



Technical Memorandum

Date: August 19, 2024

Project: Crabapple Crossing Feasibility Study

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Re: Crabapple Creek Crossing Feasibility Study Technical Memorandum

1 Introduction and Background

Replacement of the crossing structure that conveys Crabapple Creek under US Highway 30 (US 30) at mile point 15.36 is being investigated by Portland METRO and the Lower Columbia Estuary Partnership (LCEP). Wolf Water Resources (W2r) and CONSOR were contracted to assess the feasibility of this crossing replacement. This memorandum documents the following research, observations, and design alternatives of the feasibility assessment:

- Project context and background
- Site Conditions
- Observed Geotechnical Conditions
- Stream geomorphology and biological considerations
- Alternatives considered as potential projects (crossing size, type, location, and installation methodology)
- Probable construction costs for each alternative
- Risks for implementation
- Next steps

The opportunity to enhance landscape and aquatic/terrestrial connectivity by replacement of the Crabapple Crossing facility was identified as part of an ongoing floodplain restoration design at the Multnomah Channel Marsh Natural Area (MCMNA). The crossing facility is located 15 miles north of Portland where Crabapple Creek carries flow from the Tualatin Mountains east into the MCMNA under US 30 and the adjacent railroad (**Figure 1**). Within the MCMNA, Crabapple Creek spreads across an alluvial fan and splits flow to a northern and southern wetland complex (total of 278 acres) which are each tidally connected directly to the Multnomah Channel.

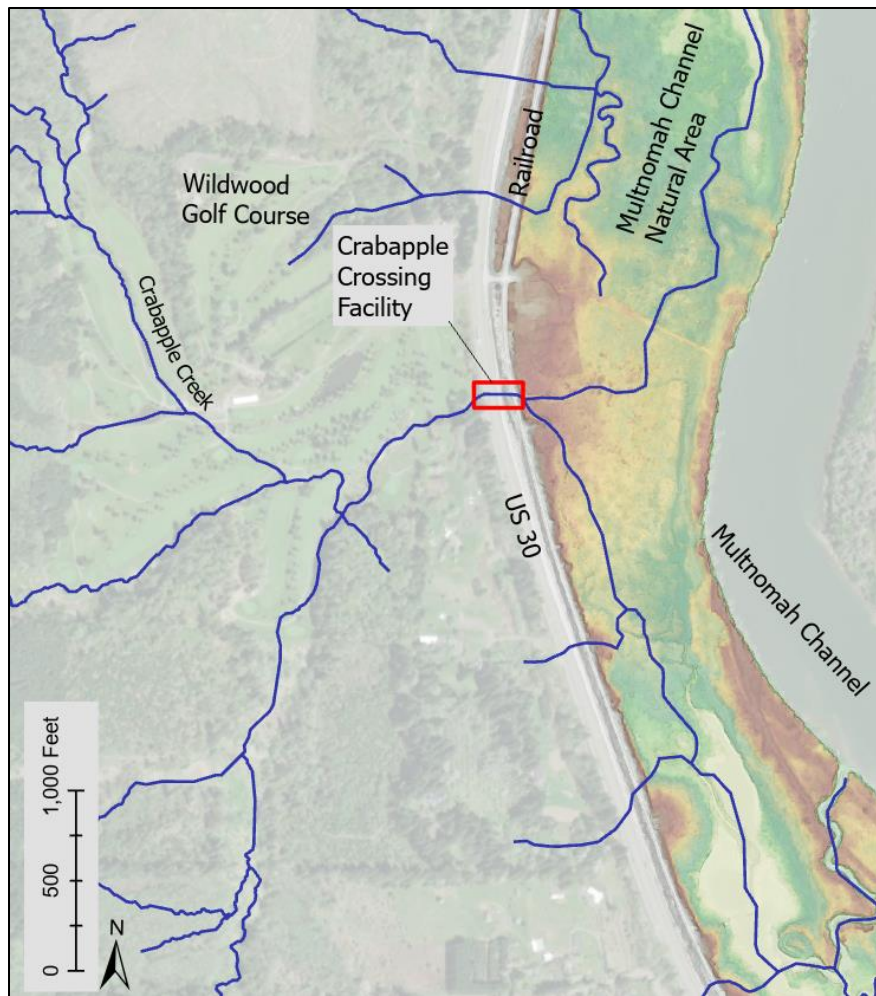


Figure 1. Project Vicinity

A crossing retrofit in this location would replace undersized culverts with larger structures sized to allow passage under the road by both aquatic and terrestrial species, as well as restore sediment and hydrologic continuity between the headwaters and MCMNA. This (coupled with restoration actions in the MCMNA) would restore fish passage to approximately 5 miles of aquatic and riparian forested habitat along Crabapple and Patterson Creeks and improve permeability of the highway/railroad corridor for terrestrial wildlife.

Metro recently included this Project as a high priority for their Multnomah Channel Headwaters Target Area. Metro noted the project will restore connectivity between 10 square miles of undeveloped high quality upland habitat west of US 30 with over 500 acres of low floodplain habitat east of US 30. Benefits include restoration of biotic connectivity and watershed processes along with increased climate resilience through stormwater attenuation, water quality improvements, and genetic continuity between the two ecosystems. Additionally, Metro recently pledged \$3.5 million to aid the Trust for Public Land and Oregon State University purchase a 3,111-acre parcel of forest land in the Tualatin mountains that includes nearly all of the 2,585-acre Crabapple Creek watershed. This property acquisition has also been funded by the Forest Legacy Grant Program (\$10.2 million) and is likely to proceed, indicating long term stewardship and conservation of the headwaters habitat in question are likely as well.

The project location is also identified by the Oregon Department of Fish and Wildlife (ODFW) as a Priority Wildlife Connectivity Area (PWCAs) as part of the Oregon Conservation Strategy. Specific conservation action recommendations for the PWCA are to restore and protect habitat. The West Multnomah Soil and Water Conservation District (WMSWCD) has also prioritized the Crabapple Watershed for protection, restoration, and monitoring in their Long-Range Business Plan (2021-2025).

This connectivity priority is also supported by Bonneville Power Administration (BPA) as a key funding partner for the adjacent MCMNA floodplain restoration project which includes reconnecting 278 acres of floodplain habitat and Crabapple Creek to Multnomah Channel by removing two water control structures. BPA has provided the initial funding to carry out this feasibility study for the Crabapple Creek Reconnection Project.

Project stakeholders include the aforementioned funding/land management groups as well as the following additional landowners and jurisdiction holding agencies: Oregon Department of Transportation (ODOT), ODOT Rail, Portland & Western Railroad/Genesee and Wyoming Railroad (PWRR/GWRR), ODFW, National Marine Fisheries Service (NMFS), and the Wildwood Golf Course (Golf Course). Ongoing coordination with all the project stakeholders is paramount in project development.

2 Study Goals & Objectives

Enhancement of habitat interconnectivity between the Multnomah Channel floodplain and the headwaters of Crabapple Creek is the overarching goal of the Crabapple Crossing project. This goal is built on the following constituent opportunities:

- Enhancement of aquatic species passage across US 30/railroad.
- Enhancement of terrestrial species passage across US 30/railroad.
- Restoration of hydrologic and sediment continuity across US 30/railroad.

To understand how the overarching project goal might be achieved, this study seeks to accomplish the following objectives:

- Characterize the existing morphological, geotechnical, biological, and infrastructure contexts that inform the range of technically feasible alternatives.
- Characterize the expected costs for the selected technically feasible alternatives.
- Characterize the relative degree to which each alternative meets the project goals.

3 Existing Site Conditions

At the existing/proposed crossing site shown on **Figure 1**, US 30 is a five-lane highway with a shared left hand turn lane. The width of US 30, including shoulders, is approximately 90 feet wide. Guardrail is present on either side of US 30 and the east side also includes a concrete drainage curb. At the drainage curb, north of the crossing site, there is a catch basin draining to an unknown discharge point. Utility markers indicate that a buried fiber optic cable parallels US 30 to the east, offset approximately 5 feet from the edge of pavement.

The Golf Course is located west of US 30. The ninth hole of the Golf Course parallels US 30, with the edge of the fairway offset approximately 175 feet from the guardrail. At the foot of the US 30 embankment is a drainage ditch extending from the entrance to the Golf Course south to Crabapple Creek. Overhead utilities

parallel the drainage ditch to the west. This area of the Golf Course has few trees apart from clusters near Crabapple Creek.

East of US 30 is a single-track railroad owned by ODOT Rail and operated by PWRR/GWRR. The distance from the guardrail to the edge of track is approximately 65 feet at the proposed crossing site. A narrow basin exists between the US 30 and railroad embankments, effectively functioning as a drainage ditch, with dense vegetation. Overhead utilities parallel the railroad to the west, offset approximately 15 feet from the track. The area east of the railroad is heavily forested and a barbed wire fence at the foot of the embankment parallels the railroad.

