys).
- Understand BNSF requirements and priorities. This is important for both the local sponsor and the consultant team. Follow BNSF-approved design guidelines.
- Involve BNSF from the beginning. The BNSF Public Projects Team should be contacted at the outset of project planning. The Public Projects Team will coordinate within the company to get the appropriate staff assigned for the coordination and reviews necessary.
- Ensure BNSF needs do not conflict with local sponsor's needs.
- Consider BNSF operations in design.
- Respect BNSF’s structure, purpose, and process.
- Understand BNSF submittal requirements and review periods. Plan adequate time for reviews, including preparation of legal agreements between parties.
- Utilize BNSF construction crews that can install replacement structures. At Meadowdale and in many cases, this is likely the best approach given their expertise in the work and their comparative ease in coordinating internally with BNSF operations.

Figure 4. Railroad Crossing at Meadowdale Beach Park
View facing upstream from beach of railroad crossing pre-project (top) and mid-construction with new railroad bridge installed (bottom).

Figure 5. Restored Estuary Habitats at Meadowdale Beach Park
Top shows estuary excavated upstream of railroad bridge.
Bottom shows outlet channel downstream of railroad bridge.

6.0 Potential Grant Funding Opportunities

The timing of this project aligned with the passage of the federal Bipartisan Infrastructure Law (BIL, also known as the Infrastructure Investment and Jobs Act [IIJA]) and state allocations on salmon recovery that exceeded previous investment levels. Funding became a focal interest for restoration partners and BNSF during this phase of the project. Many parties, including BNSF, tribes, and state agencies/boards (e.g., Puget Sound Partnership, WDFW, Leadership Council) are interested in the development of an implementation funding strategy. While a full funding strategy for the suite of projects is outside of the scope of this effort, this chapter describes some potential funding sources for restoration implementation (both design and construction) to be considered in the future. It will be important to better understand the details of each site to determine alignment with funder goals (fish passage, safety, public accessibility, infrastructure resiliency), eligibility, local partners, and estimated costs. Additionally, BNSF has expressed a strong interest in grouping (bundling) project sites based level of complexity, a corridor approach in distinct geographies, those with a single local sponsor or landowner (e.g., JBLM), or other similarities. Groups are preferable to working through the list one at a time. These groups will be developed based on the information gathered during additional site assessment and may be informed by alignment to possible funding opportunities (e.g., all sites with the possibility of commuter improvements).

This chapter is organized by funding source type:

- Federal and state funding specific to fish passage and salmon recovery.
- Federal funding specific to railroads.
- New funding opportunities under development.

A summary table (**Table 5**, at the end of this chapter) includes relevant details of federal/state fish passage and salmon recovery funding opportunities as well as federal funding specific to railroads. New funding opportunities are not included in the table, but will be tracked closely and considered in a future detailed funding strategy.

6.1 Federal and Washington State Funding Specific to Fish Passage and Salmon Recovery

There are many funding programs at the federal and state level specific to fish passage and general salmon recovery. A funding strategy will be particularly useful for identifying which projects and sponsors are the best fit for these funds. To position projects to be competitive, it will be useful to gather information to understand the level of support of funding programs for the railroad crossing replacements, develop local support for the work, and navigate timing for funding requests based on competition and other local priorities. At a regional level, it will also be important to coordinate across project sites and partners so that similar projects are not competing for the same funding. Because these projects will be relatively costly, it will also be important to not “use up” available funding resources on these projects alone because grant programs and local sponsors like to spread the funding around. Separate legislative requests or the creation of carve-outs or new funding programs may be warranted to avoid that issue. The newer funding programs based on the recent infrastructure investments described in the next section may help mitigate this concern, with a major increase in available funding expected over the next 5 years. The following funding sources are familiar to the restoration community; therefore, points of contact and other basic details are not included below. Instead, some observations are included on fit to the grant-funding program based on current policies to consider in a future funding strategy. In addition, BIL funding opportunities relevant to restoration of Puget Sound are being tracked and summarized by the Puget Sound Partnership in an online tool available here.

6.1.1 Salmon Recovery Funding Board and Puget Sound Acquisition and Restoration

NOAA's Pacific Coast Salmon Recovery Fund is distributed to Washington State's Recreation & Conservation Office (RCO) as an annual grant. Each salmon recovery region in the state receives an allocation. In the Puget Sound region, each Lead Entity area (watershed) receives an allocation based on a formula that results in varying amounts to each watershed. Funding is awarded through a Lead Entity-directed and region/state approved process to identify, rank, and recommend projects for funding through the Salmon Recovery Funding Board (SRFB). Because the Puget Sound Acquisition and Restoration (PSAR) funding is allocated every other year through the same process, this funding source is included here as well. The process of approving projects includes a review by a technical panel contracted by RCO to consider the merits and technical considerations of individual projects on behalf of the SRFB.

It will be beneficial to understand the keys to success from the Meadowdale Beach Park restoration project and other funded projects that have involved BNSF. The SRFB/PSAR process has historically had concerns with the cost-benefit and/or elements of projects that include costly infrastructure not directly related to benefits to fish. Costly projects providing multiple benefits that go beyond just benefits to fish need to be strategic in determining the amount of fish-focused funding to request from these funding sources. Railroad projects have been scrutinized by grant application reviewers in the past and can be expected to require numerous grants in addition to SRFB/PSAR to complete a project. This project focusing on stream mouth and embayment restoration along the railroad corridor on the eastern shore of Puget Sound is included in the Puget Sound Salmon Recovery Council's Legacy Projects Portfolio and listed in the 2022-2026 Action Agenda under the Special Focus Area: Infrastructure" section.

In addition, these stream mouth passage projects will be competing with other expensive local priorities such as estuary and floodplain restoration. The funding decisions for SRFB and PSAR are intended to be linked to the local salmon recovery plan. Each plan was originally written in the early 2000s as part of NOAA's recovery plan for the Endangered Species Act (ESA) listed Puget Sound Chinook salmon. Due to the science available at the time, nearshore and estuary habitat restoration tended to be de-emphasized compared to recovery work in the freshwater portion of large rivers. More recently, local salmon recovery plans have been updated and include more of an emphasis on nearshore and estuary habitats. If the local salmon recovery plan has not been updated to include nearshore habitat restoration and fish passage to non-natal streams, food web dynamics, or climate change adaptation strategies, the benefits of the stream-mouth railroad crossing replacement projects may be less well understood or supported by local reviewers. This funding may be the best fit where the Lead Entity has identified the importance of these habitats for their population(s), the railroad is known as a priority barrier to address for recovery, and/or where there are few other large-scale restoration projects seeking funding (overall or in a given year).

6.1.2 PSAR Large Capital Projects

A portion of the PSAR funding, typically any funds up to $30 million, is distributed through an allocation formula to watersheds, as described above. Separate from that, there is a PSAR Large Capital Projects grant competition process in which funding is awarded to projects based on a ranked large capital list. Ahead of the Washington State Legislative session that establishes the state budget, projects are submitted and reviewed regionally to be included in the full budget request for PSAR funds in the Washington State capital budget. Projects must have the support of the local Lead Entity, similar to the process above. In addition, they must compete across the region with other large projects. Those seen as costlier or benefiting a private entity such as BNSF may receive more scrutiny not only in the regional review process but by the legislature. The timing and choice of project sites will be important when considering which projects are the best fit for this competition. The benefits of this program are that large, expensive projects that are necessary salmon recovery are the purpose of this funding source and, therefore, align with many of the priority projects identified in this project.

6.1.3 Estuary and Salmon Restoration Program

WDFW administers a Puget Sound-wide competitive grant through the Estuary and Salmon Restoration Program (ESRP) with a prioritized project list for each biennium. The four grant categories include the following: restoration and protection, small grants, regional pre-design, and shore friendly. Grants are managed by RCO and are typically lower funding requests and awards because the total program is generally under $20 million. The focus of the program is on restoring nearshore and estuary processes through removal of modifications. The stream-mouth railroad crossing replacement projects may not compete well against projects that are removing–not replacing–infrastructure; however, the associated habitat restoration that is possible due to the replacement of railroad stream-crossings may be a strong fit for ESRP. This was the case for the Meadowdale Beach Park restoration project, which received $1 million from ESRP to support the estuary habitat restoration that was only possible because of the replacement of the undersized culvert with a wide bridge.

6.1.4 Brian Abbott Fish Barrier Removal Board

This WDFW-managed funding source identifies projects for fish passage barrier correction, primarily focused on culverts that follow the principles outlined in RCW 77.95.180. Projects are ranked ahead of the legislative session and funded in order through two pathways: a statewide call, and a focus area approach (subwatershed). There is a 15% match requirement for construction and no grant award limit. Projects requesting over $500,000 must submit preliminary designs. Competition for these funds is substantial due to the focus on barrier corrections across the state and the massive number of culverts that need replacing by local jurisdictions, private landowners, and others. This funding source may need to be altered or a special carve-out/legislative request made to fund the BNSF projects. It is unclear how these passage projects along a railroad will rank in a process that is focused on road culverts; upstream habitat length is a factor, and most of the stream mouth projects provide access to relatively small watersheds.

6.1.5 Aquatic Lands Enhancement Account (RCO)

The Aquatic Lands Enhancement Account (ALEA) funding source is generated from aquatic leases managed by Washington Department of Natural Resources (DNR). A portion of the funds is distributed through a competitive funding source administered by RCO. The program has a $1 million maximum per project and a 50% match requirement. Grants may be used for the acquisition, improvement, or protection of aquatic lands for public purposes, such as improved access to the waterfront. Aquatic lands are considered all tidelands, shore lands, harbor areas, and the beds of navigable waters. It requires “control and tenure” through ownership, lease, use agreement, or easement in perpetuity for restoration (50 years for acquisition).

6.1.6 NOAA Coastal & Marine Restoration Grants – Community-Based Restoration Program

This funding source is administered by NOAA’s Restoration Center, which supports restoration projects that use a habitat-based approach to rebuild productive and sustainable fisheries, contribute to the recovery and conservation of protected resources, promote healthy ecosystems, and yield community and economic benefits. Awards range from $75,000 to $3 million; no match is required, but a 1:1 match with non-federal funds is encouraged. NOAA’s review process is national and requires relatively large acreage or mileage benefits to fish, so the best stream mouth project(s) to consider are those with the most upstream habitat to be made accessible. In addition, NOAA considers the local salmon recovery plan priorities, so it will be useful to ensure that the project is aligned with local priorities, has many supportive partners, and can show strong match given the landowner. Additionally, NOAA was a strong supporter of the Salish Sea Marine Survival Project, so connecting this work to the recommendations that came out of that research and demonstrating the regional/Evolutionarily Significant Unit (ESU) benefits of this work to the genetic diversity and survival of Puget Sound Chinook smolts may be informative to reviewers.

6.1.7 National Coastal Resilience Fund

This funding program is managed by the National Fish and Wildlife Foundation (NFWF), with 2022 funding from NOAA, U.S. Environmental Protection Agency (EPA), Department of Defense, Shell, AT&T, Occidental, and TransRe totaling $39.5 million. The program started in 2018 and has been as high as $48.5 million. Historically, 27 to 49 projects have been funded annually. The program funding is expected to greatly increase with the additional of BIL funding over the next few years. This is a nationally competitive process for projects that are within their “resilience hubs,” which include portions of Puget Sound. Projects must increase protection for communities from coastal storms, sea level change, inundation, and coastal erosion, while also providing habitat for fish and wildlife species. There is an expectation of 1:1 non-federal matching funds. Grant awards average $250,000 to $5 million. This funding source would be ideal for stream mouth projects where flooding is likely without passage improvements and potentially considering sea level rise impacts on the railroad and/or specific project sites. In the most recent competition, no projects from Washington State were awarded funds. Stream mouth projects that combine fish benefits with community protection may be competitive in future rounds if they intersect with the priority locations along the coast.

6.1.8 America the Beautiful Challenge

The America the Beautiful Challenge (ATBC) is a new public-private grant implemented through the NFWF intended to streamline grant funding opportunities for new voluntary conservation and restoration projects around the United States. ATBC consolidates funding from multiple federal agencies and the private sector to enable applicants to conceive and develop large-scale projects that address shared funder priorities and span public and private lands. Requirements and eligibility vary depending on the federal funding source. The Department of Interior (DOI) Tracks 1 and 2, Implementation and Planning respectively, look to be most promising for stream mouth crossings at railroads. These require state government agencies or Indian tribes to be the project sponsor. Match requirements vary based on the sponsor with Non-profit 501(c) organizations, local governments, municipal governments, and educational institutions. Federal government agencies, businesses, individuals, and international organizations are ineligible.

In 2022, the Puget Sound Partnership served as the project sponsor and an application was developed that included preliminary design development for 42 of the priority sites, in addition to other infrastructure-related requests at the Hood Canal bridge to benefit salmon recovery. The application was not successful, but the development of the proposal was a helpful exercise to develop messaging, budget estimates, and gather letters of support ranging from BNSF to the Senator Cantwell's office.

The Department of Defense funding being allocated through ATBC, called "Grants to Buffer and Benefit Public Lands" (Track 3), may be appropriate for certain stream mouth projects on or near JBLM or other areas that fall within that Sentinel Landscape designation in the South Sound. These will be considered in a future funding strategy.

6.1.9 National Culvert Removal, Replacement, and Restoration Grant Program

Another new funding opportunity made possible through BIL is the National Culvert Removal, Replacement, and Restoration Grant Program (Culvert Aquatic Organism Passage [AOP] Program). It is managed through the Department of Transportation Federal Highway Administration. There is $200 million available with a maximum award of $20 million and a minimum of $10,000 with a 20% non-federal match requirement. Eligible entities are a unit of local government, an Indian tribe, or a state.

A request for proposals is currently open, with full proposals due in February. This is anticipated to be an annual program over the next 5 years, so tracking the projects that are awarded funding in the first year will be a good indication of what stream mouth projects may be competitive in future years.

The Notice of Funding Opportunity specifically states that priority is given to restore passage for anadromous fish stocks listed as endangered or threated under the ESA, as well as stocks that have been identified as prey for other protected and listed species like the Southern resident orcas. Priority is also given to projects that open up more than 200 meters of upstream habitat.

6.1.10 Additional Funding Sources to Consider

Other fish passage and salmon recovery funding sources to consider in a future detailed funding strategy include Bureau of Indian Affairs, NOAA Critical Stock Funding, U.S. Fish and Wildlife Service (USFWS) National Coastal Wetland Conservation, and other tribal-directed funds or carve-outs from specific programs in cases where a tribe is the project sponsor or a key player at a specific site. Additional consideration should be given to local funding sources like Cooperative Watershed Management Grants in King County (Flood Control Zone District funds allocated to Water Resource Inventory Areas [WRIAs]) and other opportunities for certain project sites that meet eligibility. Additional NFWF programs such as the Southern Resident Killer Whale (SRKW) Program may be considered as NFWF releases a funding strategy or criteria for such funding opportunities.

As the funder of Phases 2 and 2 of this work, National Estuary Program (EPA) funding was not included in the potential funding sources listed here; however, continued support from the NEP Habitat Strategic Implementation Leads to plan and design the next phase of work will be pursued. Other NEP programs managed by Restore America's Estuaries, Local Integrating Organizations, or others will be considered at the individual site level when a funding strategy is further developed.

