City of Bellevue - Utilities

Lower Coal Creek Flood Hazard Reduction Project

Coal Creek Bridges Preliminary Design Report

TETRA TECH

October 2016

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PREPARED FOR

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1. INTRODUCTION

Over the last two decades, the City of Bellevue has received and responded to numerous flood complaints along Coal Creek associated with backed-up storm drains, blocked culverts and channel overflows. The Lower Coal Creek Flood Hazard Reduction project will implement flood protection measures to abate these problems and provide up to 100-year flood protection. This report provides a basis of design for the design phase of the project to replace five culverts in the Newport Shores neighborhood with bridges that meet current bridge design standards.

1.1 PROJECT LOCATION

The project is in the southwest corner of the City of Bellevue in the Newport Shores neighborhood, immediately west of I-405 and 3,000 feet south of I-90 (see Figure 1). The Newport Shores neighborhood is a single-family residential neighborhood developed in 1960s. Coal Creek flows southeast to northwest through the middle of the neighborhood, with five streets crossing the creek. The creek discharges to Lake Washington about 600 feet downstream of lower Skagit Key.

1.2 OBJECTIVES

The objective of this phase is to identify the replacement option and design criteria for five culverts in Lower Coal Creek so they will meet current design guidelines for fish passage, flood conveyance, debris passage, and traffic safety. Section D4-04.4 (B) of the Surface Water Design Standards (COB, 2016) specifies the 100-year peak flow rate as the design level of service for conveyance.

1.3 PREVIOUS INVESTIGATIONS

Numerous investigations of Coal Creek in the project area have been conducted over the past 30 years, including the *Coal Creek Basin Plan and Environmental Impact Statement* (King County, City of Bellevue, 1987), *Sustainable Flood Prevention Plan for Skagit Key Reach* (Spearman Engineering, 1997), and the *Coal Creek Stabilization Program Environmental Impact Statement* (Tetra Tech/KCM, 2006). The most recent investigation was the *Lower Coal Creek Flood Hazard Reduction Alternatives Analysis* (NHC, 2015).

1.4 NEED FOR PROJECT

The *Lower Coal Creek Flood Hazard Reduction Alternatives Analysis* (NHC, 2015) showed the existing Coal Creek structures in Newport Shores could not meet current standards for flood conveyance and fish passage and evaluated alternatives that would meet current standards. The findings documented in this report led to the recommendation to replace the culverts with bridges.

The existing culverts are undersized and unable to pass the 100-year peak flood without overtopping at all but lower Skagit Key Crossing. Also, during periods of high flow depth in the creek, floodwaters can backflow through storm drain outfall connections at the creek and cause flooding on City streets where catch basin inlet elevations are below the creek stage.

The undersized culverts are submerged starting at the 2-year peak flood event which increases the potential for flooding due to debris clogging the structure. Debris clogging was reported at Cascade Key during a large flood in December 2007 which caused flooding at this location.

Corrugated metal pipe arches are located at lower Skagit Key and Newport Key. These structures have been in place for about 50 years which is much longer than the typical design life of about 30 years for metal pipe arch structures. The top of the structure at lower Skagit Key is also starting to sag under the roadway.

The culvert under Cascade Key is reported to be a partial fish barrier due to high flow velocity and low depth at the exposed concrete bottom at the upstream end of the culvert.

1.5 PROJECT SCOPE

The scope of work for this project is to replace five existing culverts in lower Coal Creek with structures that meet current design guidelines for fish passage, flood conveyance, debris passage, and traffic safety. It includes the following:

- Channel design, including scour protection and streambed gravel specification, for natural channel through the bridges.
- Structural and civil design for new bridge structures to replace the culverts at Cascade Key, upper Skagit Key, Glacier Key, Newport Key, and lower Skagit Key (see Figure 1).
- Roadway design at upper Skagit Key, Glacier Key, and Newport Key to provide sufficient freeboard during the 100-year flood event.
- Design of an inverted stormwater siphon for future outfall construction at Glacier Key and Newport Key.
- Utility relocation.

1.6 PRELIMINARY PROJECT SCHEDULE

The project schedule is based on completing most of the construction during July and August to comply with U.S. Army Corps of Engineers and Washington Department of Fish and Wildlife limitations on in-water work. The current schedule assumes that one bridge will be constructed in 2017, two in 2018 and the remaining two in 2019. Table 1 shows the project milestone schedule.

1.7 PROJECT FUNDING

The Lower Coal Creek Flood Hazard Reduction project is currently funded in its entirety by King County Flood Control District.