Crabapple Creek is conveyed beneath US 30 and the railroad in a dual barrel concrete culvert at approximately milepost (MP) 15.36. The barrels are 8 feet wide by 6 feet tall. At the upstream end of the culvert, concrete wing walls were observed. The thalweg elevations of Crabapple Creek at the inlet and outlet are approximately 24 feet and 22.4 feet respectively (slope = 0.6%). The surface of US 30 is at varies in elevation between approximately 50 and 54 feet. The ODOT TransGIS culvert and bridge resource inventories indicate conflicting lengths for the structure (234 or 254 feet respectively). The inlet and outlet of the structure were surveyed to verify the structure length and found to be approximately 262 linear feet away from each other, which reflects a minimum length of the structure assuming a straight connection between the inlet and outlet.

The culvert is not a continuous structure, but rather occurs in three sections. Per a 1999 survey (Fishman, 1999) the culvert has 3 sections: a US 30 upstream section and a railroad downstream section, which “are connected in the middle by a 75-foot ramped section with a 5-10% slope”. This geometry does not quite seem to align with the total slope across the road, however aggradation of the streambed upstream and downstream of the culvert made verification of this survey challenging. However, the Fishman survey also makes mention of explicit hydraulic conditions observed, noting “depth was less than 2 inches and velocities were in excess of 10 feet per second” which indicates the existing culvert is not fish passable under the observed hydrologic conditions (“early March 1999, following several weeks of regular rainstorms”).

The culvert extends east of the railroad before daylighting. The top of the railroad embankment is at an elevation of approximately 36 feet and the narrow basin between the US 30 roadway and the railroad embankment is at an elevation of approximately 33 feet. Concrete wing walls for what appears to have been a railroad bridge crossing Crabapple Creek were observed, and it assumed that the bridge was abandoned in place when the culvert was installed.

There is some moderate accumulation of material at the culvert inlet, though it is generally unobstructed there (**Figure 2**). However, the outlet of the culvert has experienced significant aggradation in recent years and the outlet is now entirely backwatered and barely visible (**Figure 3**).



Figure 2 – Crabapple Creek crossing underneath US Hwy 30, upstream inlet. Photo Orientation: SE/looking downstream. Photo Credit: LCEP, 2023



Figure 3– Crabapple Creek, downstream outlet underneath railroad. Photo Orientation: W/looking upstream.

Left: Taken 2016, Right: Taken 2020. Photo Credit: LCEP

3.1 Hydrology

Continuous exceedance probability (CEP) flows and peak annual chance exceedance (ACE) flows were obtained for Crabapple Creek from USGS Streamstats (USGS, 2022). These flows are relevant context for consideration of alternatives and the CEP flows particularly are used to assess hydraulics for fish passage. Flows are summarized below in **Table 1**.

Table 1 - Crabapple Creek Hydrology (USGS, 2022)

Flow Event	Return Period (years)	Flow in Crabapple Creek (CFS)
95% CEP Flow	-	0.08
50% CEP Flow	-	4
5% CEP Flow	-	45
50% ACE Event	2	192
1% ACE Event	100	558

3.2 Construction Access Options

Anticipated site access routes and approximate work areas are displayed below in Figure 4. While it may be possible to construct the project entirely within the ODOT ROW on the west side of the highway, the actual ROW location will need to be surveyed during design. It will also likely be desirable to limit disturbance to vegetation at the toe of slope and use the open areas within the golf course to facilitate access and construction. Access west of US 30 is anticipated to be off the entrance to the Golf Course at NW Gallaher Drive. An existing open grass area would allow a 15ft wide construction access path without impacting golf course operations. The area near the proposed crossing site is a relatively flat grassy area.

Across US 30 from the Golf Course entrance, an existing gravel road owned by Metro extends east to the Multnomah Channel. East of the at-grade railroad crossing for the private road, an access road could be constructed extending south to the proposed crossing site. To facilitate the access road, tree removal would be needed.

It is anticipated that access to the narrow basin between the US 30 and the railroad embankments, as necessary, could be obtained from US 30 during lane closures, rather than from the private road.

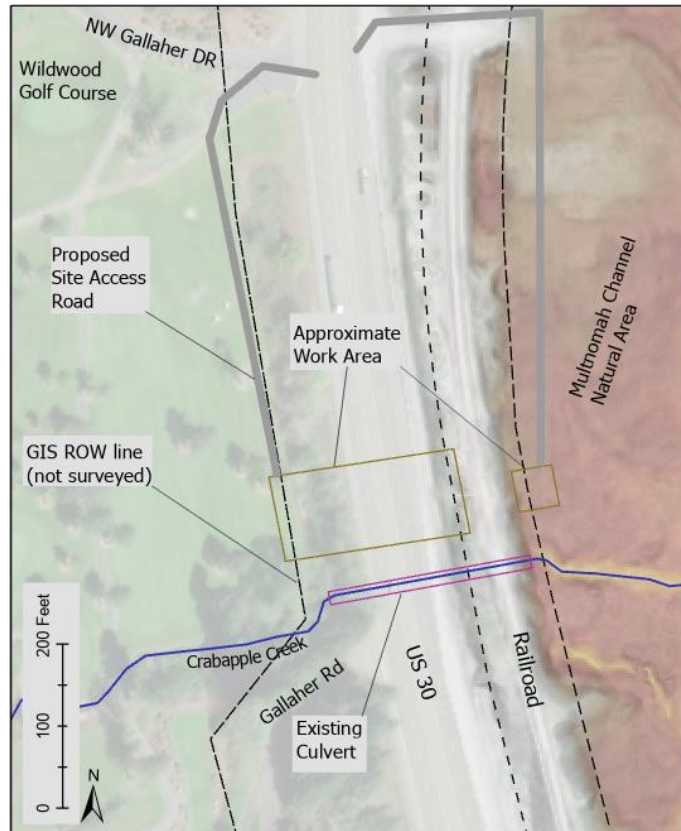


Figure 4 - Overview of proposed site access road and work area locations in relation to existing culvert

3.3 Geotechnical Conditions

Aspect Consulting completed six borings near the proposed crossing site (AB-01, AB-02, AB-03, AB-04, AB-05, and AB-06). Borings AB-01 and AB-04 were in either shoulder of US 30 and Borings AB-02 and AB-03 were in the travel lanes. Borings AB-01 and AB-03 were terminated at 55.6 feet below ground surface (bgs) and 60.8 feet bgs, respectively. Conversely, Borings AB-02 and AB-04 were terminated at 3.2 feet bgs and 9 feet bgs respectively due to drilling refusal. Borings Logs are available in **Appendix A**.

Beneath the asphaltic concrete and gravel layers, fill or road embankment fill was encountered to between 7.5 and 9.5 feet bgs. For Borings AB-01 and AB-03, beneath the fill or road embankment fill was sandy silt with gravel or silty sand with gravel, silt with gravel, and silty sand to 25 feet bgs. Beneath 25 feet bgs to between 28.2 and 30.5 feet bgs were silt and clay facies. Beneath the silt and clay facies was silt or silty sand to between 38 and 39.5 feet bgs to where Troutdale Formation, the bearing unit, was encountered.

Borings AB-05 and AB-06 were performed adjacent to the railroad and were terminated at 60.0 feet bgs and 40.58 feet bgs, respectively. For Borings AB-05 and AB-06, beneath the embankment fill was sandy silt with gravel or silty sand with gravel, silt with gravel and cobbles, and sandy silt to 7.5 feet bgs. Beneath 8 feet bgs to between 18.5 and 27 feet bgs was silt and clay facies. Beneath the silt and clay facies was silt or silty sand to where Troutdale Formation, the bearing unit, was encountered at 30 to 37 feet bgs.

Groundwater was encountered at approximately 25 feet bgs of the roadway during subsurface explorations in September 2023 and 13 feet bgs adjacent to the railroad in June 2024.

Discussion

The soil between the fill and Troutdale Formation is soft and potentially liquefiable. At the proposed crossing depths between approximately 20 and 30 feet bgs of US 30, woody debris and wire debris were encountered. Although not identified, ODOT embankments may contain cobbles or large boulders (2- to 30 foot in diameter).

At grade, ballast rock was observed beneath the railroad track. Geotechnical investigations adjacent to the railroad indicate low cohesion to cohesionless, soft to medium stiff clay and silt and sandy clay soil with scattered layers of silty sand with gravel and cobbles. It is possible that ground improvements may be needed to facilitate crossings beneath the railroad.

4 Biological Considerations and Stream Morphology

4.1 Terrestrial Species Presence and Needs

In addition to numerous aquatic, semi-aquatic, amphibious, and bird species the MCMNA is home to a variety of mammals including cougar, elk, black-tailed deer, river otter, and beaver. These species would all benefit from greater access to move across US 30 between MCMNA and the Tualatin Hills.