6.2 Federal Funding Specific to Railroads

There are several funding opportunities for the improvement, development, and connectivity of railroads made possible by the federal government. These programs include RAISE, CRISI, INFRA and FRA. While they are not specifically focused on protecting salmon habitat, they could be leveraged with intentional railroad designs to assist in the funding of culvert projects. The descriptions below include details based on the most available information as of spring 2022, which is subject to change. The project team will maintain a list with the most up-to-date information regarding eligibility, application process, agency contacts, and additional information that will be used as a funding strategy is developed.

6.2.1 RAISE: Rebuilding American Infrastructure with Sustainability and Equity

RAISE, Rebuilding American Infrastructure with Sustainability and Equity, is the latest version of a discretionary grant program funded by the U.S. Department of Transportation (USDOT). It has previously been known as TIGER (Transportation Investment Generating Economic Recovery) from 2010 to 2018 and BUILD (Better Utilizing Investment to Leverage Development Transportation Discretionary Grants Program) from 2018 to 2020. Congress has dedicated nearly $10.1 billion for 13 rounds of previous National Infrastructure Investments that have significant local or regional impact.

Funds for the Fiscal Year (FY) 2022 RAISE grant program are to be awarded on a competitive basis for surface transportation infrastructure projects that will have a significant local or regional impact. The USDOT is looking to award projects that align with the President's greenhouse gas reduction goals, promote energy efficiency, support fiscally responsible land use and transportation-efficient design, increase use of lower carbon travel modes such as transit and active transportation, incorporate electrification or zero emissions vehicle infrastructure, increase climate resilience, support domestic manufacturing, incorporate lower carbon pavement and construction materials, reduce pollution, and recycle or redevelop brownfield sites. The FY 2022 RAISE round will be implemented, as appropriate and consistent with law, in alignment with the priorities in Executive Order 14052, Implementation of the Infrastructure Investments and Jobs Act (86 Federal Register 64355), which are to invest efficiently and equitably, promote the competitiveness of the U.S. economy, improve job opportunities by focusing on high labor standards, strengthen infrastructure resilience to all hazards including climate change, and to effectively coordinate with state, local, tribal, and territorial government partners. This program is referred to as the Local and Regional Project Assistance Program in the IIJA/BIL.

Non-federal match requirements are 20% or greater unless the project is an exempted community. Match can include state revenue, local revenue, or private funding or other programs allowed through the BIL (tribal transportation program, federal lands transportation programs, and others that are unlikely to qualify for stream mouth projects).

In addition to capital awards, USDOT will award at least $75 million for eligible planning, preparation, or design of projects eligible for RAISE grants that do not result in construction with FY 2022 RAISE funding. USDOT will also award at least $15 million for projects located in areas of persistent poverty or historically disadvantaged communities as defined by Transportation Disadvantaged Census Tracts (Historically Disadvantaged Communities Tool).

The deadline for applications in FY 2022 was in April 2022, and selections were announced in August 2022. Additional rounds are anticipated with BIL funding. Project partners should work with BNSF, the federal delegation, and others to better understand and track this opportunity, including eligible sponsors. Eligible applicants include states, local governments, public agencies, special purpose districts, or tribes.

A partnership between BNSF and local communities could directly meet the goals of supporting fiscally responsible land use and transportation efficient design, increasing climate resiliency, strengthening infrastructure resilience to all hazards including climate change, and effectively coordinating with state, local, tribal, and territorial government partners.

6.2.2 CRISI: Consolidated Rail Infrastructure and Safety Improvement Program

CRISI, Consolidated Rail Infrastructure and Safety Improvement Program, is a competitive grant program that funds projects that improve the safety, efficiency, and reliability of intercity passenger and freight rail. Areas with documented casualties are preferred, and this program includes multiple tracks: 1. Planning, 2. Preliminary Engineering (PE)/National Environmental Policy Act (NEPA), 3. Final Design/Construction, and 4. Safety Programs & Institutes. Applicants to this funding mechanism must provide a Statement of Work (SOW), Benefit-Cost analysis (BCA), and Environmental Readiness that identifies private sector, state, and/or local funding. The federal preference for project funding is 50% or less. At least 20% of funding must come from a non-federal match, although the average matching percent of projects selected over the lifetime of the CRISI program (from FY 2017 to FY 2020) is 49%.

This funding source may only be feasible for stream mouth passage projects if the culvert improvements are part of a larger project. Furthermore, there is typically a preference for “shovel-ready” projects where design and permitting are complete in advance of funding. Project partners will need to do additional research on this funding source and better understand the individual project sites to determine eligibility for this funding source. The 2022 grant recipients were regional projects and did not include any from Puget Sound or Washington State.

6.2.3 INFRA: Infrastructure for Rebuilding America

INFRA, Infrastructure for Rebuilding America, is funded by the USDOT. It funds highway and railroad projects of regional and national economic significance. Projects that improve local economies and create jobs are prioritized, and grants are considered based on how they would address climate change, environmental justice, and racial equity. INFRA projects are rated on the extent that they apply innovative technology and whether they can deliver projects in a cost-effective manner. In the past, demand for INFRA grants has far exceeded the available funds. The 157 eligible applicants collectively requested $6.8 billion in grant funds–more than seven times the amount of funding available. USDOT estimates that approximately 44% of proposed funding will be awarded to rural projects.

A related initiative, INFRA Extra, will allow certain INFRA applicants the opportunity to apply for Transportation Infrastructure Finance and Innovation Act (TIFIA) credit assistance for up to 49% of eligible project costs, if the project advanced for funding, but was not awarded due to resource constraints.

This funding source may only be feasible if the culvert improvements are part of a larger project. Project partners will need to do additional research on this funding source and better understand the individual project sites to determine eligibility for this funding source.

6.3 State of Good Repair Grant Program

The Federal Railroad Administration (FRA) is an agency housed under the USDOT. FRA is organized into eight regions; BNSF is in Region 8, which includes Washington, Oregon, Idaho, Montana, Wyoming, North Dakota, and South Dakota.

The Federal-State Partnership for State of Good Repair Grant Program for Fiscal Year 2021 had $198 million in funding nationwide to repair, replace, and rehabilitate Qualified Railroad Assets to reduce the state of good repair backlog and improve Intercity Passenger Rail Performance. This grant is often referred to as the Partnership Program and is intended to benefit both railroad assets in the Northeast Corridor (NEC) and public or Amtrak-owned infrastructure, equipment, and facilities. Applicants should note that the Partnership Program has distinct eligibility requirements based on project locations.

This grant requires a BCA to quantify elements like the value of travel time savings and other issues that our project will not directly benefit. This would be an extremely difficult and time-consuming process to attempt to quantify and develop a proposal, with very low chances of success.

The issues of landslides along the tracks and sea level rise could be a better angle with FRA because those slow/halt passenger rail. The project team should continue coordinating with BNSF and the federal delegation on this opportunity. Additional coordination with Washington State Department of Transportation (WSDOT) and even Sound Transit may be helpful.

6.4 New Funding Opportunities Under Development

Several additional opportunities under the BIL are under development or recently announced. The project team will track the details of the National Fish Passage Program (USDOT), National Fish Passage Program (USFWS), and the NOAA Fish Passage Program to identify the program details, successful proposals from the first year, and likely alignment with streamflow projects. The project team will also monitor the Federal Emergency Management Agency (FEMA) grant programs and others that might be unique fits for certain project sites as we better understand the sites and determine if certain stream mouth projects meet the eligibility requirements.

TABLE 5.
SUMMARY OF POTENTIAL FUNDING SOURCES

Funding Source	Grant Program Priorities					Grant Program Details					
	Fish Passage	Railroad/ Passenger Safety	Infrastructure Resiliency	Beach Access	Other	Geographic Area	Grant Availability	Grant Pool Available	Match	Award Size	Notes
Salmon Recovery “Lead Entity-directed” Funding: SRFB, PSAR (RCO)	Primary Objective					Watershed-specific allocations and funding decisions; funding available in all Puget Sound watersheds	Annual	Varies based on watershed allocation	15% required	$100,000s to low millions.	Large-scale passage projects may only qualify in places where these are high priority within the local salmon recovery plan chapter. Grant rounds are generally run annually, but PSAR funds are available biennially.
Puget Sound Restoration & Acquisition Fund (PSP/RCO)	Primary Objective					Puget Sound	Biannual	Varies	0% required 15% encouraged	Multi-million	Match is not required but may benefit scoring; recent criteria used for PSAR gave additional points to projects benefiting certain Chinook salmon stocks. For stream mouth projects, those include Stillaguamish, Nooksack, and Skagit. A conceptual design is required for engineering and design projects. Recent biennium funding was ~$15M.
Estuary & Salmon Restoration Program (ESRP) (WDFW/RCO)	Primary Objective					Puget Sound	Biannual	$12M-$15M	30% required	Typically under $1M	There is a 30% match but other RCO-administered funds qualify. Funding is usually modest (under $1M), but the program commits to multiple phases and monitoring, so could be valuable to fund a portion of projects with this source.
Brian Abbott Fish Passage Barrier Removal Board	Primary Objective					Washington	Biannual	Varies	15% required	No limit	There is a $200,000 limit on design projects with no match requirement if designs are completed within 18 months. Construction projects have no upper limit and a 15% match. It is unclear how these stream mouth projects on a railroad will rank in a process focused on road culverts.
Aquatic Lands Enhancement Account (RCO)	Secondary Objective			Primary Objective		Washington	Biannual	Varies	50% required	$1M	One of the few funding sources that considers public beach access as a criterion. The funding is generated from aquatic leases managed by DNR, so funding is variable.
Coastal & Marine Restoration Grants Community-Based Restoration Program (NOAA)	Primary Objective		Secondary Objective			National	Annual	Varies	0% required 50% encouraged	$75K-$3M	Preference for capital projects with quantitative (miles/acres) over qualitative improvements. More flexibility in monitoring, capacity-building, and other aspects of successful project implementation may be feasible once under contract based on a priority “anchor project.”
National Coastal Resilience Fund (NFWF)	Secondary Objective		Primary Objective			National	Annual	$25M-$50M	50% required	$250K-$5M	National competition. A minimum 1:1 non-federal match is expected. Total funding is expected greatly increase with BIL funds so a good source to consider.
America the Beautiful Challenge (NFWF)	Primary Objective					National	Annual	Varies	10% required for State applicants 3%- required for tribal applicants	$1M for planning	Details here reflect the DOI funding tracks. The DOI Implementation Grants are capped at $5M and must be completed in 4 years, while the planning grants are capped at $1M and must be completed within 1 year. This funding is assumed to be open annually for next 4 years if federal funding is allocated.

Funding Source	Grant Program Priorities					Grant Program Details					
	Fish Passage	Railroad/ passenger safety	Infrastructure resiliency	Beach access	Other	Geographic Area	Grant availability	Grant pool available	Match	Award size	Notes
National Culvert Removal, Replacement, and Restoration Grant Program (USDOT/Federal Highway Administration)	Primary Objective					National, but priority given to West Coast stocks of anadromous salmon and SRKW prey	Annual	$200M	20% required	Up to $20M	This is a new funding program closing in February 2023. Pending funding, grant rounds will open annually through 2026.
Rebuilding American Infrastructure with Sustainability and Equity (RAISE) (USDOT)		Primary Objective				National	Annual	$1.5B	20-50% non-federal match required	Minimum of $1M or $5M	Projects in certain locations have minimum cost requirements; minimum award for urban projects is $5M and minimum for rural is $1M.
Consolidated Rail Infrastructure and Safety Improvement Program (CRISI) (FRA)		Primary Objective			Primary Objective		Annual	$368M	20% non-federal match required	~$5M-$60M	The focus of this funding source is on intercity passenger and freight railroad safety. Funding was allocated to regional corridor projects in 2022, none in Puget Sound/Washington State.
Infrastructure for Rebuilding America (INFRA) (USDOT)		Secondary Objective			Primary Objective		Annual				Unlikely to be a fit for stream mouth projects. More research needed.
State of Good Repair Program (FRA)		Secondary Objective			Primary Objective		Annual	$198M			Requires a benefit-cost analysis and focus on travel time. Unlikely to be a fit for standalone stream mouth projects. More research needed.

7.0 Conceptual Design Development for Three Priority Sites

This chapter presents a design analysis for the restoration of three priority coastal stream mouths through the replacement of BNSF crossing structures. For each site, information is provided on existing conditions, the proposed restoration, and key considerations to be evaluated further through discussions with BNSF, local partners, and additional information gathering and analysis. The information provided for the three sites is intended to support a continued dialogue between the project team and BNSF regarding project implementation coordination, design, and construction.

The three priority sites that are the focus of this report were identified through an inventory and prioritization of the culverts and bridges at the mouths of coastal streams and embayments routed through the railroad corridor on the Puget Sound shoreline between Olympia and the U.S.-Canada border (Confluence et al. 2019). The three sites were selected from among 45 priority streams identified among the 196 coastal streams that were evaluated and prioritized (see Figure 3). The three sites were chosen based on the geographic distribution throughout the railroad corridor, the apparent differences in the engineering complexities associated with each site, the differences in anticipated crossing structures needed at each site, and the willingness of the landowner to partner on the restoration work. In this way, the three sites demonstrate the range of complexities and solutions that may apply to the full list of priority sites.

The three sites evaluated are **Squalicum Creek estuary** (Bellingham, WA), **Japanese Gulch Creek estuary** (Mukilteo, WA), and an **unnamed creek estuary on JBLM** in Pierce County, WA. A map of the location of the three sites is provided in **Figure 6.**

7.1 Squalicum Creek Estuary

The railroad crossing over the Squalicum Creek estuary in Bellingham is on a railroad spur line that serves the Port of Bellingham (Port). The crossing is one structure comprised of six box culverts. The railroad spur culverts crossing is one of three crossing structures over the estuary that are constraining stream and estuary ecological processes and preventing estuarine habitat functions; the crossing structures are too short to span the active stream/estuary zone and short enough to impact streamflows during flood conditions. The three crossing structures are located in an approximately 250-foot-long reach of the channel, and all are downstream of river mile 0.1. From upstream to downstream, the crossings and ownership are: Roeder Avenue culverts (City of Bellingham), railroad spur culverts (BNSF), and a truck bridge (Port of Bellingham). **Figure 7** presents an overview of the estuary. Restoration of the railroad spur crossing would address a partial fish passage barrier at the mouth of the largest creek in the City of Bellingham and allow for restoration to enlarge and enhance the constrained estuary. In this way, the restoration would benefit all anadromous salmonids throughout the Squalicum Creek watershed and amplify the benefits of substantial habitat restoration work that has been completed upstream by restoring full passage into the creek system. Notably, the restoration would benefit Puget Sound Chinook salmon, which are listed as threatened under the federal ESA and are highly dependent on estuary habitats. In addition, the restoration would provide additional benefits by reducing flooding associated with the impoundment of water upstream of the railroad bridge during high flows.

Figure 6. Location of the Three Creeks Evaluated for Restoration Design

Figure 7. Squalicum Creek Estuary Site with Three Crossings

7.1.1 Overview of the Site

Railroad Spur Crossing

The railroad spur crossing over Squalicum Creek that serves the Port is located in the vicinity of the BNSF Railway mainline bridge at Milepost 98.400 on Bellingham Subdivision, Line Segment 50. The BNSF mainline crosses the creek several hundred feet upstream on a large, elevated trestle and is not part of the project. The railroad spur crossing is located at 48º45’38.43”N and 122º30’30.78”W. The spur line ends just north of the creek and services two Port tenants.

The railroad spur crossing is one structure that is comprised of six concrete box culverts (**Figure 8**). Each cell is 8.1 feet wide by 2.5 feet tall (WDFW 2018a). The railroad spur crossing is located at the outlet of Squalicum Creek. During high tide, water levels approach or exceed the top of the openings of the six culverts that form the crossing structure. At low tide, the creek outflow is split among the openings of the six culverts and is commonly spread out and very shallow. Figure 8 includes photos of high tide and low tide conditions at the bridge.

The railroad spur crossing is identified as a fish passage barrier of unknown passability in the WDFW Fish Passage and Diversion Screening Inventory Database (WDFW 2018a; Site ID 991079). The unknown passability designation is how WDFW characterizes fish passage barriers in tidal environments because WDFW has not developed barrier identification criteria for fish passage at tidal sites. The site is considered a barrier due to the water surface drop ranging from 1.3 to 2.5 feet among the six cells. This means there is a waterfall moving downstream during low tides that would entirely prevent upstream fish passage during such conditions. The crossing is likely not a barrier during high tide when tidal waters would backwater upstream of the bridge. The concrete apron associated with the culverts likely also affects fish passage at medium to low flows because of shallow water depths. The creek channel downstream of the railroad bridge includes many large riprap boulders assumed to have been placed for grade control or fish passage improvements.

The spur railroad crossing is situated between two additional bridges. Immediately downstream of the railroad bridge is a Port-owned truck bridge which Port tenants regularly use to convey materials between a storage area north of the stream and facilities and transport routes south of the stream. Approximately 150 feet upstream is a bridge owned by the City of Bellingham. The upstream bridge is part of Roeder Avenue, which is a two-lane arterial road with bike lanes and serves as a major transportation corridor for Port activities. See Figure 7 for an overview of the site.

Roeder Avenue Culverts

The Roeder Avenue crossing consists of a three-cell concrete culvert **(Figure 9**). Each cell is 8 feet wide by 4 feet tall (WDFW 2018b). Water flow at the Roeder Avenue crossing is tidally influenced. The culverts are identified as a fish passage barrier of unknown severity by WDFW (2018b; site ID 991104). WDFW (2018 a,b) indicate that a concrete flume extends from the Roeder Avenue culverts to the railroad spur culverts.

Figure 8. Railroad Spur Crossing Over Squalicum Creek Estuary at High Tide (top) and Low Tide (bottom)

Photo source: top – Rosario Archaeology 2011; bottom – A. MacLennan 2019.

Figure 9. Roeder Avenue Culverts Looking Downstream to Culverts (top) and Looking Upstream to Culverts (bottom)

Photo source: WDFW.

Port Truck Bridge

The Port bridge is a concrete slab bridge with wood footings above and outside of bankfull width (WDFW 2018c; site ID 602275). The bridge is 60 feet long and water flow at the Port bridge is tidally influenced **(Figure 10**). The creek channel substrate under the bridge and downstream is a mix of concrete rubble, riprap, and some stream cobbles. The bridge is classified as a fish passage barrier of unknown severity by WDFW (2018c) due to a water surface drop of 1.4 feet associated with the concrete rubble.

Additional Site Characteristics

The railroad bridge and the Roeder Avenue culverts are potentially eligible for listing as historic resources on the National Register of Historic Places (NRHP) because they are both over 50 years old. The railroad bridge was constructed in 1909, and the Roeder Avenue culverts were constructed in 1962 (Rosario Archaeology 2011). Rosario Archaeology (2011) concluded that neither bridge would meet the criteria for inclusion in the NRHP. However, this determination will need to be revisited as part of the permitting required for construction.

The Squalicum Creek estuary is in a different location, much smaller, and significantly degraded compared to its historic condition **(Figure 11**). Restoration at this site is unlikely to restore historic conditions because a significant amount of land filling of historic tidelands occurred in Bellingham Bay that affected the Squalicum Creek estuary, which is now used by the Port. Currently, the estuary is confined in a narrow channel not much wider than the stream channel upstream of the estuary. The banks are lined with riprap, and the thalweg channel of the estuary is covered with a mix of concrete flume, concrete rubble, and large boulders. Channel confinement would be predicted to cause higher flow velocities that cause greater erosion; therefore, it is likely the bank and bed hardening with concrete and boulders in this portion of the Squalicum Creek estuary has happened in response to erosive flows that result from the channel confinement. Because of the narrow confinement of the estuary and the materials comprising the substrate, the quantity and quality of habitat in the estuary are substantially degraded.

Further, Ecology has identified upland areas adjacent to the estuary as contaminated under the Model Toxics Control Act (MTCA; Ecology 2022; **Figure 12**). MTCA is the law in Washington State that governs the cleanup of sites where toxic substances are harming or threatening humans or the environment. Ecology has a Toxics Cleanup Program to manage the cleanup of MTCA sites, and the agency maintains a database of MTCA cleanup sites.

Figure 10. Port Bridge Looking Downstream at Bridge (top) and Looking Upstream at Bridge with Railroad Spur Crossing Culverts in Background (bottom)

Photo source: top – Anchor QEA, bottom – WDFW.

Figure 11. Squalicum Creek Estuary Circa 1910–1926

Arrow points to Railroad Crossing, which is still in place. Extensive land conversion and development following this photo led to further realignment of existing creek and estuary route.

Photo source: Whatcom Museum Photograph No. 3219.003807 from Rosario Archaeology (2011).

Figure 12. Contaminated Sites in the Vicinity of the Squalicum Creek Estuary

Source: City of Bellingham – City IQ.

To the west of the estuary, the "Mt. Baker Products" site is identified as having contaminated soil and groundwater, with surface water suspected as also being contaminated. Ecology's MTCA Cleanup Site ID for the area is 1035, and the site is listed as "awaiting cleanup." Two additional contaminated sites are identified east of the estuary, and both are categorized as "cleanup started" (Ecology 2022). The Yorkston Oil site (MTCA Cleanup Site ID 6248) has contaminated soil and groundwater. In 2019, three underground storage tanks were removed from the site. The Northwest Fuel site (MTCA Cleanup Site ID 2611) has contaminated soil and groundwater. In 2018, Ecology wrote a letter indicating that cleanup is not active at the site (Ecology 2022). These soil contaminants are due to legacy uses on Port properties, and the current activities do not appear to be ongoing sources of contamination.

A City of Bellingham-owned sewer main exists below the creek bed at the Roeder Avenue location. The City will be constructing a sewer lift station in 2023–2025 that includes infrastructure allowing lowering of the portion of pipe below Squalicum Creek. This section of sewer main will likely be lowered in conjunction with the future fish passage improvement.

7.1.2 Site Hydrology and Existing Culvert Capacity

Site hydrology associated with existing structures can be used to determine the adequacy of the capacity of existing water crossing structures to pass large flow events. A numeric analysis of the hydraulic conveyance capacity of the bridges in the Squalicum Creek estuary was not conducted. The inadequacy of the existing crossings and the Squalicum Creek channel was exemplified during a major storm that occurred in November 2021. Photo frames from a City of Bellingham video recorded from a drone show the flooding in the area following the storm (**Figure 13**). One or more of the crossings significantly restricted water flow, trapped debris, and exacerbated flooding around the estuary, while creek flows upstream were high enough that the streambanks overtopped.

Hydrology and hydraulic calculations were not prepared to inform the sizing of the replacement structures. Due to the three crossings being located at the outlet of the creek, the estuary restoration envisioned would be wider than dictated by hydraulic analysis. The crossings are located in a part of the estuary that would be wider due to the stream and coastal processes acting on the site. Future design work at the site should include hydraulic analysis and incorporate future projections for sea level rise.

7.1.3 Description of the Restoration Opportunity

Replacement of the railroad spur crossing alone would remove a partial fish passage barrier, but would not address the two other barriers in the estuary and would keep the estuary in an unnaturally narrow and degraded condition. For this reason, the restoration concept for replacing the railroad spur crossing includes a larger project that holistically addresses all three crossings by replacing them with longer structures to reduce the impacts from the crossings on stream functions and fish passage while also expanding the estuarine aquatic area (i.e., areas inundated when tides are at or above mean higher high water [MHHW]). In this way, addressing the BNSF railroad crossing would be completed as one element of a larger estuary restoration project involving other partners, including the City of Bellingham and Port. **Table 6** describes the existing and proposed widths for the restoration concept. As a restoration concept, the proposed sizes and locations are for discussion purposes and can be adjusted in future planning and design steps. A conceptual rendering of the restoration concept is presented in **Figure 14,** and a conceptual engineering drawing is presented in **Figure 15**. The conceptual design was developed by applying an assumption of the portion of adjacent land that could be converted to estuary. This needs to be discussed with stakeholders. In addition, climate change projections will need to be considered to ensure the proposed crossing structure sizes are adequate.

The proposed railroad spur bridge is a six-span, 158-foot-long bridge. The new railroad spur bridge and its approaches would be in a slightly straighter alignment than the existing culverts. The new alignment ties into the existing tracks on either side of the creek. The existing railroad spur crossing would be removed. The proposed Roeder Avenue bridge is a 143-feet-long, pile-supported structure. The proposed Roeder Avenue bridge will be in the same alignment as the current culverts. The proposed Port bridge is a five-span, 128-foot-long bridge in the same location as the existing bridge. The three proposed bridges allow for increased widening of the estuary moving downstream. The higher skew angles for the proposed Roeder Avenue and railroad spur bridge require longer bridge lengths than the Port bridge, which crosses perpendicular to the creek channel.

TABLE 6.
SQUALICUM CREEK ESTUARY BRIDGE REPLACEMENTS TO ACCOMMODATE RESTORATION

Crossing	Existing	Proposed
Roeder Avenue	70 ft long culverts	143 ft long bridge
Railroad Spur	70 ft long culverts	158 ft long bridge
Port Truck	60 ft long bridge	128 ft long bridge

The estuary restoration will more than double the size of the current estuary from approximately 0.35 acre to 0.75 acre. As noted above, this conceptual design is based on an assumption of how much land can feasibly be converted in this highly constrained area, which is entirely fill of historic tidelands. As part of the estuary restoration, the concrete debris and rocks currently covering the channel will be removed and replaced with sand and gravel substrate. These natural substrates will support more prey production and provide better habitat for outmigrating salmon and trout. A vegetation planting plan for riparian and wetland plants will be prepared after structural design is finalized. Due to the limited space available for the estuary and the interest in maximizing lower elevation aquatic habitat, it is assumed that steep slopes will be necessary to transition from the aquatic to upland habitats. The steep slopes and new bridges are expected to require bank stabilization. The slope and lateral extent of the transition can be explored further in a future alternatives analysis. Riparian vegetation is planned wherever possible along the shoreline that it is compatible with adjacent land uses. Over time, riparian vegetation can provide shade, produce insect prey for salmon, input organic matter (leaves and branches) that supports aquatic prey production, and create habitat structure by small and large wood pieces falling into the estuary (Brennan 2007).

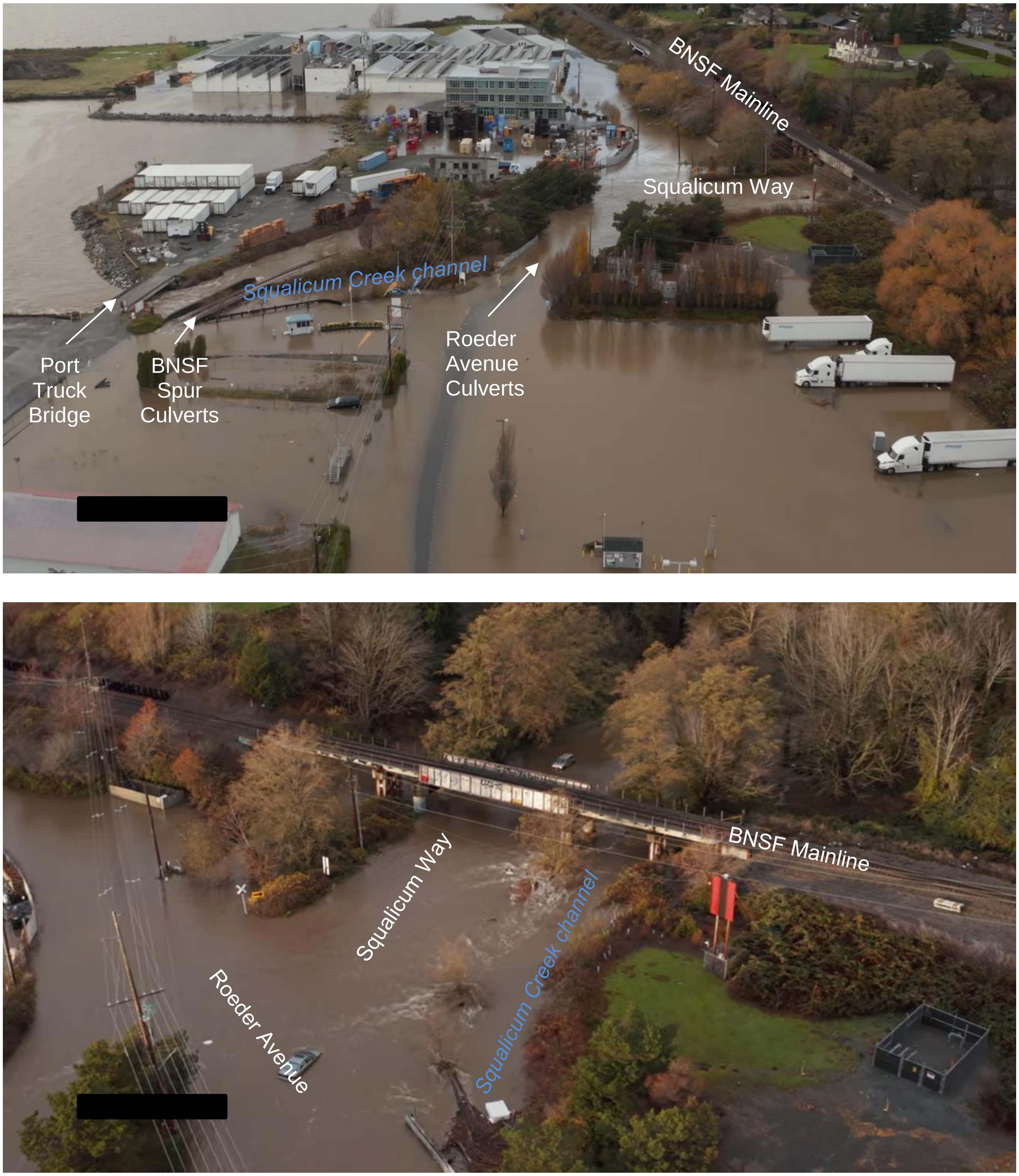

Figure 13. Squalicum Creek Estuary Flooding During November 15, 2021 Storm

Top shows railroad culverts inundated above openings for creek and Roeder Avenue culverts flooded on all sides. Bottom photo is facing upstream from Roeder Avenue culverts (guardrail visible in bottom center of image).

Source: City of Bellingham (2021).