A high incidence of wildlife-vehicle collisions is typically the major driver of terrestrial animal passage projects at highways. ODOT furnished wildlife-vehicle collision density for the project vicinity along US 30 between MP 5 and 25 for this study (**Figure 5**). Note: ODOT wildlife-vehicle collision data is only collected for large-bodied wildlife (e.g. deer, elk, bear, or cougar), other wildlife collision is not recorded in the database.

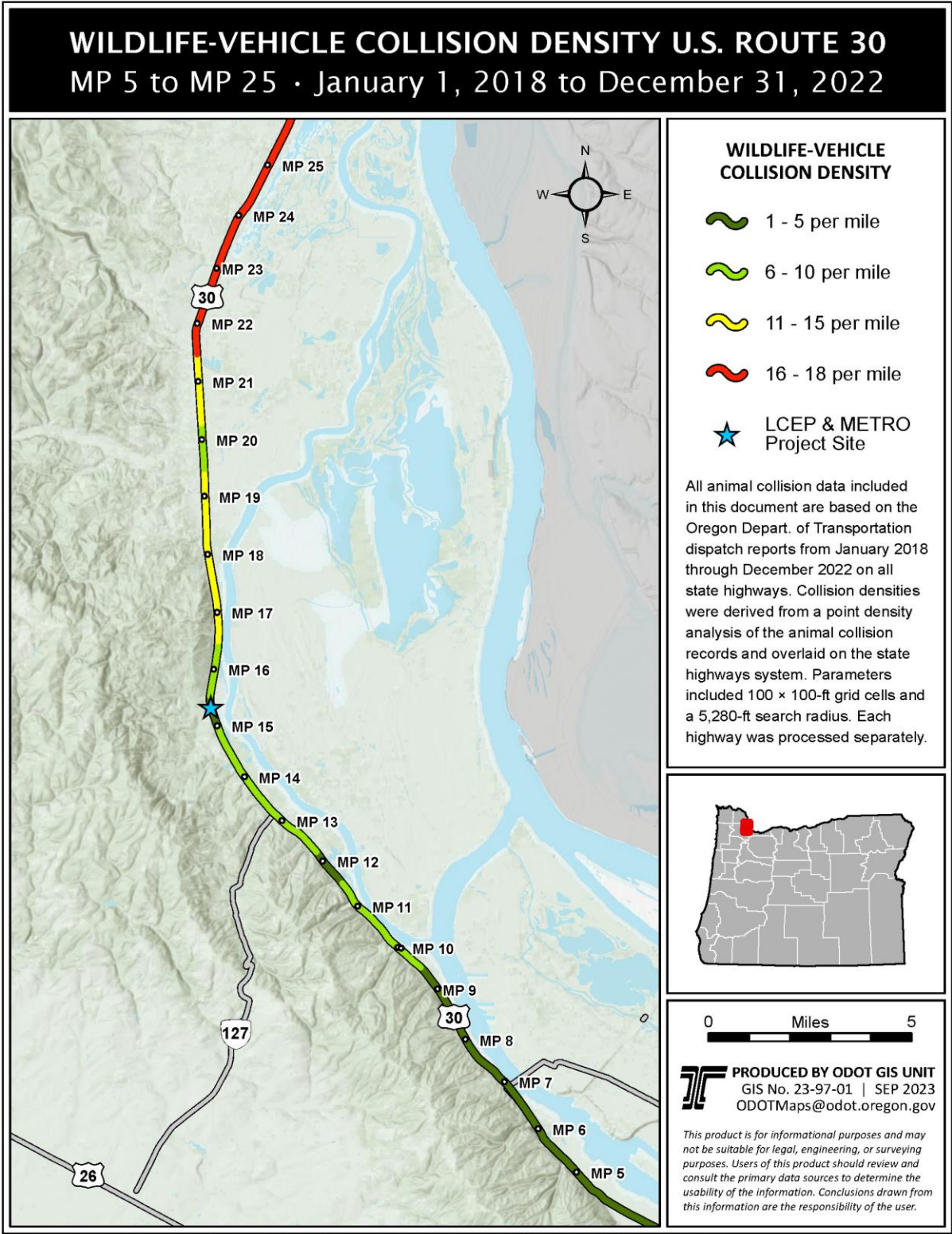


Figure 5 - Wildlife-vehicle collisions near the project location

The collisions shown in **Figure 5** were nearly all with deer (a handful of elk and smaller wildlife, and one bear were recorded). This collision data indicates a relatively low incidence of large-bodied wildlife vehicle conflict at the project location (indicated with a star), it may however still be a site that sees mortality incidences with smaller wildlife (e.g. reptiles, amphibians, and birds). However, the road embankment at the project site is very high and steep relative to the surrounding floodplain which may form a natural barrier to passage, it is possible that providing safe/accessible passage in this location might make a preferential path between the Tualatin hills and the MCMNA and adjacent floodplain which could reduce collision incidence between MP 12 and MP 16.5. This interpretation is based on limited information and a larger scale telemetry study of deer in the project vicinity would likely be needed to understand and quantify changes in animal movement and collision frequency.

A potential crossing should be sized based on the needs of the targeted wildlife. Some of the most comprehensive guidance available for sizing terrestrial wildlife passage comes from the Federal Highway Administration (FHWA) in the Wildlife Crossing Structures Handbook (FHWA, 2011). This handbook indicates the following minimum and preferred wildlife underpass structure dimensions for the following applicable crossing types:

Table 2 - Terrestrial Wildlife Crossing Structure Guidelines (FHWA, 2011)

Crossing Type	Minimum Geometry	Recommended Geometry	Target Species
Large Mammal Underpass (hot sheet 6)	Width: 20 ft Height: 10 ft	Width: >40 ft Height: >15 ft	Deer, Elk, Bear, Cougar. Would also be used by smaller mammals including fox, coyote, mink, skunk, opossum, raccoon. May be used by red legged frog.
Underpass with Waterflow (hot sheet 8)	Width: 6.5 ft (reliably dry) Height: 10 ft	Width: >10 ft (reliably dry) Height: >13 ft	Red Legged Frog, Deer, Elk, Bear, Cougar. Would also be used by smaller mammals including fox, coyote, mink, skunk, opossum, raccoon.
Small to Medium Sized Mammal Underpass (hot sheet 9)	Species dependent Width: 1-4 ft Height: 1-4 ft	Species Dependent	Red Legged Frog (likely to use due to riparian location) fox, coyote, mink, skunk, opossum, raccoon
Amphibian Tunnel	Varies with Structure Length	Width: >7.5 ft Height: >5.75 ft	Red Legged Frog. Would also be used by small mammals including fox, coyote, mink, skunk, opossum, raccoon

Geometry targets for large mammals are substantial and not necessarily achievable within the physical constraints at the project area, primarily the vertical clearance between the creek bottom and the top of the railroad embankment. However, maximizing the crossing opening will generally maximize the number of species that would use the crossing with the stipulation that there is cover for smaller prey species in the form of brush or some other periodic shelter.

The existing culvert could remain in place to provide some additional permeability. However, due to the size and elevation of the existing crossing (relatively narrow with an outlet soffit that is often below water) it is unlikely to be a favored path for most species. That condition might change if beaver activity at the outlet of the existing culvert changes to adapt to the new crossing (which is almost certain) but the utility of the existing crossing for wildlife under post project conditions is unknown at this time.

4.2 Aquatic Species Presence and Needs

Currently there is no documented anadromous fish presence in the Crabapple Creek headwaters. However, that must be interpreted in the context of heavily limited fish passage into the downstream wetland complex due to the presence of two large water control structures in each of the two tidal sloughs. If anadromous fish passage was restored to and through this location, approximately 5 miles of in-stream habitat would be opened in Crabapple, Patterson, and Morgan Creeks. Fish distribution and habitat conditions upstream of the Crabapple Creek culvert have been assessed by McNatt 2017 and Fishman 1999. Key findings include:

- Patterson and Crabapple creeks were inhabited almost entirely by native fish and amphibians (McNatt, 2017, Fishman, 1999).
- Fish species include resident cutthroat trout, rainbow trout, pacific lamprey, western brook lamprey, sculpin, dace, and stickleback. Cutthroat trout included a range of sizes, suggesting a self-sustaining population is present (McNatt, 2017, Fishman, 1999).
- No anadromous salmonid species were found upstream of US 30 (McNatt 2017, Fishman, 1999).
- The highest value aquatic habitat in study area was found in Patterson and Crabapple Creek above US 30 (McNatt, 2017)
- Crabapple and Patterson Creeks have some spawning habitat suitable for coho salmon if passage was restored (McNatt, 2017).