Figure 14. Conceptual Rendering of Squalicum Creek Estuary Restoration

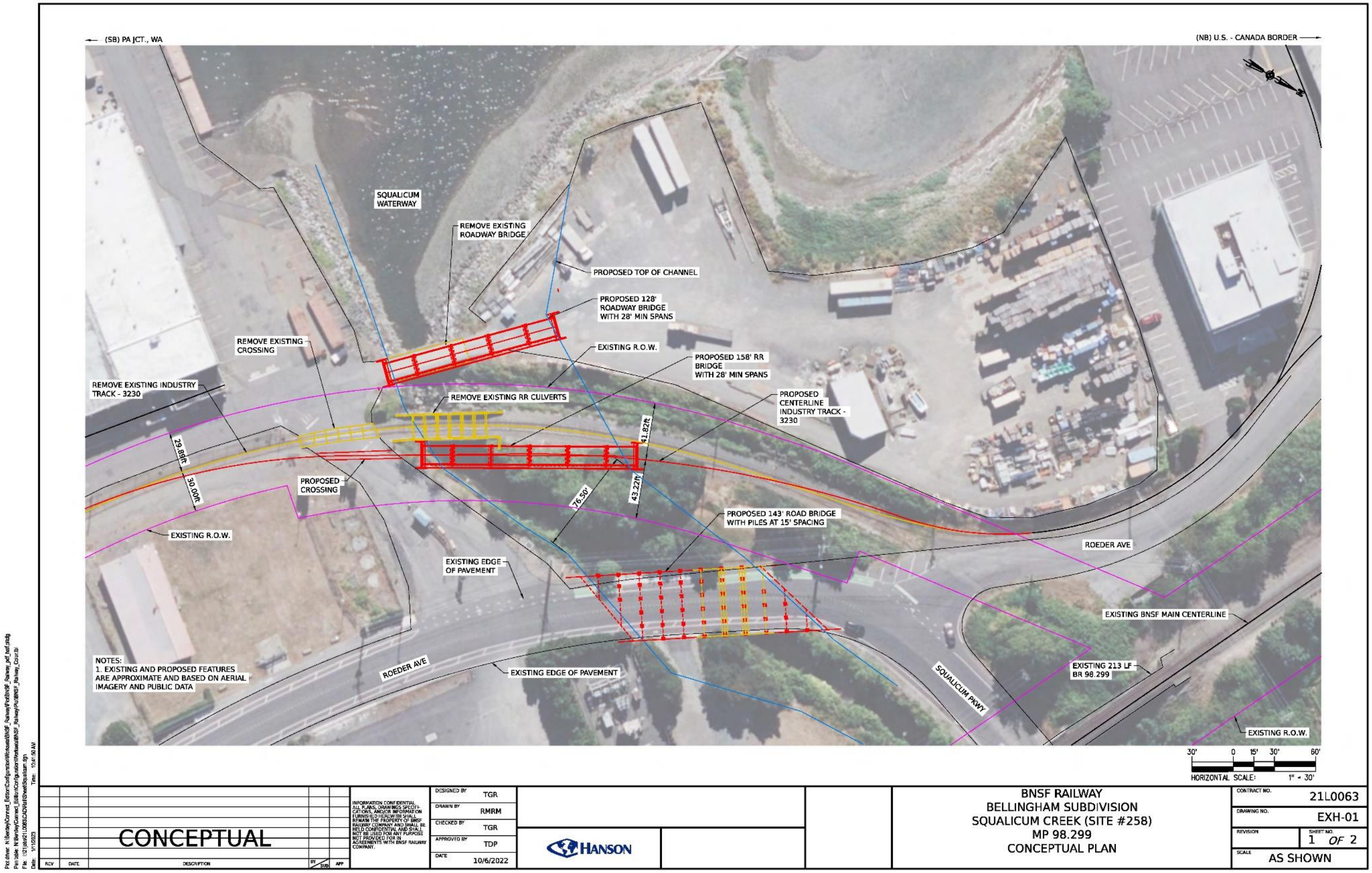

Figure 15. Conceptual Engineering Plan View of Squalicum Creek Estuary Restoration

The estuary expansion entails excavating the northwestern shoreline of the creek to convert upland to aquatic habitat. This area is part of the Mt. Baker Products MTCA site, and cleanup of the area through excavation of contaminated sediments and isolating any remaining contaminated areas would be a required part of the restoration. More information is needed on site conditions and extent to inform such contaminant remediation.

Restoration Benefits to Salmon and Trout

Squalicum Creek supports six species of anadromous salmon and trout, including Chinook salmon, coho salmon, chum salmon, winter steelhead, coastal cutthroat trout, and bull trout (WDFW 2022; NWIFC and WDFW 2022). Puget Sound Chinook salmon, Puget Sound steelhead, and bull trout are all listed as threatened under the federal ESA. Restoration of the Squalicum Creek estuary will provide significant benefits to anadromous salmon and trout, as well as other fish and wildlife species who use estuary habitats.

The benefits will occur by removing three partial fish passage barriers, enhancing and expanding estuary habitat, and improving upstream access to valuable spawning and rearing habitat. This will improve access to approximately 8 miles of Chinook salmon habitat in the Squalicum Creek basin as well as providing access to over 30 miles of documented, presumed, and accessible habitat for coho and chum salmon, winter steelhead, coastal cutthroat trout, and bull trout **(Table 7**). Improving accessibility to mainstem and headwater reaches of this creek will enhance the beneficial impacts of at least 23 completed and ongoing salmon habitat restoration projects in this watershed by the City of Bellingham, WSDOT, and the Nooksack Salmon Enhancement Association.

TABLE 7.
EXISTING AND POTENTIAL HABITAT UPSTREAM OF SQUALICUM CREEK MOUTH RESTORATION SITE ACCESSIBLE TO SALMON, STEELHEAD, AND TROUT POST-PROJECT

Species	Documented Presence (Miles)	Documented Rearing (Miles)	Presumed (Miles)	Gradient Accessible (Miles)	Total (Miles)
Fall Chinook	7.9	--	--	--	**7.9**
Coho	16.4	--	6.2	14.5	**37.1**
Fall Chum	3.9	--	4.7	25.1	**33.7**
Winter Steelhead	9.7	3.4	--	23.1	**36.2**
Bull Trout	0.6	--	20.8	16.3	**37.7**

The restored estuary will particularly benefit Chinook and chum salmon, which are the most dependent on estuarine habitats as juvenile fish (Healey 1982). Estuaries are the transitional habitats for salmon as they outmigrate from freshwater to saltwater habitats as juveniles, and reverse the transition when returning as adults. For juvenile salmon outmigrating from their natal creeks to begin the marine portion of their life cycle, a gradual transition from freshwater to saltwater is beneficial for allowing their bodies to complete the physiological transition needed to adapt to saltwater (Simenstad et al. 1982). The larger size of the restored estuary will provide more habitat for the juvenile salmon to stay in compared to the current narrow channel, which likely results in the fish being transported rapidly through the estuary to Bellingham Bay. In estuaries, juvenile salmon can also experience rapid growth through feeding on high-calorie prey available in productive estuaries (Simenstad et al. 1982). Rapid growth at this life stage is beneficial as larger salmon are more likely to survive in the marine phase to return as adults to spawn (Duffy and Beauchamp 2011).

In addition to benefiting juvenile salmon originating in Squalicum Creek, the estuary restoration will also benefit juvenile Chinook salmon originating in the Nooksack River and other river systems. Squalicum Creek estuary is the second coastal wetland habitat encountered by juvenile salmonids traveling east as they outmigrate from the Nooksack River delta just 2 miles west of Squalicum Creek. After outmigrating from their natal (origin) estuary, a portion of the juvenile Chinook salmon will migrate along the shallow habitats of Puget Sound and move into the estuaries of other creek systems (i.e., non-natal estuaries). Based on abundance, non-natal estuary habitats are preferentially used by juvenile Chinook in the nearshore (Beamer et al. 2005). In addition, Beamer et al. (2013) documented juvenile Chinook using the lower stream reaches of non-natal streams. Recent studies show that approximately 30% of the adult ESA-listed Chinook returning to the Nooksack River are the result of a fry outmigration life-history strategy (Campbell et al. 2019), a life-history strategy associated with prolonged nearshore and estuary rearing. Furthermore, a 2016 study (Beamer et al. 2016) shows that existing Bellingham Bay nearshore and pocket estuary habitats have documented use by ESA-listed Nooksack natural origin juvenile Chinook, including early Chinook (i.e., spring run). Recovery of the Nooksack's two populations of early Chinook are required for delisting. The study also found that these juvenile Chinook utilize nearshore and pocket estuary habitats to a greater extent than other Bellingham Bay habitats, including the Nooksack River delta. These habitat types have been documented in a number of recent studies as being utilized by non-natal juvenile Chinook salmon, juvenile steelhead, and bull trout (Beamer et al. 2016; Beamer et al. 2003; Hirschi et al. 2003). These studies document the importance of restoring non-natal estuaries to benefit the recovery of Puget Sound Chinook salmon.

Flood Reduction Benefits of Restoration

The proposed restoration would address several natural hazards identified by the Port and City in the 2021 Whatcom County Natural Hazards Mitigation Plan (Whatcom County 2021). The existing crossings restrict high streamflows, causing frequent flooding of Roeder Avenue at high tides and significant regional flooding during storm events. Increases in storm frequency and intensity have led to several recent historic flooding events that closed a main Port and City transportation corridor (Roeder Avenue/Squalicum Way). As described above, the area experienced major flooding during the November 2021 storm (see Figure 13). The existing crossings restricted water flow, trapped debris, and exacerbated flooding around the estuary. The flooding persisted for days, and local businesses were forced to close for 2 weeks (Baumgarten pers. comm.). The proposed restoration would help alleviate flooding.

7.1.4 Considerations for Restoration Design and Construction

Given the complexity of the restoration project, which includes three bridges and impacts on surrounding land uses, a full alternatives analysis would be needed for the Port, City, BNSF, other stakeholders, and the community to select a preferred alternative for design and construction. During the preparation of this site analysis and conceptual design, the City, Port, and BNSF have all participated in restoration planning discussions and are seeking funding for the next steps toward restoration implementation. This section identifies and describes site factors that will need to be considered in the alternatives analysis and design.

Adjacent Land Uses

The proposed restoration area includes heavily used portions of Port property and public right-of-way. The proposed estuary expansion entails converting Port upland areas into aquatic habitat. This affects the Port and its tenants and will require their input and agreement. The replacement of a bridge on a City arterial street will require City input and agreement.

Sizing and Alignment of Bridges

The proposed bridges are lengthened to allow for widening of the Squalicum Creek estuary. As a restoration concept, the proposed sizes and locations described in this report are for discussion purposes and can be adjusted in future planning and design steps. To fully achieve the desired objectives for habitat enhancement, flood reduction, transportation, and climate adaptation, the superstructure of each bridge must be high enough to not be inundated during high water levels from the creek or bay and to provide sufficient height for predicted sea level rise at this site for the life expectancy of the structures. This is a trade-off between the length of each bridge span and the depth of each horizontal beam. Longer beams require deeper horizontal beams. Raising the railroad bridge to gain vertical clearance would entail grade adjustments starting well to the east of the bridge. The feasibility and cost of grade adjustments will need to be considered by BNSF and the Port. The proposed Roeder Avenue bridge creates the opportunity for the City to adjust the intersection of Roeder Avenue and Squalicum Way. The intersection design would also need to consider the future City trail planned to extend down Squalicum Way to Roeder Avenue.

The proposed restoration concept presented above includes bridge alignments that are very similar to the existing alignments. Alternative alignments of the bridges could be considered. A variation of the proposed restoration concept would be realigning the railroad bridge to cross more perpendicular to the channel. This would shorten the length of the railroad bridge, which in the proposed concept is crossing the estuary at an angle, but would require reworking the railroad track and usage for Mt. Baker Products. Another restoration alternative could be to expand the project area upstream to re-route Squalicum Creek to the west and have the estuary routed into the restored pocket beach that is west of the existing estuary. This would convert a wide corridor through the Mt. Baker Products facility to estuary.

Railroad Track Grades and Geometry

The existing bridge is at grade with the surrounding areas, which allows truck traffic within the Port to cross the tracks. The vertical clearance between the bottom of the proposed railroad bridge and the restored estuary channel will need to be sufficient to pass high flows from the creek throughout all tide stages. Further study will be needed during the alternatives analysis to understand if adequate clearance can be provided. Additionally, the railroad spur crossing is in the middle of a sharp curve and will require further analysis to develop an optimum horizontal alignment that minimizes impacts on local rail operations, Port property, and estuary improvements.

Site Contamination

The documented soil and groundwater contamination, along with suspected surface water contamination, will need to be carefully considered. As described above, the soil contamination is due to legacy uses on Port properties that are listed as MTCA Cleanup sites by Ecology. Depending on information provided by the Port, its tenants, and Ecology, more information may be needed to characterize the spatial extent of contamination, the contaminants present, their concentrations, and the media that are contaminated (e.g., soil, groundwater, surface water, and substrate). The information on Ecology's website (Ecology 2022) does not include any recent site assessment documentation.

Cultural Resources

The proposed restoration will be subject to Section 106 of the Historic Preservation Act as part of the consultation process necessary to obtain the required permits from the U.S. Army Corps of Engineers (USACE). Under Section 106, the project proponent (lead agency) must consult with all affected tribes and with the Washington State Department of Archaeology and Historic Preservation (DAHP). Any effect the project may have on historic resources must be taken into account and mitigated. Following the initiation of Section 106, a literature review will be needed to provide a context for the area, including all known/previously recorded resources. An archaeological survey (shovel probes) may be needed at each of the existing culvert locations and in the new locations. The precise relationship between the existing culverts and any possible archaeological sites will need to be determined, which is an element of the archaeological survey. The project will also require Historic Property Inventory forms for all of the non-archaeological resources within the APE that are over 50 years old, including the railroad bridge. Additional research will be required to determine what other, if any, resources would require a Historic Property Inventory. A trained monitor will likely be required during construction.

Within the project area, the railroad spur and Roeder Avenue crossings are potentially eligible for listing as historic resources in the NRHP because they are both 50 years old or greater. Each structure would need to be evaluated for NRHP criteria during project planning and permitting. Given the age of the railroad bridge, demolition would be considered an adverse effect that would permanently affect the resource. Due to the fact the bridge has been determined eligible for listing in the NRHP, DAHP would likely request project alternatives that would not include demolition and/or less significant impacts. Generally speaking, DAHP prefers project alternatives with the smallest impact(s) on historic properties. If an impact on the bridge cannot be avoided, DAHP will determine the required mitigation in coordination with the lead agency. It is likely (if demolition cannot be avoided) that mitigation for the bridge would involve some combination (see below) of documentation, salvage, or interpretation. There is the possibility of relocation as a mitigation option, although that seems unlikely.

Just upstream of the project area, Squalicum Creek passes between two NRHP-listed historic properties: Eldridge Avenue Historic District and the Eldridge Homesite and Mansion. The City has a website with more information about the area: https://cob.org/services/planning/historic/buildings/eldridge-homesite. Relocating the stream may have an impact on one or both properties, in which case DAHP would require mitigation. There are several other built resources in the vicinity of the culvert, some of which have not been evaluated for their eligibility for listing in the NRHP. In addition, a historic archaeological site is near the project location, according to DAHP's Washington Information System for Architectural and Archaeological Records Data (WISAARD). The DAHP statewide predictive model classifies the area as

Very High Risk for archaeological sites, and it has been subject to several previous cultural resources surveys. There is a high likelihood that work associated with the project will encounter historic resources, and the project will likely require monitoring during construction, in addition to the Section 106 assessment.

Construction Access and Staging

The site is within a gated portion of Port properties. Access to the site is readily available by multiple routes. Staging areas could be provided on Port property, if allowed, and potentially in a Port parking area next to Squalicum Creek and north of Roeder Avenue.

Geotechnical Assessment

Published geologic maps indicate that the area southwest of Roeder Avenue is modified land or artificial fill, indicating the shoreline has been modified by constructing fills to create useable land throughout the project area. The area northeast of Roeder Avenue is mapped as Pleistocene continental glacial drift or Quaternary undifferentiated glacial drift. The City of Bellingham geologic hazards map indicates that the fill southwest of Roeder Avenue is a medium-high seismic hazard area, and the area north and northeast of Roeder Avenue is mapped as a former coal mine area. The City of Bellingham Coal Mine Map indicates that the mine workings were approximately 1,000 feet below ground surface in the project area.

Based on review of a recent geotechnical report (GeoEngineers 2022) for the proposed City of Bellingham Roeder Lift Station project, located immediately northeast of the Roeder Avenue culverts, the site is underlain by manmade fill of varying thickness, overlying beach and intertidal deposits of varying thickness, overlying glacial drift. Bedrock depth at the site is anticipated to be several hundred feet. The project explorations encountered interbedded, loose to medium dense sand and stiff to very stiff clay. Maximum explored depth was 50 feet. Competent bearing soil was not encountered.

A geotechnical study will be a critical component of the alternatives analysis and design of the three bridges. Based on available information, we anticipate the proposed bridges would require deep foundations, and that seismic site response would be an important design consideration, as the loose sand deposits reported for the proposed Roeder Lift Station project are susceptible to liquefaction and lateral spreading during the design seismic event.

Utilities

Surface and subsurface utilities will need to be planned for. The City has sewer, water, and storm utilities within the project area. The City's water line is attached to the Roeder Avenue culverts and will need to be included in the proposed bridge design. The City is designing a lift station that allows flexibility for a future lowering of the sewer line under Squalicum Creek in the project area. Construction of the lift station is planned for 2023–2025, and lowering of the sewer line would be possible after project completion.

7.1.5 Site-Specific Next Steps

Each of the owners of the existing crossings will need to review the available information for the proposed bridge replacement. Their review will inform whether the proposed bridge replacements should be further developed. Likewise, The Port, City of Bellingham, and BNSF will need to review the available information for the proposed bridge replacement and identify additional information needs and requirements to include in the alternatives analysis.

A full alternatives analysis will be needed for the Port, City of Bellingham, BNSF, other stakeholders, and the community to select a preferred alternative for design and construction due to the complexity of the restoration, which includes three bridges and impacts on surrounding land uses. The alternatives analysis should include more detailed site assessment of the restoration considerations identified above and extensive coordination with landowners, stakeholders, and the community.

The project will require substantial funding support, likely from multiple grant sources. A funding strategy is needed to identify potential funding sources and develop an implementation plan. The City of Bellingham is contracting for such a funding strategy. Applying for and managing grant contracts will require participation by the City of Bellingham, Port, and BNSF and conceptual support from the Lummi Nation, Nooksack Indian Tribe, and WDFW.

7.2 Japanese Gulch Creek Estuary

Japanese Gulch Creek passes under the BNSF railroad in three parallel pipe culverts at a single location. The crossing is at BNSF track mile post 28.899 on Scenic Subdivision, Line Segment 50. The crossing is located at 47º57’01.58”N and 122º17’37.05”W. The culverts are currently part of a series of culverts that the last 1,400 feet of the creek flows through before flowing into Puget Sound. The City of Mukilteo has completed designs for a restoration project downstream and proposes to daylight the stream just downstream of the railroad crossing by moving the creek out of a culvert and into an open channel. Restoration of the railroad crossing would be the last action required to restore full fish passage into Japanese Gulch Creek. This also builds upon past investments by the City of Mukilteo to improve fish passage and habitat quality in the creek upstream of the railroad. The restoration would benefit ESA-listed Puget Sound Chinook salmon, which are highly dependent on estuary habitats.

7.2.1 **Overview of the Site**

Japanese Gulch Creek is a salmon-bearing stream in close proximity to the Snohomish River. The lowermost section of the creek is routed through approximately 1,400 feet of culverts starting at Mukilteo Lane and ending under the Mount Baker Terminal (rail/barge loading wharf) where a culvert flows onto the beach (**Figure 16**).

Three tracks cross the creek: Two BNSF mainline tracks and one stub track that ends approximately 600 feet east of the site. The creek crosses approximately 20 feet east of a Number 24 sized crossover switch stand that will likely need to be removed and replaced to accommodate construction. The Japanese Gulch Creek culverts are close to an at-grade railroad crossing (BNSF MP 28.880. US DOT #085452V) connecting Mukilteo Lane to First Street. **Figure 17** provides photos of the site.

Japanese Gulch Creek is in a natural stream channel upstream of the box culvert under Mukilteo Lane **(Figure 18).** Downstream of Mukilteo Lane, it next enters a concrete headwall that has three parallel culverts that extend under the railroad tracks **(Figure 19)**.

Figure 16. Japanese Gulch Creek Site Showing Culvert Network of Lowermost Creek Section

Figure 17. Three BNSF Tracks at Japanese Gulch Creek Crossing Location

Top photo shows three railroad tracks and closest one is auxiliary track. Bottom photo is center track including switch and cross-over track.

Figure 18. Japanese Gulch Creek Culvert Under Mukilteo Lane

Top photo facing downstream to entrance into box culvert. Bottom photo looking downstream through box culvert and one of the three round culverts under the railroad is visible in distance.

Figure 19. Headwall Upstream of Railroad Crossing

Top photo shows grating over headwall. Bottom photo looking downstream shows the three round culverts under the railroad.

The three round culverts under the railroad are 44, 36, and 24 inches in diameter. The 44-inch culvert is approximately 2 feet lower than the 24-inch culvert, which is 4 inches lower than the 36-inch culvert. Therefore, these culverts are activated at different streamflows, with the largest culvert conveying the low-flow stream while the other two culverts only carry flow when stream depth is sufficiently deep. On the downstream side of the railroad tracks, the three culverts flow into a junction box. At the junction box, three culverts enter from under the railroad and two culverts exit toward the beach at different angles. Only one of the culverts is currently functional, and the other one is clogged and not carrying water. The round culvert extending from the downstream junction box to the beach at the Mount Baker Terminal is 48 inches in diameter and approximately 1,300 feet long (shown on **Figure 16**).

The City of Mukilteo has designed a creek daylighting and estuary restoration project immediately downstream of the railroad right-of-way. This downstream restoration project will remove the creek from the downstream culverts and into restored estuary habitat. This will also provide salmon a more direct route to Japanese Gulch Creek because the outlet will be located just north of the railroad crossing, whereas currently salmon need to enter the pipe 1,300 feet northeast at the Mt. Baker Terminal.

7.2.2 Site Hydrology and Existing Culvert Capacity

Hydrology information for Japanese Gulch Creek was developed by Natural Systems Design and Waterfall Engineering in 2009 for a restoration project immediately upstream in the creek. These flows were used by the design team for the City of Mukilteo's estuary habitat restoration downstream of the railroad crossing. Natural Systems Design and Waterfall Engineering (2009) estimated hydrological flows in Japanese Gulch Creek considering it to be an urbanized basin with greater than 20% impervious surfaces. **Table 8** presents the flow rates estimated for Japanese Gulch Creek (Natural Systems Design and Waterfall Engineering 2009).

TABLE 8.
JAPANESE GULCH CREEK HYDROLOGICAL FLOW RATES

Flow Return Interval	Flow (cubic feet per second [cfs])	+1 SE (cfs)	-1 SE (cfs)
Q_2	21	32	9
Q_{10}	37	56	17
Q_{25}	46	70	21
Q_{50}	53	82	25
Q_{100}	60	92	27

Notes: Flow Return Interval subscript indicates the number of years for flow-recurrence interval. For example, Q_{100} is the 100-year peak flood flow. SE = standard error.

The ability of the three existing culverts under the railroad to convey Q_{100} flows was evaluated using the HY-8 Culvert Hydraulic Analysis Program (FHWA 2022). The accuracy of the hydrologic flow rates in Table 8 is uncertain; therefore, to have a conservative understanding of the existing capacity, the Q_{100} and the Q_{100}+1SE flows were evaluated. The model predicts that the three culverts will have sufficient capacity for both flow rates evaluated and meet BNSF's current drainage design criteria.

The finding that the existing culverts provide sufficient capacity to convey Q_{100} and the Q_{100}+1SE flows was further supported by a series of model runs made with different assumptions about tailwater elevations, such as would occur if the outlet of the culverts were at low enough elevations to be backwatered by tidal water. Topographic survey information for the culvert invert elevations was not available, but it is believed that the culvert outlets are all backwatered by tidal water. Model runs were conducted for Q_{100} and the Q_{100}+1SE flows assuming 0-, 1-, 2-, and 3-foot deep tailwater. The outputs of all model runs showed water depths below the top of the culverts, which indicates there is sufficient capacity to convey Q_{100} and the Q_{100}+1SE flows.

7.2.3 Description of the Restoration Opportunity

Replacement of the three round culverts under the railroad tracks with larger crossing structures whose size meets stream simulation requirements for fish passage would remove a fish passage barrier. The benefits of this action would complement the City of Mukilteo's planned restoration downstream and completed restoration upstream. The City of Mukilteo is planning to excavate a large estuary on its property downstream of the railroad to provide aquatic habitat for salmon. The downstream restoration project includes a 15-foot-wide bottomless arch culvert under First Street. The culvert width was based on the bankfull width of the creek, measured as 11 feet, and applied Barnard et al. (2013) stream simulation formula to arrive at the need for a 15-foot-wide culvert. The culvert will extend from the junction box at the margin of the BNSF right-of-way downstream to the City's parcel.

To provide adequate width for fish passage, the proposed railroad crossing includes two 8-foot-wide by 4-foot-tall box culverts, which expands the conveyance capacity beyond what the existing culverts provide. These culverts meet the minimum width requirements per stream simulation and are compatible with the downstream crossing width in the City of Mukilteo's restoration. Coordination is needed with the City of Mukilteo to match culvert and channel dimensions of the two proposed projects since they will need to connect to each other. The box culvert lengths will be extended to include the crossing under Mukilteo Lane and to connect with the downstream culvert. Conceptual engineering drawings are presented in **Figures 20 and 21.**

Topographic survey data have not been collected for the site. Based on available information, including observations made during a site visit, there is little vertical clearance to work with between the invert elevations of the existing culverts and the top-of-tie elevation. This restricts the options for the replacement structures and the installation techniques that are possible. There does not appear to be sufficient clearance for a bridge. The conceptual design includes two box culverts that are 4 feet tall. The box culverts would need to be installed via cut-and-cover because there is insufficient depth of cover for a jack-and-bore installation method. The new box culverts would require the removal of the existing culverts and junction boxes. The cut-and-cover installation method is not ideal for BNSF's double-track mainline and will be very difficult to accomplish without a heavy impact on rail operations.

A hydraulic analysis of the performance of the proposed box culverts using the 100-year flow event indicates that the two box culverts will provide ample capacity to convey the flows. Further analysis would be needed during engineering design to ensure that suitable fish passage conditions are provided at both high and low flows. The analysis conducted for a similarly sized culvert at the restoration project immediately downstream determined that fish passage criteria could be met. WDFW will need to review

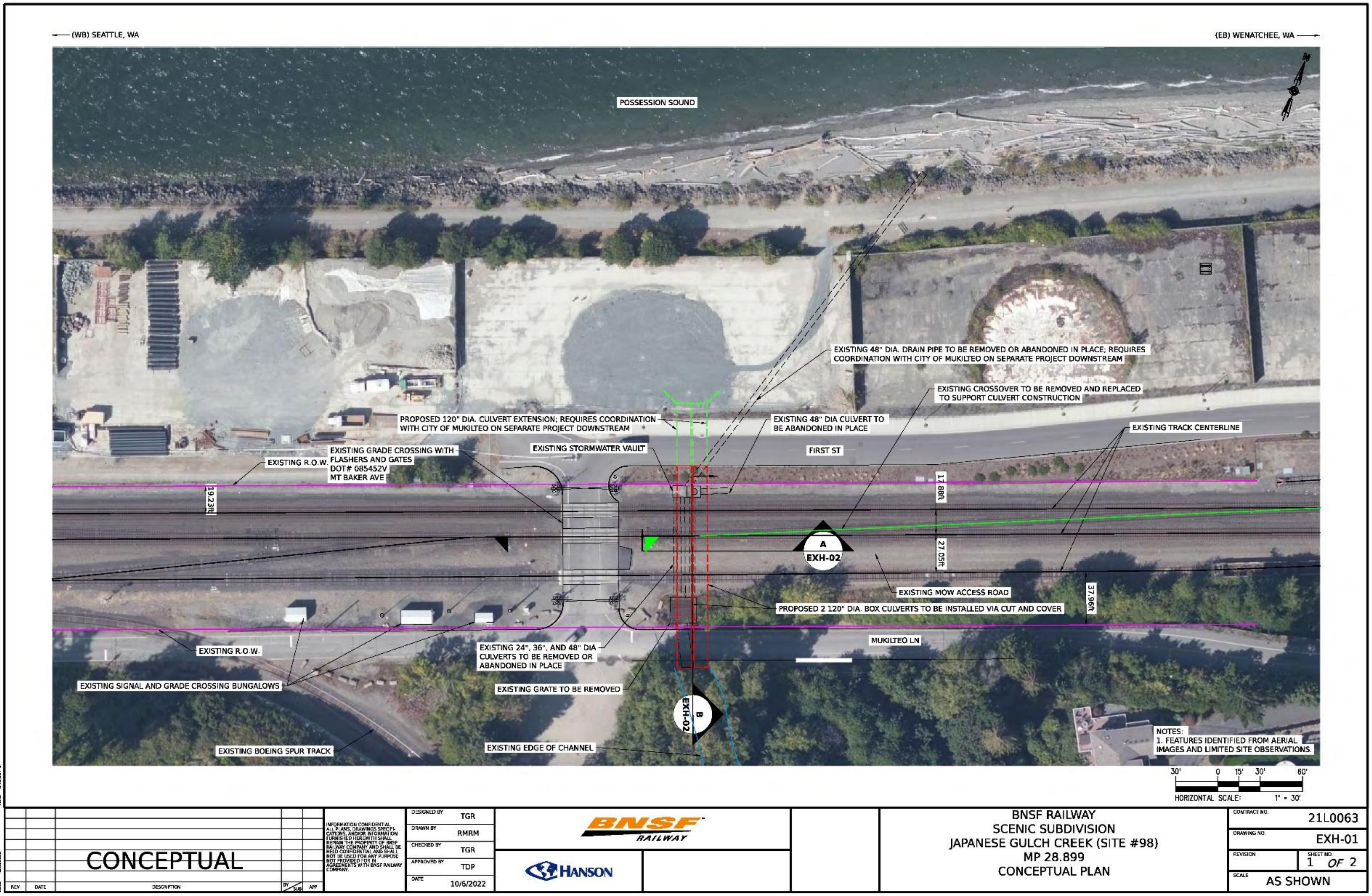

Figure 20. Conceptual Engineering Plan View of Replacement Culverts Under Railroad Tracks at Japanese Gulch Creek