Removal of the downstream water control structures is being pursued as part of the floodplain restoration design for MCMNA. Providing fish passage to the habitat upstream of US 30 would require replacement of the existing crossing. Fish passage requirements take the form of threshold hydraulic parameters (maximum velocity and minimum depth) predicted through a crossing. Minimum depth criteria for Coho and Steelhead (NMFS, 2011) are:

- Adult salmonid minimum depth is one foot.
- Juvenile salmonid minimum depth is six inches.

Maximum velocities are listed by culvert length in **Table 3** below.

Table 3 - Maximum Allowable average velocity for fish by species and life stage (NMFS, 2011)

Culvert Length (ft)	Maximum Average Velocity (ft/s)		
	Chinook, Steelhead, Sockeye, and Coho Adults	Pink and Chum Adults	Juvenile Salmonids
<60	6.0	5.0	1.0
60-100	5.0	4.0	1.0
100-200	4.0	3.0	1.0
200-300	3.0	2.0	1.0
>300	2.0	2.0	1.0

Prior to implementation of a crossing replacement, a fish passage plan must be approved by ODFW and/or National Marine Fisheries Service (NMFS). One pathway to an approved fish passage plan is to

demonstrate that hydraulic fish passage parameters are met. This means that the designed crossing must meet minimum depth and maximum velocity requirements for all present species and life stages between the 5% and 95% continuous exceedance probability (CEP) flows. Natural passage conditions can also be used to limit the range of flows over which these parameters must be met. For example, if the low flow 95% CEP is too low to allow passage in the natural channel upstream or downstream of the structure then the lowest flow that allows passage in the adjacent natural channel could be used to demonstrate fish passage through the structure.

Given the low overall slope (~0.6%) across the culvert and the existing structure width it is expected that any structure width greater than the existing one could meet hydraulic fish passage requirements with appropriate channel section and profile design. Typically, the limiting factor in hydraulic fish passage design is structure width and slope as they relate to average velocity, where overly steep or narrow culverts exceed the velocity threshold for fish passage.

4.3 Stream Morphology

While hydraulic fish passage requirements are sufficient to meet either state or federal permitting requirements, the stream simulation methodology is often preferred by regulators and project proponents due to the desire to more closely match the full range of fluvial processes that are present in the natural stream. Stream simulation fish passage design requires use of the bankfull width (BFW) as a design parameter so measurements of BFW were taken upstream (US) and downstream (DS) of the culvert during field investigations. Those measurements are summarized below in **Table 4**.

Due to the likely need for federal financial support of this project (which would require fish passage consultation with NMFS), the NMFS stream simulation sizing was chosen as a representative/conservative width target for some of the alternatives.

Table 4 - Bankfull width (BFW) measurement summary.

Relative Location	Distance (ft)	Measured Width (ft)	BFW	Notes
DS	211	14.1	14.1	Measured top to top, channel after flow splits
DS	159	18.7	18.7	Measured top to top
DS	105	20.5	20.5	Measured top to top
DS	48	29.5	20.5	Measured top to top
Culvert	0	16		Culvert Face
US	55	19.5	19.5	Measured toe to toe
US	79	15.3	15.3	Measured toe to toe
US	110	15.5	16.5	Measured toe to toe, BFW est. from Google Earth
US	154	10.5	16.5	Measured toe to toe, BFW est. from Google Earth
US	197	10.2	16.5	Measured toe to toe, BFW est. from Google Earth
Average Upstream BFW (ft)			16.9	
Average Downstream BFW (ft)			19.9	
Average BFW (ft)			17.6	
Crossing Width (ft) - NMFS			30	Downstream BFW x 1.5
Crossing Width (ft) - ODFW			26	Downstream BFW x 1.2 + 2

Additional stream simulation design parameters include:

- Approximately matching upstream and downstream slopes
- Sufficient clearance to allow maintenance activities as needed (min 6 feet)
- Sufficient embedment to allow for intermittent scour of the substrate
 - Minimum 3 feet
 - Between 30% and 50% of the structure height
- Streambed materials should be similar in composition to those found naturally upstream and downstream
 - Erosion resistant materials may be incorporated for hydraulic roughness to avoid simplification to a plane-bedded morphology.

4.4 Culvert Length and Lighting

The distance between existing open channels upstream and downstream of the culvert is long compared to typical culvert crossings. This introduces specific challenges for fish passage including lack of lighting (natural or artificial) along the structure length. Fish prefer ambient natural lighting and are less likely to enter a dark culvert. Bridges tend to offer better lighting conditions than culverts. Other methods of appropriately lighting the culvert should be considered in greater detail during design and may include increasing interior clearance in the culvert, adding skylights, adding artificial lighting, among others.

5 Crossing Feasibility Study

5.1 Alignment

The proposed alignment, shown on **Figure 5**, **Figure 6**, and **Figure 1**, is approximately 75 feet north of the existing culvert. An alignment to the south is not preferred because of Gallaher Road and observed above grade bedrock. Conversely, an alignment further north is not preferred because it increases the amount earthwork needed to channelize Crabapple Creek. It is recommended that the existing culvert remain in place during construction for water management. The proposed alignment crosses beneath US 30 and the railroad with an approximate length of 275 feet.

5.2 Crossing Requirements

Crabapple Creek

The minimum width of the crossing for conveying Crabapple Creek is controlled by the selected fish passage design approach. Using the stream simulation approach indicates a minimum crossing span of 30 feet (see section 4.3 above). Using a hydraulic passage design approach, the minimum crossing span is a function of the slope and hydrology.

The bottom of the crossing shall be installed tying into the upstream and downstream thalweg elevations (approximately 24 and 22.4 feet respectively). The minimum allowable cover depth beneath the railroad tracks is 4.0 feet per AREMA railroad standards, although greater cover is preferred, indicating a maximum internal clearance of 8 feet. An 8-foot internal clearance would result in a corresponding depth of cover beneath US 30 between 17 and 21 feet. Profile figures for each alternative are included and can be used to assess cover depth for the crossing structures considered (Section 5.4). For alternatives with separate crossings for the highway and railroad, the internal clearance of the culvert beneath US 30 only will be increased to 14 feet which yields a depth of cover between 13 and 17 feet. Both of these clearances exceed

the minimum requirements for vertical clearance in fish passage structures. Applicable requirements come from NMFS and ODFW:

NMFS – “The minimum vertical clearance between the crossing bed and the culvert or bridge deck soffit elevation should be no less than 6 feet to allow access for debris removal.” (NMFS, 2022)

ODFW – “for open-bottomed road-stream crossing structures, a minimum of 3 feet vertical clearance from the active channel width elevation to the inside top of the structure.” (ODFW, 2023)

Given an active channel depth less than three feet (which is preferred), the NMFS requirement is the governing minimum clearance. However, we recommend considering greater clearance for ease of maintenance in the future particularly if heavy equipment is likely to be used for maintenance activity.

Terrestrials

Two types of terrestrial organism crossings are considered.

1. Full sized conveyance under US 30 only:
 - a. Intended to meet minimum geometry requirements for large mammals (and all smaller organisms).
 - b. Opening 20 feet wide by 10 feet high
 - Culvert opening 12 feet high to accommodate native material and shrub cover infill.
2. Context constrained semi-dry conveyance under the railroad:
 - a. Maximum sized conveyance under railroad will not meet vertical clearance for large mammals.
 - b. Must be low enough be at least partially engaged by flood flows (to achieve stream simulation hydraulic opening).
 - c. Includes a high dry passage bench against one wall that will include dense brush embedment for cover.
 - d. Opening 15 feet wide by 6 feet high.

5.3 Structure Types

Two structure types can meet the crossing requirements, culverts and bridges.

Culvert

A four-sided rectangular culvert can be installed using either an open cut or trenchless installation technique. Initial outreach to regional precast concrete manufacturers indicates that culverts meeting the requirements are not common but may be able to be fabricated.

Installation Techniques

An open cut installation technique, per initial coordination with ODOT, may be possible within the US 30 right-of-way. To facilitate installation, it is assumed that US 30 would operate with one lane in either direction, under reduced speed conditions. Within the ODOT Rail right-of-way, an open cut installation technique is not possible as it is unlikely that permission to interrupt rail line service for construction would be granted.

Another installation technique for culverts is box jacking. Box jacking is a trenchless technique that includes installing precast concrete rectangular sections using the thrust force of a hydraulic jacking system. The soil

within the installed rectangular sections can be excavated using either hand mining or other spoil removal methods. A shaft on either end of the installation houses tunneling and other equipment. A lubrication system is typically used to minimize sliding friction. After installation, contacting grouting of voids outside of the culvert is completed.

The maximum width for box jacking is dictated by the geotechnical conditions, length of the drive, and other considerations but is typically limited to widths of 20 feet or less. The combined drive length, beneath US 30 and the railroad of 275 feet, is within the technical envelope of the box jacking installation method.