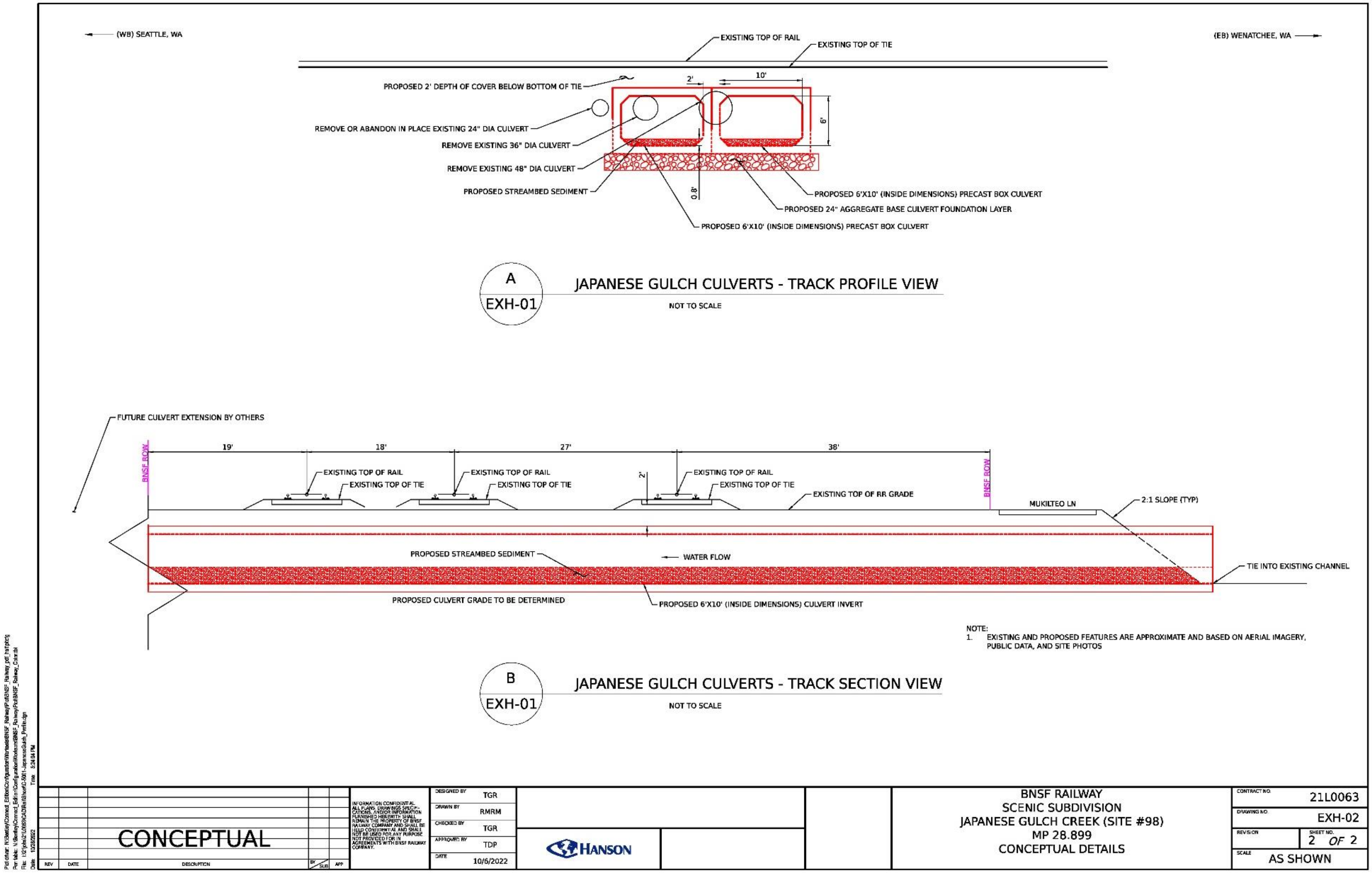

Figure 21. Conceptual Engineering Profile and Section of Replacement Culverts Under Railroad Tracks at Japanese Gulch Creek

the proposed two-culvert design to ensure that suitable conditions are provided to meet fish passage criteria.

Restoration Benefits to Salmon and Trout

The proposed culvert replacement under the railroad tracks at Japanese Gulch Creek will provide benefits to Puget Sound fall Chinook salmon, as well as coho, fall chum, and pink salmon and winter steelhead by providing full fish passage into the creek habitats upstream. This will complement the City of Mukilteo's fish passage and habitat restoration project downstream, which will facilitate salmon reaching the BNSF culverts. There is approximately 0.6 mile of accessible habitat upstream for anadromous salmon and trout (NWIFC and WDFW 2022). Juvenile Chinook salmon have been documented in Japanese Gulch Creek upstream of the railroad crossing (McDowell pers. comm.). Also, it will improve access for coastal cutthroat trout that, while not listed in NWIFC and WDFW (2022), were documented in Japanese Gulch Creek by Beamer et al. (2013). Improving accessibility to mainstem and headwater reaches of this creek will enhance the impact of four earlier phases of restoration that the City of Mukilteo has completed upstream in the creek.

Connectivity to Other Restored Habitats

The proposed railroad culvert replacement is located between upstream areas already restored by the City of Mukilteo and the planned estuary restoration downstream. In this way, the proposed railroad culvert replacement would address a "missing link" in the restoration of Japanese Gulch Creek that would otherwise prevent the full benefits of other restoration actions from being achieved.

7.2.4 Considerations for Restoration Design and Construction

There are several complexities to constructing the proposed replacement box culverts to carry Japanese Gulch Creek under the BNSF railroad tracks. Factors such as the railroad infrastructure requiring Cooper E-80 loading, short embankment height, adjacent land uses, and adjacent cultural resources are particularly challenging and would need to be worked through to develop a feasible restoration plan. These considerations and others are described below.

Railroad Infrastructure

The site includes three railroad tracks (two mainline and one stub track) and a crossover switch in the anticipated construction area. The crossover will need to be removed and replaced and will require engineering, materials, and construction costs, as well as have impacts on BNSF operations.

Immediately west of the Japanese Gulch Creek culverts, a grade crossing (Mt. Baker Avenue) connects Mukilteo Lane to First Street. The close proximity of this grade crossing should be considered during design and construction.

Railroad Track Elevations

The track elevations are low at the site compared to the invert elevations of the culverts currently conveying Japanese Gulch Creek under the railroad tracks. There is little vertical clearance to work with between the invert elevations of the existing culverts and between the bottom-of-tie elevation (although there are no available survey data to verify the elevation differences). The short embankment height restricts the options for replacement structure options and construction methods.

Topographic survey data are needed to more fully evaluate the feasibility of the proposed culverts based on clearance requirements between them and the railroad top-of-tie. The elevations may create challenges for connecting to the culvert downstream that will be installed as part of the City of Mukilteo's estuary restoration project.

Adjacent Land Uses

In this segment of the railroad, roads run running parallel to the BNSF tracks on either side of the BNSF right-of-way. Mukilteo Lane is the road on the landward side. It is a two-lane road that connects to the arterial Mukilteo Boulevard to the east and to the Old Town Mukilteo neighborhood to the west. First Street is the road on the waterward side. It is a two-lane road that provides the only vehicular access to the City of Mukilteo's Edgewater Park located east of the Japanese Gulch Creek crossing. While these streets provide easy access to the site, they will also require planning with the City of Mukilteo and vehicular traffic control.

The City of Mukilteo's planned estuary restoration project is adjacent to the BNSF right-of-way. The City of Mukilteo is finalizing the design and seeking construction funding. The proposed Japanese Gulch Creek culverts under the rail tracks will need to connect to the culvert included in the estuary restoration project. The City of Mukilteo's restoration design has the culvert at a specific elevation that is constrained by a sewer line that will run over it and fiber optic and other utility lines that run under it. Close coordination will be needed between these projects.

Cultural Resources

The proposed restoration project will be subject to Section 106 of the Historic Preservation Act as part of the consultation process necessary to obtain the required permits from the USACE. Under Section 106, the project proponent (lead agency) must consult with all affected tribes and with DAHP. Any effect the proposed project may have on historic resources must be taken into account and mitigated, which is part of the consultation process. Following the initiation of Section 106, a literature review will be needed to provide a context for the area, including all known/previously recorded resources. An archaeological survey (shovel probes) may be needed at the existing culvert location and in the new location. The precise relationship between the existing culverts and any possible archaeological sites will need to be determined, which is an element of the archaeological survey. The project will also require Historic Property Inventory forms for all of the non-archaeological resources within the APE that are over 50 years old. Additional research would be required to determine what other, if any, resources would require a Historic Property Inventory. A trained monitor will likely be required during construction.

The project is located within Japanese Gulch, which is known to have archaeological resources associated with an early 20th-century village. Japanese Gulch, as it is known, was a village inhabited by Japanese lumber workers employed at the Crown Lumber Company and dates from the early 1900s to the 1930s. It spans approximately 0.5 miles south from the shoreline, roughly 0.2 mile wide. The DAHP statewide predictive model classifies the area as Very High Risk for archaeological sites, and the area has previously been subject to multiple cultural resources assessments. The engineering drawings for the downstream restoration by the City of Mukilteo indicate there is an "archaeologically sensitive area" within the BNSF right-of-way and extending north under First Street.

Construction Access and Staging

Given the presence of streets in the area, access to the site is readily available by multiple routes. There is a gravel parking area next to Japanese Gulch Creek on the south side of Mukilteo Lane that could provide an area for staging. Depending on construction timing, an additional staging area may be available on the City of Mukilteo property downstream where they plan to restore the estuary. However, this staging area will not be available if the City completes its project first.

Geotechnical Assessment

Published geologic maps indicate that the area north of Mukilteo Lane is modified land or artificial fill, indicating the shoreline has been modified by constructing fills to create useable land throughout the project area. The area south of Mukilteo Lane is mapped as Pleistocene sediments of the Whidbey Formation, commonly very dense, glacially consolidated deposits.

We did not find any existing subsurface explorations within the project area. Explorations completed for a project along the BNSF tracks approximately ½ mile northeast of the site encountered about 20 feet of loose to medium dense fill overlying very dense Whidbey Formation deposits.

A geotechnical study will be a critical component of the alternatives analysis and design of the replacement crossing structures. Based on available information, we anticipate that the proposed box culverts could bear in granular bedding material placed and compacted prior to culvert placement.

Utilities

Surface and subsurface utilities will need to be planned for. There are fiber optic and water utilities downstream of the railroad right-of-way. More information is needed on potential utilities in the proposed project area.

7.2.5 Site-Specific Next Steps

BNSF will need to review the available information for the proposed culvert replacement. Their review will inform whether the culvert replacement should be considered and further developed. BNSF may identify additional information needs.

A next step for refining the project is to obtain topographic survey for the top-of-rail, the three existing culverts under the track, the two existing junction boxes, the culverts into and out of the two junction boxes, the upstream culvert under Mukilteo Lane, and a portion of Japanese Gulch Creek upstream of Mukilteo Lane.

Coordination is necessary with the City of Mukilteo on the culvert included in its proposed downstream restoration design, which is nearing final design. The size and elevations of that culvert will affect the connection to the proposed culverts under the BNSF tracks.

7.3 Unnamed Creek Estuary at JBLM

Fourteen culvert outlets were identified emptying from the BNSF right-of-way along the Puget Sound shoreline on JBLM lands. All of the drainages flowing into the culverts are unnamed creeks. This design analysis focused on a culvert and stream near the north end of JBLM. The outlet is located at 47º09'11.74"N and 122º37'06.90"W. The stream is the longest one according to stream network data layers. The crossing is at BNSF Milepost 17.332 on Seattle Subdivision, Line Segment 52. The unnamed creek passes under the BNSF railway in one round culvert. The railroad embankment is right on the shoreline, and the replacement of the culvert would support restoration of the creek's estuary.

7.3.1 Overview of the Site

The unnamed creek is located along Cormorant Passage, which is the area between the mainland and Ketron Island (**Figure 22**). JBLM has indicated that they do not have plans for working on this portion of the base and would allow temporary access to the project site for construction. The culvert is near the north end of JBLM and approximately 4.5 miles from the Nisqually River delta. The creek provides 1.49 miles of stream habitat where coho salmon have been documented (NWIFC and WDFW 2022). The lower portion of the watershed (approximately 0.75 mile) is on in JBLM lands, and the upstream portion extends into the Town of Steilacoom. The JBLM portion is fully vegetated with no signs of development. The Town of Steilacoom portion flows through residential areas and includes some well-vegetated reaches.

Two mainline rail tracks cross the culvert (**Figure 23**). The outlet of the culvert is buried by riprap and appears to be slightly perched. After exiting from the culvert, the creek discharges over the beach **(Figure 24)**. Upstream of the railroad, the creek channel has good stream gravel and riparian cover. The creek has a small drop as it enters a round culvert with an inside diameter of 35 inches and outside diameter of 51 inches (**Figure 25**). While the creek channel is incised approximately 1 foot and has a bankfull width of 4 feet, the creek corridor upstream is fairly wide before transitioning to steep valley walls.

7.3.2 Site Hydrology and Existing Culvert Capacity

Hydrology information for the unnamed creek was estimated using the StreamStats program (USGS 2019). The watershed boundaries in StreamStats did not align with the stream network depicted in other datasets. To be conservative, the StreamStats output (13 cfs) was doubled to estimate the Q_{100} flow (26 cfs) for the existing and proposed culvert capacities. The existing culvert currently cannot pass the Q_{100} flow; the hydraulic model estimated 1.7 feet of headwater over the top of the pipe. Therefore, significant upstream flooding would be anticipated during 100-year flow condition, but would not come close to overtopping the railroad tracks.

7.3.3 Description of the Restoration Opportunity

Replacing the existing round culvert under the railroad tracks with larger crossing structures whose size meets stream simulation requirements for fish passage would remove a fish passage barrier. The proposed replacement would provide young salmon with restored estuary and freshwater habitats for rearing and growth.