Another installation technique for culverts is tunnel boring using a tunnel boring machine (TBM), but initial research indicates that tunnel boring is prohibitively expensive, particularly for shorter drives, due to the high capital cost of the TBM equipment and thus it was not further pursued.

Bridge

The bridge option would require a bridge length of approximately 60-75 feet to span the improved width of Crabapple Creek, accommodate scour processes, and permit terrestrial crossing. The noted span requirement would make a precast/prestressed concrete (PS/PC) bridge type the preferred option. This type of segmental bridge construction and installation can benefit by reduction of costs, construction time, environmental impacts, and the maintenance of traffic compared to conventional cast-in-place concrete or steel bridges.

Installation Techniques

The bridge elements would be precast off-site and delivered to the project site where they would be erected by crane. To facilitate the installation of the bridge and keep vehicular traffic lanes open on US 30 the bridge would be built in a two-stage construction sequence allowing for half the bridge to be constructed at time while leaving open half of US 30 open for vehicular traffic.

5.4 Alternatives

For the proposed alignment and crossing requirements, four Alternatives with a combination of structure types and installation techniques were developed.

Alternative 1

Alternative 1 is depicted in plan (**Figure 6**), profile (**Figure 7**), and section (**Figure 8**) views below. Alternative 1 includes the installation of a 30-foot-wide culvert beneath US 30 and two in line parallel 15-foot-wide culverts beneath the railroad for conveying Crabapple Creek. The 30-foot-wide culvert would have an internal clearance of 14 feet and the 15-foot-wide culverts an internal clearance of 8 feet, to meet AREMA standards. The paired parallel culverts are intended to increase the total span to the width recommended by NMFS for stream simulation while remaining constructable without open trenching. One of the paired culverts will contain a lower dedicated in-stream profile while the other will include a higher floodplain and small dry passage bench. The culvert beneath US 30 would be installed using an open cut technique and the parallel culverts beneath the railroad installed using a box jacking technique. The drive length for box jacking beneath the railroad is approximately 75 feet. It is assumed that the existing culvert would be abandoned in place for Alternative 1.

This alternative is intended to use a stream simulation fish passage approach, improve passage for large and small mammals and amphibians across US 30, and improve passage for all organisms under the railroad (except for large mammals which can cross at grade without difficulty).

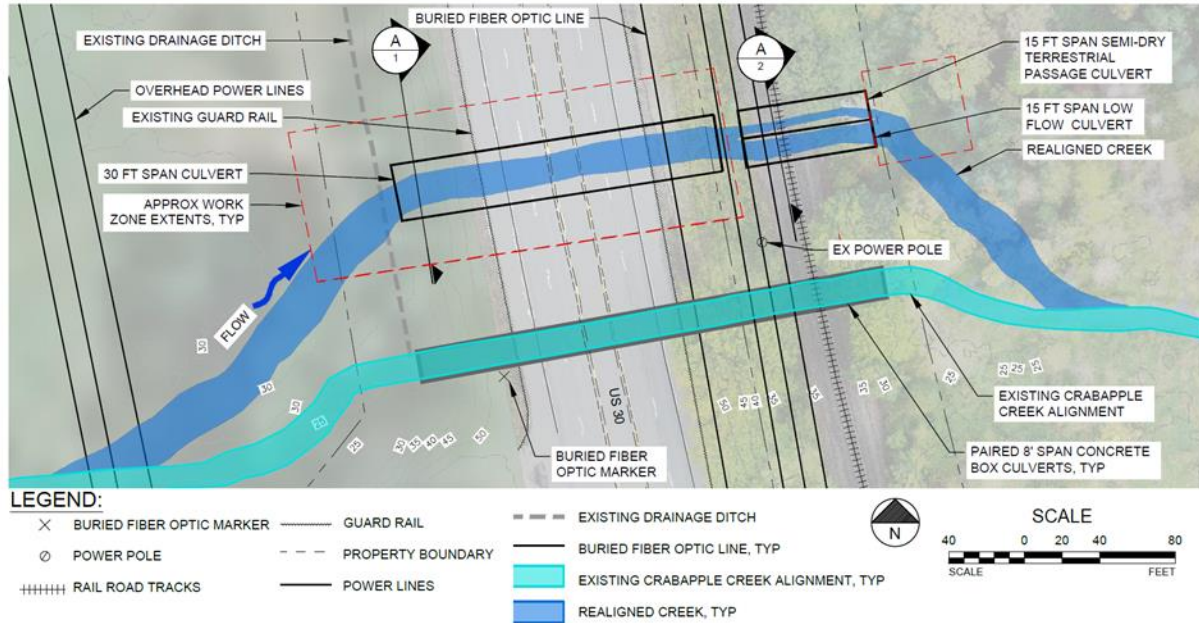


Figure 6 - Alternative 1 plan

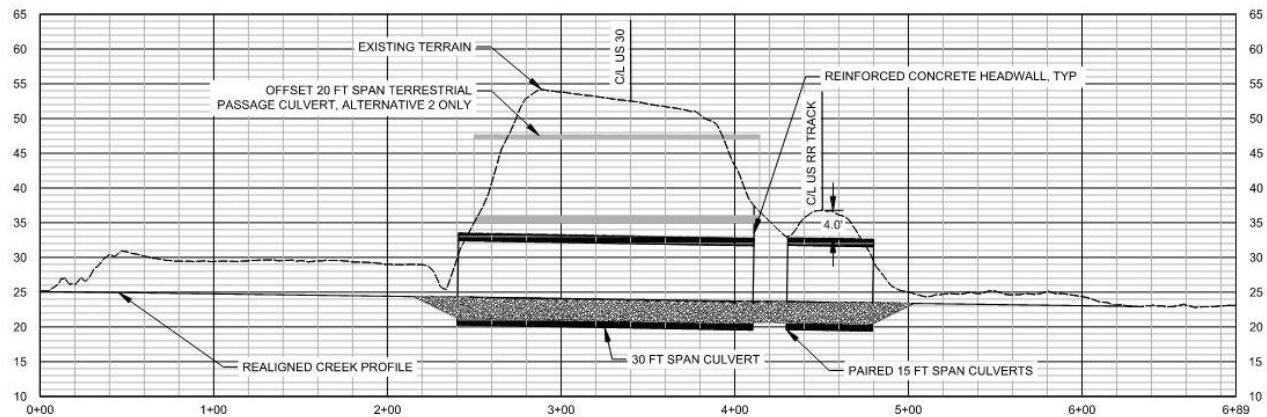


Figure 7 - Alternative 1 and 2 profile

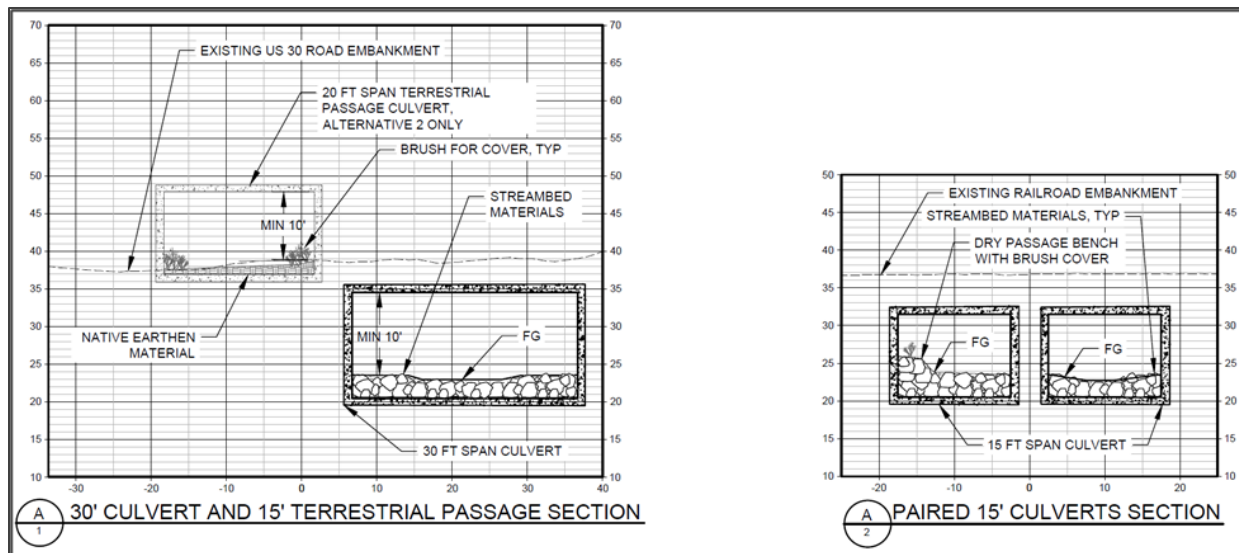


Figure 8 - Alternative 1 and 2 sections

Alternative 2

Alternative 2 is depicted in plan (**Figure 9**), profile (**Figure 7**), and section (**Figure 8**) views above/below. Alternative 2, beneath US 30, includes the installation of a 30-foot-wide culvert with an internal clearance of 14 feet (including streambed and floodplain materials) for conveying Crabapple Creek and a parallel 20-foot-wide culvert for conveying terrestrials, both installed using an open cut technique. Beneath the railroad, two parallel/paired 15-foot-wide culverts with internal clearances of 8 feet for conveying Crabapple Creek would be installed using a box jacking technique. One of the paired culverts will contain a lower dedicated in-stream profile while the other will include a higher floodplain and small dry passage bench. The drive length for box jacking beneath the railroad is approximately 75 feet. It is assumed that the existing culvert would be backfilled and abandoned in-place for this Alternative.

This alternative is intended to use a stream simulation fish passage approach and improve passage for large mammals across US 30 and for small mammals and amphibians across both the railroad and US 30.

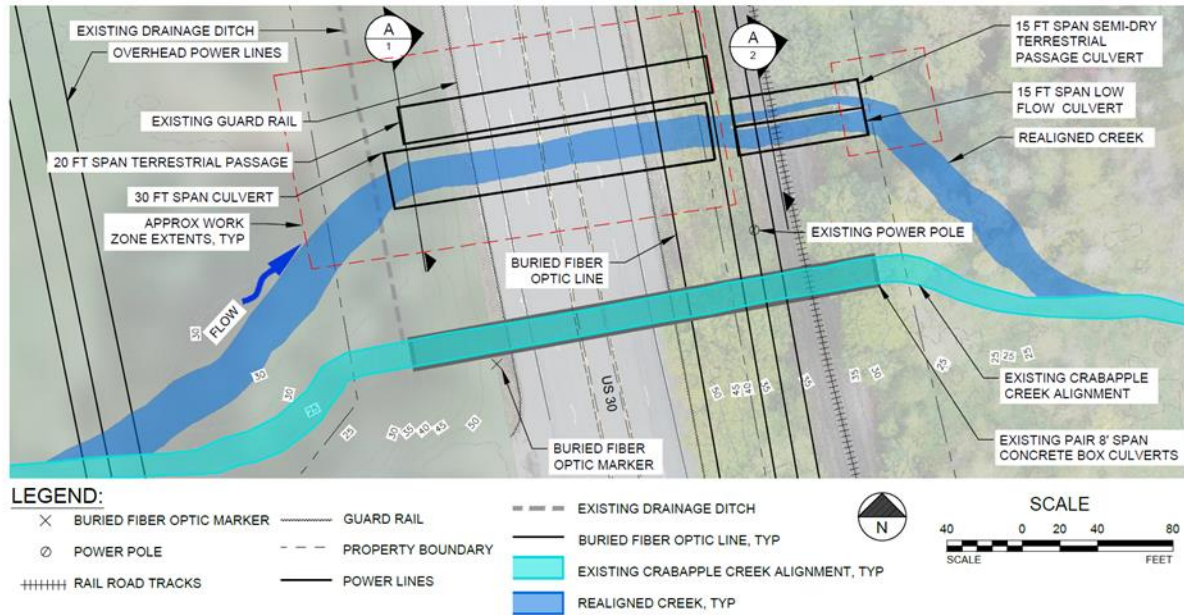


Figure 9 - Alternative 2 plan

Alternative 3

Alternative 3 is depicted in plan (**Figure 60**), profile (**Figure 71**), and section (**Figure 82**) views below. Alternative 3 includes the installation of a continuous 20-foot-wide culvert with an internal clearance of 8 feet beneath US 30 and the railroad for conveying Crabapple Creek. The culvert would be installed using a box jacking technique. The drive length is approximately 275 feet. It is assumed that the existing culvert would be retained for this Alternative. An elevated walkway (not pictured) could be included to improve small mammal passage.

This alternative is intended to use a hydraulic fish passage approach and provide marginal passage improvements for small mammals and amphibians across the railroad and US 30.