To provide adequate width for fish passage, the proposed railroad crossing is one 8-foot-diameter round culvert. This diameter is two times the existing bankfull width. It is larger than a stream simulation result of 6.8 feet for freshwater. The larger diameter culvert is proposed because the crossing location is tidally influenced; therefore, the new culvert needs to provide adequate capacity for both the tidal saltwater and

Figure 22. Unnamed Creek Site Near North End of JBLM

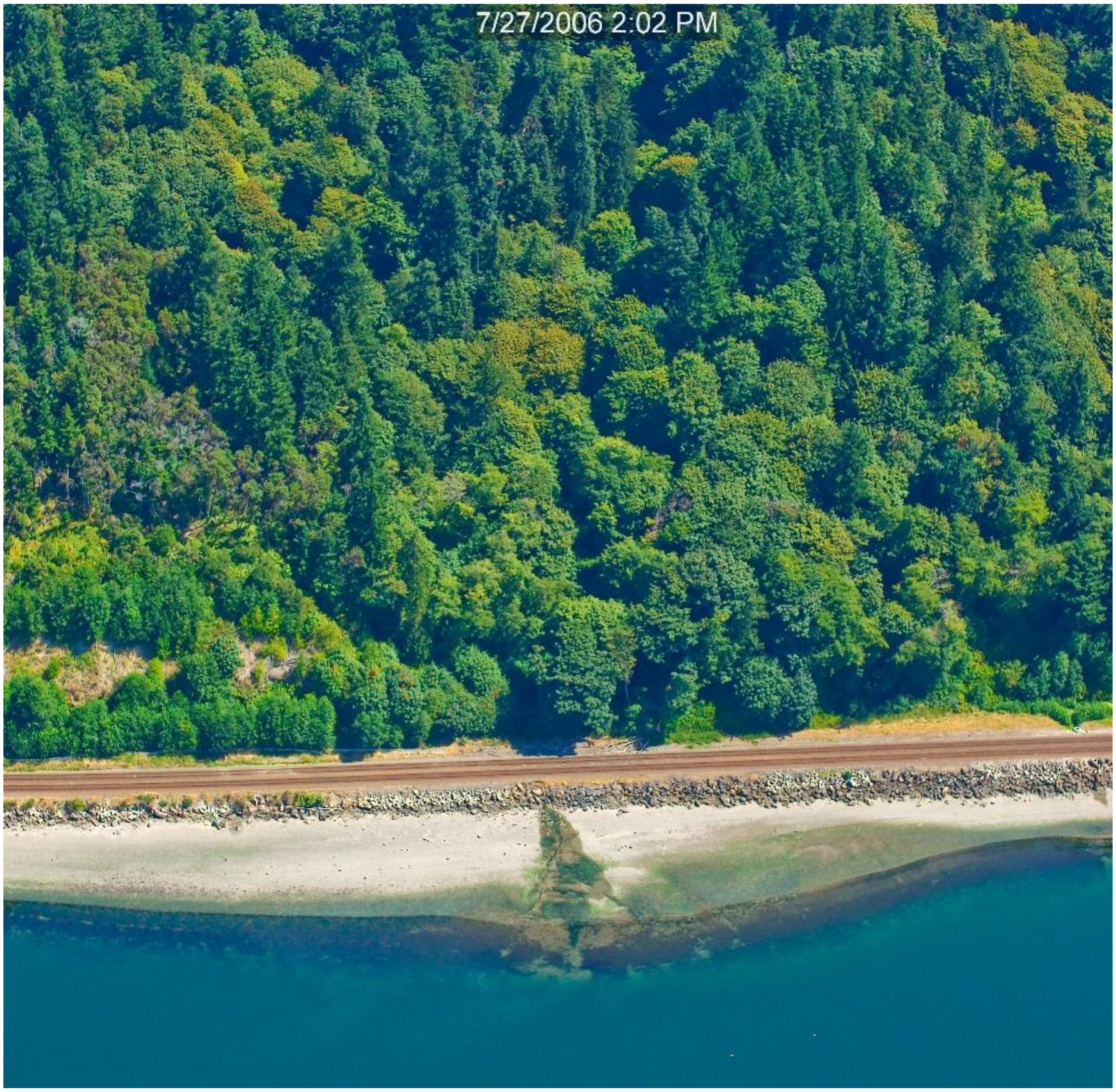

Figure 23. East-Facing View of Shoreline Rail Embankment, Creek Outlet, and Well-Vegetated Watershed

Source: Ecology (2006).

Figure 24. Culvert Outlet of Unnamed Creek

Top photo shows outlet of the culvert midway up the embankment and buried by riprap. Bottom photo shows the flow of the creek across the beach with Ketron Island in the distance.

Figure 25. Unnamed Creek Channel and Culvert Inlet

the creek's freshwater. Additional capacity analysis will be needed when survey elevations are available to include the tidal elevation, which informs tidal prism upstream of railroad and tailwater depths used in hydraulic calculations. Conceptual engineering drawings are presented in **Figures 26 and 27**.

The replacement culvert would likely be installed using jack-and-bore techniques. The railroad embankment appears to provide approximately 12 feet of vertical distance between the invert elevation of the existing culvert and the top-of-tie. It is expected that the new culvert will be installed at a lower elevation in order for the outlet to be at the bottom of the embankment on the beach side. There appears to be sufficient vertical clearance to install the new culvert and maintain more than the minimum distance required between the top of the culvert and the top-of-tie.

A hydraulic analysis of the performance of the proposed 8-foot-diameter culvert indicates that it would be large enough to pass a Q_{100} flow event in the creek. The level of resilience beyond the Q_{100} flow event has not been calculated. Assuming no tidal tailwater control, flow depth in the culvert would be less than 3 feet, which allows sufficient freeboard and vertical clearance to add streambed material or embed the culvert, if needed. When the tailrace control is set at mean higher high water, the culvert passes the Q_{100} flow but is full. Since topographic survey data have not been collected for the site, further analysis will be needed after survey data are collected to accurately model site conditions.

Restoration Benefits to Salmon and Trout

The proposed culvert replacement under the railroad tracks at the unnamed creek at JBLM will provide improved access for coho salmon documented in this stream (NWIFC and WDFW 2022) as well as migrant juvenile Chinook salmon from other stream systems. The project is located in within 5 miles of the Nisqually River, a natal Chinook salmon river. This habitat will be particularly beneficial if the culvert replacement results in backwatering. Stream mouth culverts with backwatering and suitable habitat upstream have been found to have juvenile Chinook salmon abundances statistically indistinguishable from stream mouths without culverts (Beamer et al. 2013). This will improve access to approximately 1.5 miles of creek length for coho salmon (NWIFC and WDFW 2022). In addition, surf smelt and Pacific sand lance spawn within 1 mile of the site, and the beaches near the project site likely support those important forage fish species.

7.3.4 Considerations for Restoration Design and Construction

The restoration project at the unnamed creek at JBLM will require coordination with JBLM and presents access and staging issues. The information provided below regarding JBLM coordination and access is based on input from John Richardson, JBLM Fish and Wildlife Biologist. Other than the additional coordination needed given the site's location on JBLM, it appears to be a relatively straightforward site for both design and construction. Design and construction considerations are described below.

Adjacent Land Uses

The culvert replacement project is on the Puget Sound shoreline on JBLM lands. Close coordination with JBLM representatives will be necessary to gain formal approval for the shoreline work and the necessary access to the Solo Point boat ramp. The construction logistics will need to include planning for JBLM operations schedules. The project site is within JBLM's North Impact Area, which is a live fire training.

Figure 26. Conceptual Engineering Plan View of Replacement Culvert Under Railroad Tracks at Unnamed Creek on JBLM

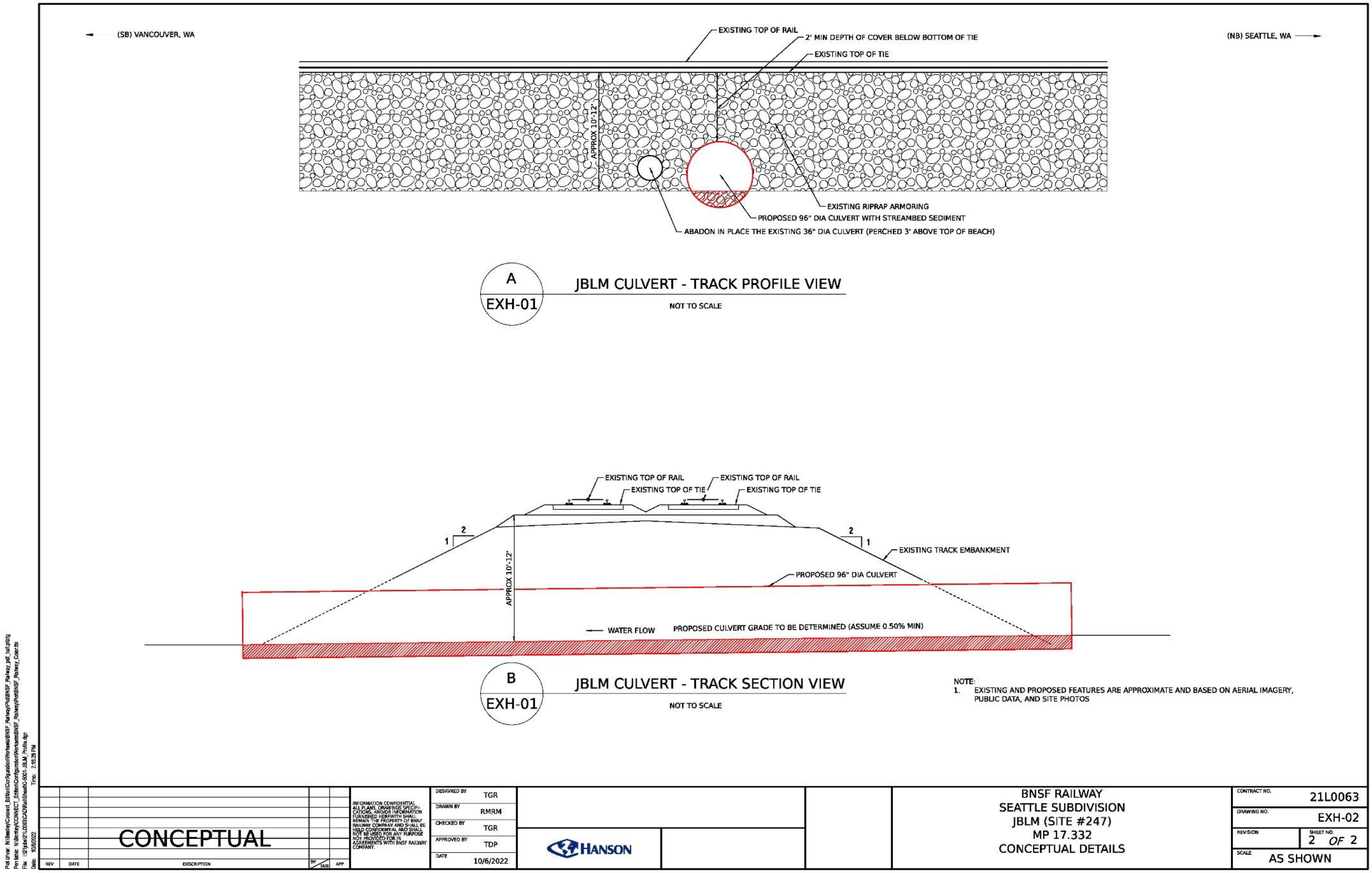

Figure 27. Conceptual Engineering Profile and Section of Replacement Culvert Under Railroad Tracks at Unnamed Creek on JBLM

area. However, the project site is located in a portion of the North Impact Area without any firing ranges. The project is unlikely to impacted training or be impacted by training (Richardson pers. comm.).

Given the added complexities associated with working on JBLM, the construction of replacement culverts at multiple JBLM sites on the shoreline should be considered for construction in one mobilization. Fourteen culverts were identified draining from the railroad tracks along the shoreline on JBLM lands. A subset of these may be draining creeks and provide benefits to fish by replacing the shoreline culverts.

Construction Access and Staging

JBLM access approval will be needed for construction. Access to the site for construction will require at least 6-months lead time to complete all access requests and coordination (Richardson pers. comm.). If multiple sites on JBLM are to be constructed, then JBLM approval for access should be able to be combined into one single access request, but if needed, separate access requests can be made (Richardson pers. comm.).

The site is on the shoreline with no nearby streets for access. The site is approximately 1.2 miles north of a JBLM boat ramp (Solo Point). To support construction, JBLM has indicated a willingness to provide access to Solo Point, which is sometimes not available because of military operations. Access would need to be by rail or by barge, which would entail impacts on the beach that would need to be mitigated. Either route of access would be significantly challenging due to impacts on nearshore beach habitats and/or railroad operations.

There is some room upstream of the railroad tracks to stage construction materials. The bottom of the ravine is approximately 80 feet wide and extends upstream of the tracks before steepening. This area could support a jack-and-bore culvert installation. Additional staging space and area of excavation are expected to be needed to install the proposed culvert at a lower elevation.

Railroad Track Elevations

Although no topographic survey data are available, there is approximately 12 feet between the invert elevation of the existing culvert and the railroad top-of-tie. Given the proposed 8-foot-diameter culvert, this does not leave ample vertical clearance. A topographic survey is needed to more fully evaluate the feasibility of the proposed culvert and jack-and-bore installation technique based on clearance requirements.

Cultural Resources

The restoration project will be subject to Section 106 of the Historic Preservation Act as part of the consultation process necessary to obtain the required permits from the USACE. Under Section 106, the project proponent (lead agency) must consult with all affected tribes and with DAHP. Any effect the proposed project may have on historic resources must be taken into account and mitigated, which is part of the consultation process. Following the initiation of Section 106, a literature review will be needed to provide a context for the area, including all known/previously recorded resources. An archaeological survey (shovel probes) would be needed at the existing culvert location and in the new location. The precise relationship between the existing culvert and any possible archaeological sites will need to be determined, which is an element of the archaeological survey. The project will also require Historic

Property Inventory forms for all of the non-archaeological resources within the APE that are over 50 years old. Additional research would be required to determine what other, if any, resources would require a Historic Property Inventory. A trained monitor will likely be required during construction.

According to DAHP's WISAARD, there is a pre-contact archaeological site near the project location. The site was recorded in the late 20th century, and subsequent surveys were not able to field verify the extent of the site. There are also multiple known pre-contact and historic sites throughout JBLM – some in the vicinity of the proposed project – that were not recorded at their time of discovery. A 2010 project attempted to find and record these sites but did not identify all of them. Some of the identified sites were relocated at that time. In addition to the known and unrecorded archaeological sites, a 1998 report cited six previous cultural resources surveys, none of which appear to be available online through WISAARD. Details about these reports and/or any associated findings are unknown at this time. The DAHP statewide predictive model classifies the area as Very High Risk for archaeological sites. It appears that surveys and resource identification in the area are relatively limited, likely due to the long-term military ownership of the land (the base started in 1917 and significantly expanded in the 1930s).

Geotechnical Assessment

Published geologic maps indicate the site is underlain by Quaternary sediments of the Olympia nonglacial interval, characterized by interbedded sand and silt with localized gravel, some laminated silt and clay sequences, abundant plant material, wood fragments, and shells. Nearby, deposits of Quaternary recessional outwash ice-contact deposits are prevalent.

We found no existing subsurface explorations within or near the project site, and have no direct project experience near the site. Based on the mapped geology, we anticipate that culvert construction would encounter loose to medium dense silt, sand, and gravel underlying the BNSF embankment, and similar materials within the embankment.

A geotechnical study will be a critical component of the alternatives analysis and design of the proposed culvert. Feasibility of jack-and-bore construction methods should be evaluated, as depth of cover between the culvert crown and bottom of tie is likely insufficient. Constructability and limited site access will be important considerations during project planning.

Utilities

It is not known if there are any utilities in the area. Any surface and subsurface utilities will need to be identified and located during the topographic survey.

7.3.5 Site-Specific Next Steps

BNSF will need to review the available information for the culvert replacement project. Their review will inform whether the culvert replacement should be considered and further developed. BNSF may identify additional information needs.

Coordination is necessary with JBLM to ensure their continued support for the project. In addition, it will be necessary to understand JBLM's required process for formal agreement to allow the work and how to plan for JBLM's operations-related restrictions on construction.

8.0 Summary and Recommendations

Restoration of coastal stream mouths and embayments impacted by railroad embankments on the shoreline of Puget Sound can contribute meaningfully to the ongoing efforts to recover Chinook salmon listed as threatened under the ESA and improve estuary and nearshore habitats in Puget Sound. The replacement of existing crossings with larger spanning structures sized based on the latest best practices for restoring fish passage and natural processes in the estuaries will open up stream and estuary habitats for fish access and provide important non-natal estuary rearing habitat for juvenile Chinook salmon. The installation of wider stream crossings will accommodate associated habitat restoration work to improve the estuary habitats along the railroad. Wider stream openings are also expected to reduce site maintenance, such as to clear sediment or wood clogging the inlet of the crossings.

The keys to success described for the Meadowdale Beach Park restoration project (see Chapter 6) are fundamental to the successful restoration of coastal stream mouths that are currently impacted by railroad embankments. BNSF's operations along the Puget Sound shoreline are part of a national network that provides an important role in freight and passenger transportation. Stream mouth restoration that considers BNSF operations in design and involves BNSF from the beginning will be most successful in progressing through construction and achieving the desired ecological benefits.