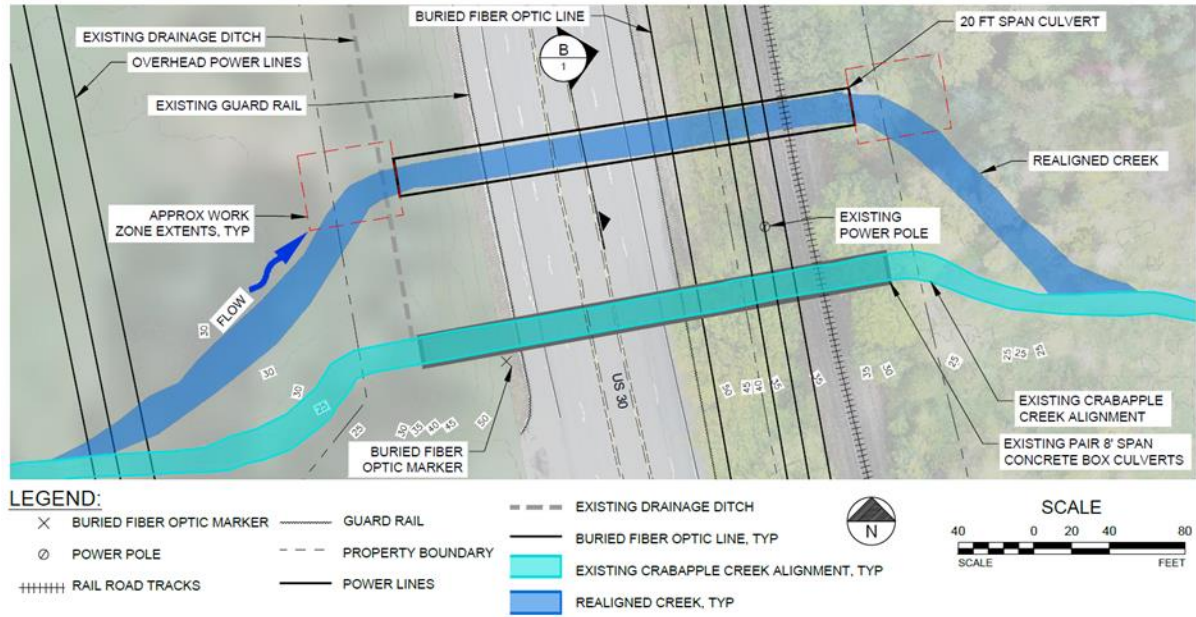


Figure 60 - Alternative 3 plan

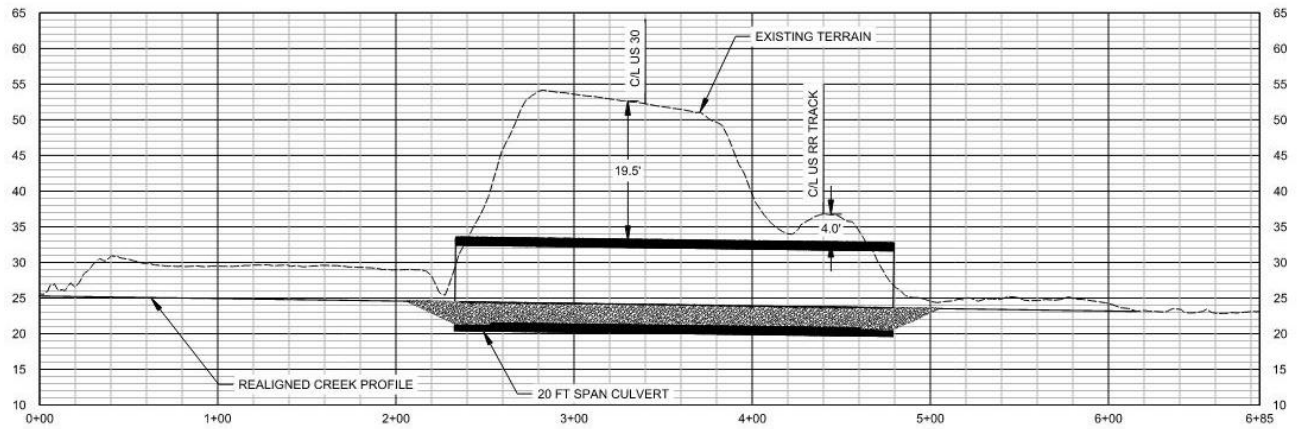


Figure 71 - Alternative 3 profile

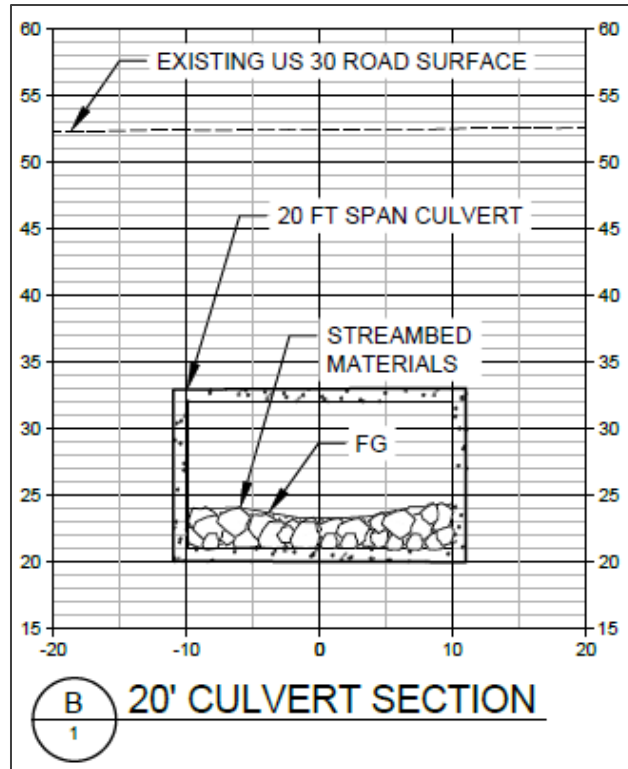


Figure 82 - Alternative 3 section

Alternative 4

Alternative 4 is depicted in plan (**Figure 13**), profile (**Figure 14**), and section (**Figure 95**) views below. Alternative 4 includes the installation of a bridge for US 30 and two parallel culverts beneath the railroad, a 20-foot-wide culvert for conveying Crabapple Creek with an internal clearance of 8 feet and a 15-foot-wide culvert for conveying terrestrials. The culverts would be installed using a box jacking technique and the drive length beneath the railroad is approximately 75 feet. It is assumed that the existing culvert would be retained for this Alternative.

Alternative 4 is intended to use a stream simulation fish passage approach and maximize passage for all mammals and amphibians across both the railroad and US 30.

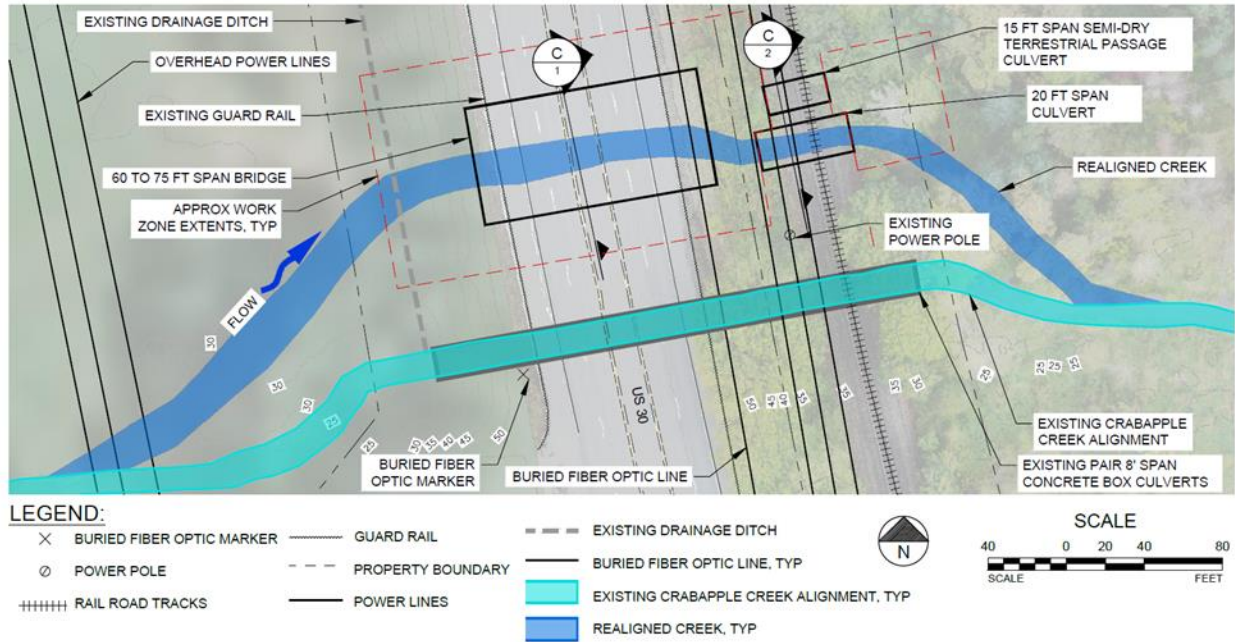


Figure 13 - Alternative 4 plan

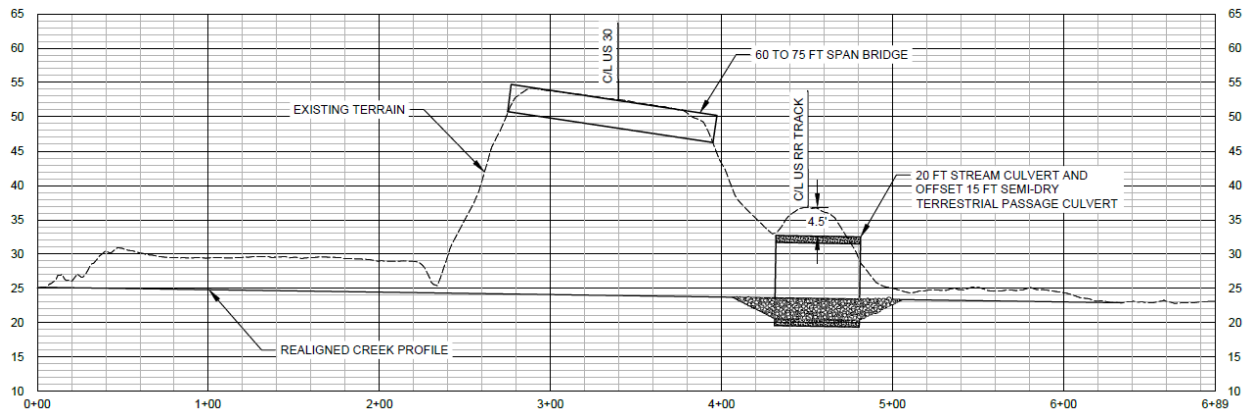


Figure 14 - Alternative 4 profile

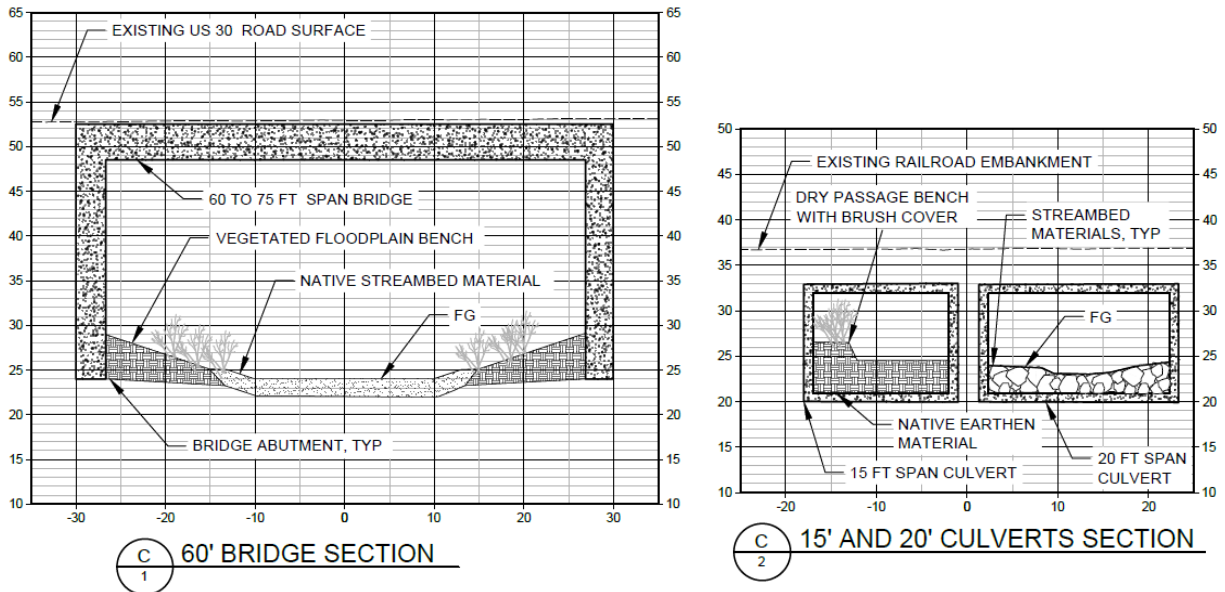


Figure 95 - Alternative 4 sections

Ancillary Work Elements

To construct the crossing, ancillary work elements were identified. Foremost, traffic control for US 30 would be needed for an open cut installation technique. In addition, work within 25 feet of the railroad typically requires flagging. Other work elements include channel excavation for the proposed alignment of Crabapple Creek, tree removal, dewatering, shoring, potential utility relocations, potential channelizing devices for terrestrials, and site restoration.

5.5 Probable Construction Costs

Class 4 estimates for probable construction costs were developed in accordance with AACE International Recommended Practice No. 17R-97 and No. 18R-97. Per the recommended Practices, a Class 4 estimate has an expected accuracy range of -30 to +50 percent at an 80 percent confidence interval with a maturity level of project defined deliverables of 1 to 15 percent. Class 4 estimates are intended for study of feasibility and use equipment factors, parametric models and judgement to estimate project construction costs.

The Class 4 estimates summarized herein utilize a +50 percent contingency to mitigate the risk associated with the project maturity level and uncertainty in the market with respect to labor, materials, and supply chain.

A probable construction cost estimate for each alternative is presented in **Table 5**, and the breakdown of estimates can be found in **Appendix B**.

Table 5 - Probable Construction Cost Estimate Ranges

Alternative	Construction Cost Estimate
Alternative 1	\$5,400,000 - \$8,200,000
Alternative 2	\$7,000,000 - \$10,600,000
Alternative 3	\$5,400,000 - \$8,200,000
Alternative 4	\$10,100,000 - \$15,200,000

5.6 Discussion

The four Alternatives are summarized in **Table 6**. Each Alternative requires using a trenchless installation technique beneath the railroad. Alternatives 1, 2, and 3 strictly include culverts, whereas Alternative 4 is a hybrid approach with both a bridge and culverts. Alternatives 1, 2 and 4 will allow daylighting of the stream between the railroad and the highway, details for which can be worked out in design.

Table 6 - Alternative Geometry and Construction Summary

Alternative	US 30 (for Crabapple Creek)	US 30 (for Terrestrials)	US 30 Installation Technique	Railroad (for Crabapple Creek)	Railroad (for Terrestrials)	Railroad Installation Technique
1	30-foot culvert	Bench inside culvert	Open Cut	(2) 15-foot culverts	Bench inside culvert	Box Jacking
2	30-foot culvert	Separate 20-foot culvert	Open Cut	(2) 15-foot culverts	Bench inside culvert	Box Jacking
3	20-foot culvert	Bench inside culvert	Box Jacking	20-foot culvert	Bench inside culvert	Box Jacking
4	Bridge	Bench underneath bridge	Open Cut	20-foot culvert	Separate 15-foot culvert	Box Jacking

Each alternative increases permeability of the highway and railroad embankment to aquatic and terrestrial animals and results in improved hydrologic and sediment continuity, however some alternatives offer more robust improvements. Better connectivity/permeability outcomes generally correlate with higher expected costs. Expected passage associated with each alternative for each considered species/cohort is summarized **Table 7**.

Table 7 - Alternative landscape connectivity summary

Alternative	Fish Passage Approach	Large Mammal Passage	Small Mammal Passage	Red Legged Frog Passage
No Action	Poor fish passage	None	None	Poor
1	Stream Simulation	Fair	Fair/Good	Good
2	Stream Simulation	Fair/Good	Good	Good
3	Hydraulic	None	Poor	Poor
4	Stream Simulation	Good	Good	Good

For Alternative 1, large mammal passage is provided under US 30 but only to the minimum clearance preferences due to limited space and overhead clearance adjacent to the stream. However, due to the floodplain under US 30 and dry passage bench under the railroad other considered species, small and medium sized mammals, are expected to have a considerably improved opportunity to safely cross the transit corridor.

For Alternative 2, the minimum size for large mammals under US 30 is met by both the dedicated terrestrial passage culvert and the stream simulation culvert increasing opportunity for large mammal passage over alternative 1. Additionally, all mammals (small, medium, and large) are likely to have little trouble crossing the railroad embankment at grade. The dedicated US 30 terrestrial crossing structure also improves permeability for small mammals by adding an additional safe route that will remain dry at all times, even during extreme winter flows. Passage under the railroad is the same as Alternative 1.

For Alternative 3, the primary passage improvement is for fish species and that improvement is poorer than for the other three alternatives due to the continuous unlit structure length and more limited potential for low velocity holding pools. The new hydraulic opening is not much larger than existing conditions and would likely be devoted mostly to Crabapple Creek with limited floodplain for use by small mammals or red legged frogs. An elevated walkway for small mammal passage would help somewhat, but due to the length, darkness, and poorer opportunity to provide cover usage is uncertain.

For Alternative 4, the permeability of the transit corridor is maximized within assumed parameters. An open bridge will offer a robust passage improvement for large mammals and better recruitment of vegetation in that opening will provide the most comfortable/useable passage for smaller prey species. The broadest opening of all the alternatives will offer dry riparian margin along the stream for use by red legged frogs under all but the most extreme winter flow events.

The Samara Group, LLC reviewed the design alternatives (Appendix C). The report notes that Alternatives 1, 2, and 3 may have limited wildlife passage for terrestrial species during high flow conditions when the dry passage benches can be overtopped by floodwaters. Alternative 4 with its wider dry passage benches would better retain its terrestrial connectivity during higher flow events. The report also notes that for all of the alternatives, wildlife passage would predominantly come from the north of the site since Crabapple Creek flows south of the new crossing.

6 Permitting Discussion

This project is likely to require obtaining the following permits (Table 8). This list is not comprehensive, a full review of applicable permit requirements should be made prior to moving forward with a design.

Table 8 – Permits for Crabapple Crossing

Permit	Regulatory Agency
Joint Permit Application (JPA) - Section 404 permit - DSL Removal/Fill permit - Section 401 Water Quality	- Army Corps of Engineers (USACE) - Oregon Dept of State Lands (DSL) - Oregon Dept of Environmental Quality (DEQ)
1200C Stormwater Discharge	- DEQ
ODOT R-O-W Access Permits	- ODOT & ODOT Rail
Railroad Access Permits	- Portland & Western/Genesee & Wyoming Railroad
Grading, Floodplain Development, other Local Permits	- Multnomah County

7 Risk Identification

Potential risks associated with the Alternatives were identified. To date, no fatal flaws have been documented with these design alternatives. The first risk, pertinent to each Alternative, is box jacking beneath the railroad. The suite of risks for a trenchless installation of a 15- or 20-foot-wide culvert is summarized below with potential mitigation strategies:

- Minimum allowed clearance beneath railroad track (4.0 feet)
 - Limited discussions with railroad thus far. Requirements for crossings at this location not fully understood.
- Potential need for ground improvements to address soft and cohesionless soils to create better ground conditions for proposed installation methods
 - Mitigation: Typically addressed with chemical or cementitious grouting
- Potential for inadvertent return during contact grouting
 - Mitigation: Continuous monitoring of pumping pressures and material volumes during grouting operation.
- Potential for surface/roadway settlement
 - Mitigation: Continuous monitoring during construction operation, modifications to operations in real time, plan for a worst-case scenario for post installation mitigation/restoration measures.
- Limited face support due to ground conditions
 - Mitigation: Ground improvement and/or contractor mean & methods
- Potential for cobbles/boulders or other impediments
 - Mitigation: contract documents to baseline expectation for potential obstructions, baseline number of obstructions for contractor bidding and potential change order negotiations.
- Limited pool of qualified/experienced contractors
 - Mitigation: Contractor outreach during design phase to gauge interest and qualifications of local, regional, and potential national construction firms

Most of the identified risks noted above are also applicable to Alternative 3, which includes a continuous jack beneath both US 30 and the railroad.

For Alternatives 1, 2, and 4 that include an open cut installation technique for US 30, an identified risk is excavating approximately 35 feet below the road surface and still maintaining traffic, one lane in either direction.

A major source of risk to the project is the ongoing willingness to engage with and permit the project by the land-owning stakeholders. Primarily ODOT, ODOT Rail, Portland and Western Railroad, Wildwood Golf Course, and METRO. Each of these entities has been engaged in the process of this project development and all have indicated willingness to engage with review and permitting of the project under the relevant applicable standards for their organizations. Significant additional engagement will be required on the part of these landowners to fully develop and construct the project.

8 Next Steps

The findings of this study indicate that there are a range of technically feasible alternatives that accomplish the stated project goal of enhancing landscape connectivity across US 30 at the project site. These alternatives have varying expected price points and improve landscape connectivity to varying degrees.

The project sponsor and stakeholders should decide whether to move forward toward design and select a preferred alternative. This selection could be based solely on the expected level of associated uplift, or it could balance cost and uplift against one another with input from potential funders.

If appropriate funding appears to be available, a complete permitting pathway should be identified, and a detailed design scoping exercise should be carried out to ensure that all project costs can be incorporated into project fundraising appropriately.

Appendix A – Geotechnical Report

Appendix B – Breakdown of Construction Cost Estimates

Appendix C – Wildlife Crossing Assessment for Crabapple Creek (Samara Group)