The structural requirements of railroad infrastructure necessitate that rigorous engineering standards be applied when designing stream crossings. BNSF uses a combination of industry guidance and corporate policies to guide the design and development of stream crossing structures (AREMA 2008; BNSF 2018).

Four types of stream crossing structures can be constructed through the railroad embankment (in order of maximum width from widest to narrowest): bridges, box culverts, arch culverts, and round culverts. Arch culverts are the least preferred by BNSF. The maximum sizes and possible installation methods are identified in Table 2 for each type of crossing structure. The railroad and site characteristics affect the constructability of replacement stream crossings at each site. These characteristics can affect the types of structures, installation methods, cost, and complexity of installation. Consideration of constructability is recommended at the outset of the site-specific planning.

The characteristics of each of the priority sites were summarized. Based on the anticipated size needed for the stream crossing (estimated as two times bankfull width for early planning purposes), six sites can be remedied with crossings less than 8 feet wide, four sites will require crossings between 8 and 12 feet wide, 10 sites will require crossings between 12 and 20 feet wide, 13 sites will require crossings greater than 20 feet wide, and the necessary width has not been determined for the remaining 12 sites.

Multiple state and federal grant funding programs are identified to contribute funding for the replacement of stream mouth railroad crossings. The projects can provide different types of benefits in addition to improving fish passage and restoring estuary habitats; therefore, a variety of federal and state funding programs could be applied for. Like the Meadowdale Beach Park restoration project, it will likely require multiple grants from multiple programs to piece together a substantial portion of the construction costs. Even in that example, which was considered successful in maximizing grant contributions, more than half the funding came from non-grant sources (i.e., Snohomish County).

The development of conceptual designs at the three priority sites described in this report provided an opportunity to apply the programmatic recommendations. The Squalicum Creek estuary site is a promising one because of the strong interest of the landowners (City and Port of Bellingham) and the magnitude of benefits that the restoration would provide for fish natal to the stream and non-natal salmon who would be expected to use the restored habitats. The site is challenging because the restoration would require addressing three crossings (railroad, Roeder Avenue, and a Port bridge). The Japanese Gulch Creek estuary provides an opportunity to restore a "missing link" given the restoration work completed upstream and planned downstream of the railroad. The challenges at Japanese Gulch Creek relate to coordinating the restoration with the proposed design downstream and working within constraints posed by the low embankment height of the railroad. The unnamed creek at JBLM is a comparatively straightforward restoration given the absence of surrounding infrastructure and the relatively small size of the creek. The challenges at this site will be site access and staging. For all three sites, BNSF, WDFW, and landowner reviews of the conceptual designs will be conducted during review of this draft report. Their comments will be addressed or added to the next steps for the project.

The following are the recommended next steps for moving to design and construction of priority coastal stream and embayment crossings:

- **Conduct Site Analysis and Conceptual Designs of Remaining Priority Sites–** The remaining priority sites should be evaluated based on the site characteristics described in this report and a conceptual design for restoration prepared. The BNSF planning and decision-making process begins with hydraulic and hydrologic analysis of each site. Specifically, analysis is needed on the conveyance capacity of the existing crossing structures during a 100-year flow recurrence event. BNSF uses this information to evaluate the adequacy of the existing crossing structures solely from a hydraulic perspective. The site analysis should supplement or confirm the site information gathered in the first phase and reported in Confluence et al. (2019). Additional observations through a site visit or analysis of remotely collected data should be conducted. Note that advance planning for site access approval from BNSF and adjacent landowners is necessary. Topographic survey information (including streambed elevations upstream and downstream, as well as culvert invert elevations at the inlet and outlet to inform slope) should be collected where needed to supplement earlier information. The site analysis will include evaluation of the geomorphic setting at the crossings and how that affects the recommended crossing widths. A conceptual design, such as one plan view and one cross-section drawing, should be prepared for each site to show a conceptual depiction of the recommended crossing structure type, size, and location relative to the current crossing as well as the available installation methods. The site analysis information should then be reviewed by and discussed with BNSF, WDFW, and tribes. This review is necessary to develop a common understanding of anticipated crossing structure type, size, and location. Additional coordination should occur with potential local partners.

- **Identify Project Bundles –** Information developed in the site analysis and conceptual design should be used to identify project bundles to advance together through design and construction. Project bundles are groups of sites (typically three to seven) that can be designed and constructed as a group due to similarities in approach, sponsor, location, etc. Project bundles will be an efficient approach to addressing impacted estuaries while minimizing impacts to railroad operations.

- **Prepare a Regional Implementation Plan (Plan)** – A Plan for implementing the design, permitting, and construction of all of the priority sites should be prepared through a collaborative process. Information developed in the site analysis and conceptual design work for each site would provide a strong technical basis. BNSF, adjacent landowners, tribes, WDFW, and other key stakeholders should be included in Plan preparation to ensure that a coordinated and actionable Plan is produced. The Plan should include a funding strategy, targeted schedule, permitting strategy, and the roles and responsibilities of BNSF, adjacent landowners, and key stakeholders. The funding strategy should identify contributing parties for funding beyond what can be secured through grants, including outreach to BNSF, and local, state, and federal politicians to identify additional funding sources. The permitting strategy should be developed through coordination with regulatory agencies to evaluate opportunities to streamline the permitting timeline and/or permitting documentation, and discuss potential mitigation responsibilities resulting from construction (e.g., wetland or beach impacts). The Plan should identify a construction timeline informed by the funding strategy and permitting strategy. The roles and responsibilities of BNSF, adjacent landowners, and key stakeholders should be clearly outlined to help implementation proceed in a well-coordinated manner.

- **Develop Programmatic Tidal Crossing Guidance** – The development of guidance to inform the sizing and design of replacement railroad drainage crossings in tidal areas would add efficiency and certainty to the design process at priority sites. Such programmatic guidance that could be applied to all priority sites or a large subset of sites would help expedite the design work, compared to the current case-by-case approach needed by WDFW for the agency's oversight of this work.

- **Conduct an Alternatives Analysis on Subset of Priority Sites** – Some sites may be technically complex or entail adjacent landowner considerations that require a full alternatives analysis to be conducted prior to design. This ensures that complex sites are adequately evaluated and the benefits, opportunities, and constraints of various restoration alternatives are evaluated to identify a preferred alternative to advance to design.

- **Prepare Engineering Design** for Priority Sites – The engineering design of groups of sites should begin with the site assessment, which provides more detailed information on geotechnical conditions, utilities, easements, presence of contaminated materials, and presence of archaeological or historic resources. BNSF has procedures for preliminary and final engineering design submittals and their reviews (UPRR and BNSF 2016). Likewise, reviews by WDFW and tribes should be planned for at each design stage. Subsequent steps will include applying for permits and constructing the restoration.

9.0 References

AREMA (American Railway Engineering and Maintenance-of-Way Association). 2008. Bridge Inspection Handbook. Lanham, MD.

Barnard, R.J., J. Johnson, P. Brooks, K.M. Bates, B. Heiner, J.P. Klavas, D.C. Ponder, P.D. Smith, and P. D. Powers. 2013. Water crossings design guidelines. Washington Department of Fish and Wildlife, Olympia, Washington. Available at: http://wdfw.wa.gov/hab/ahg/culverts.htm. Accessed May 2022.

Baumgarten, K. pers. comm. Conversation between Kurt Baumgarten, Port of Bellingham, and Paul Schlenger, Environmental Science Associates, on December 7, 2021.

Beamer, E.M., A. McBride, R. Henderson, and K. Wolf. 2003. The importance of non-natal pocket estuaries in Skagit Bay to wild Chinook salmon: an emerging priority for restoration. Skagit River System Cooperative, La Conner, WA.

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. Fresh. 2005. Appendix D: Delta and Nearshore Restoration for the Recovery of Wild Skagit River Chinook Salmon: Linking Estuary Restoration to Wild Chinook Salmon Populations. Appendix to Skagit River System Cooperative and Washington Department of Fish and Wildlife. Skagit Chinook Recovery Plan.

Beamer, E.M., A. McBride, R. Henderson, J. Griffith, K. Fresh, T. Zackey, R. Barsh, T. Wyllie-Echeverria, and K. Wolf. 2006. Habitat and fish use of pocket estuaries in the Whidbey basin and north Skagit County bays, 2004 and 2005. Skagit River System Cooperative. La Conner, Washington. Available at www.skagitcoop.org.

Beamer, E.M., W.T. Zackey, D. Marks, D. Teel, D. Kuligowski, and R. Henderson. 2013. Juvenile Chinook Salmon Rearing in Small Non-Natal Streams Draining into the Whidbey Basin. Skagit River System Cooperative. December 3, 2013. Available at www.skagitcoop.org.

Beamer, E., C. Greene, E. Brown, K. Wolf, and C, Rice. 2016. *An Assessment of Juvenile Chinook Salmon Population Structure Dynamics in the Nooksack Estuary and Bellingham Bay Shoreline, 2003 – 2015*. Report to City of Bellingham. Skagit River System Cooperative, La Conner, WA.

BNSF (Burlington Northern Santa Fe Railway). 2018. Guidelines for Industry Track Projects. BNSF Railway Engineering Services: System Design and Construction Kansas City, Kansas. 77 pp.

Brennan, J.S. 2007. Marine Riparian Vegetation Communities of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-02. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Campbell, L., A. Claiborne, J. Anderson, N. Overman, K. Higgins, E. Brown, A. Fowler, A. Bosworth, J. Losee, T. Livingood-Schott, M. McDonald, J. Atkinson, K. Pellet, D. Bottom, K. Jones, C. Ellings, and S. Hodgson. 2019. *Life History Strategies of Salish Sea Chinook Salmon as Inferred from Otolith Microchemistry.* Research presented at the Salmon Recovery Conference, Tacoma, WA.

Confluence (Confluence Environmental Company), ESA (Environmental Science Associates), CGS (Coastal Geologic Services), and Tulalip Tribes Natural Resources. 2019. Coastal streams and embayments prioritization along Puget Sound shores with a railroad: prioritization framework technical report. Prepared for Washington Department of Fish and Wildlife, Olympia, Washington, by Confluence, Seattle, Washington.

Duffy, E., and D. Beauchamp. 2011. Rapid growth in the early marine period improves the marine survival of Chinook salmon (*Oncorhynchus tshawytscha*) in Puget Sound, Washington. Can. J. Fish. Aquat. Sci. 68(2): 232-240.

Earth Economics. 2018. The Natural Value of Meadowdale Beach Park: A Benefit-Cost Analysis of the Meadowdale Beach Park and Estuary Restoration Project.

Ecology (Washington State Department of Ecology). 2016. Determining the Ordinary High Water Mark for Shoreline Management Act Compliance in Washington State. Available at: https://apps.ecology.wa.gov/publications/summarypages/1606029.html.

FHWA (Federal Highway Administration). 2012. Hydraulic Design of Highway Culverts: Third Edition. Publication No. FHWA-HIF-12-026: Hydraulic Design Series Number 5. 323 pp.

FHWA (Federal Highway Administration). 2022. HY-8 Culvert Hydraulic Analysis Program. Available at: https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/.

Fresh, K.L. 2006. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

GeoEngineers. 2002. Geotechnical Engineering Services for Roeder Lift Station, Bellingham, Washington. Prepared for Carollo Engineers. February 28, 2022.

Greene, C. M., J. Hall, D. Small, and P. Smith. 2017. Effects of intertidal water crossing structures on estuarine fish and their habitat: a literature review and synthesis. NOAA Fisheries and WDFW.

Healey, M.C. 1982. Juvenile Pacific Salmon in Estuaries: The Life Support System. Pp. 315-341 in V.S. Kennedy (ed.), Estuarine Comparisons. Academic Press, New York, New York. 709 pp.

Hirschi, R., T. Doty, A. Keller, and T. Labbe. 2003. Juvenile salmonid use of tidal creek and independent marsh environments in north Hood Canal: summary of first year findings. Prepared by Port Gamble S'Klallam Tribe Natural Resources.

McDowell, M. 2011. E-mail correspondence from Michael McDowell, Confluence Environmental. Seattle, Washington. April 5, 2011. As cited in Washington State Ferries Ecosystems Discipline Report for Mukilteo Multimodal Facility.

Natural Systems Design and Waterfall Engineering. 2009. Japanese Gulch Hydrology Spreadsheet. Regression Equation Analysis for Japanese Gulch Creek Fish Passage Improvements.

NWIFC and WDFW (Northwest Indian Fisheries Commission and Washington Department of Fish and Wildlife). 2022. Statewide Integrated Fish Distribution. Available at: https://geo.nwifc.org/swifd/

PSP (Puget Sound Partnership). 2022. 2022-2026 Action Agenda for Puget Sound. Puget Sound Partnership. Olympia, Washington.

Richardson, J. pers. comm. Email from John Richardson, JBLM Fish and Wildlife Biologist, and Paul Schlenger, Environmental Science Associates. November 29, 2022.

Rosario Archaeology. 2011. Cultural resources investigation for the Squalicum Creek Delta restoration project, Bellingham, Whatcom County, Washington. Prepared for the Port of Bellingham c/o Anchor QEA.

Simenstad, C. A., Fresh, K. L., & Salo, E. O. (1982). The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. In Estuarine comparisons (pp. 343-364). Academic Press.

Small, D. pers. comm. Email between Doris Small, WDFW, and Paul Schlenger, Environmental Science Associates, on November 21, 2022.

Snohomish County Parks (Snohomish County Parks and Recreation Division). 2022. Meadowdale Beach Park and Estuary Restoration Project website. Available at: https://snohomishcountywa.gov/2710/Meadowdale-Beach-Park-and-Estuary-Restor. Accessed October 2022.

United States vs. Washington. 2017. Ninth Circuit Court of Appeals Decision No. 13-35474. 59 pp.

UPRR (Union Pacific Railroad) and BNSF (Burlington Northern Santa Fe Railway). 2016. Guidelines for Railroad Grade Separation Projects. Authored by R. Friesen, January 5, 2016.

USGS (United States Geological Survey). 2019. StreamStats. Available at: https://www.usgs.gov/mission-areas/water-resources/science/streamstats-streamflow-statistics-and-spatial-analysis-tools.

WDFW (Washington Department of Fish and Wildlife). 2018a. Site ID 991079 in the Washington State Fish Passage Database. Available at: https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html.

WDFW (Washington Department of Fish and Wildlife). 2018b. Site ID 991104 in the Washington State Fish Passage Database. Available at: https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html.

WDFW (Washington Department of Fish and Wildlife). 2018c. Site ID 602275 in the Washington State Fish Passage Database. Available at: https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html.

WDFW (Washington Department of Fish and Wildlife). 2022. SalmonScape Salmon Distribution Database. Available at: https://apps.wdfw.wa.gov/salmonscape/map.html

Whatcom County Sheriff's Office Division of Emergency Management and The Resilience Institute of Western Washington University. 2021. Whatcom County Natural Hazards Mitigation Plan. September 30, 2021.

WRIA 8 (Water Resource Inventory Area 8). 2017. 2017 Chinook Salmon Conservation Plan Update. Available at: https://www.govlink.org/watersheds/8/reports/chinook-plan-update.aspx. Accessed March 2020.

WRIA 8 (Water Resource Inventory Area 8). 2019. Approved 2019 WRIA 8 Four-Year Work Plan - Capital Project and Program Priorities. Available at: https://www.govlink.org/watersheds/8/pdf/2019WRIA8FourYrWorkPlan.pdf. Accessed March 2020.

ESA