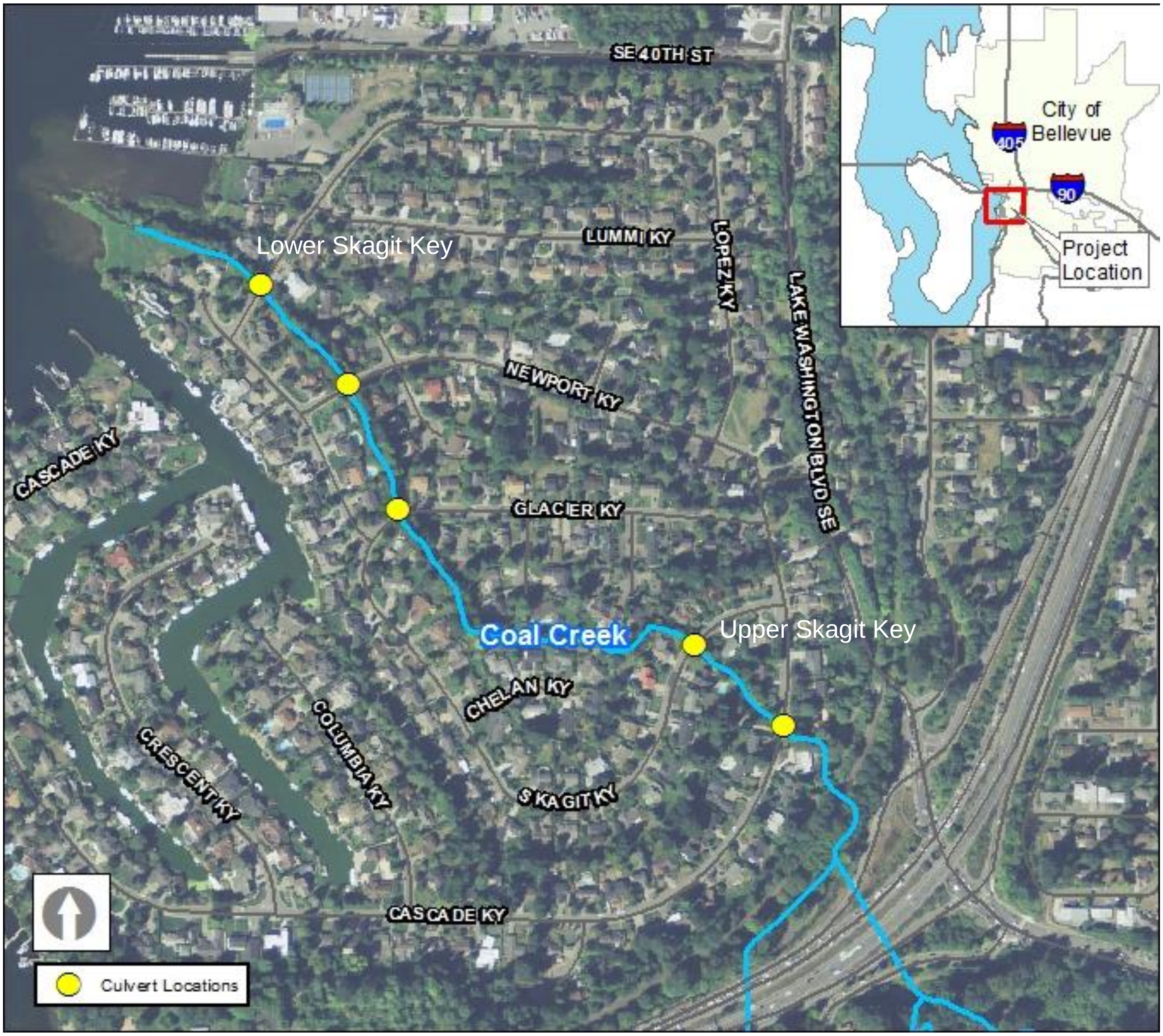

Figure 1. Project Location Map

Table 1. Project Schedule

Milestone Date	Date
All Bridges	
Preliminary Design Complete	June 2016
Federal Permits Issued	December 2016
Group 1 Bridge (Upper Skagit Key)	
Final Design	June–December 2016
State and City Permits Issued	December 2016
Construction Contract Advertised	January 2017
Construction Starts	May 2017
In-Water Construction	July–September 2017
Construction Complete	October 2017
Group 2 Bridges (Cascade Key and Newport Key)	
Final Design	January–December 2017
State and City Permits Issued	December 2017
Construction Contract Advertised	January 2018
Construction Starts	May 2018
In-Water Construction	July–September 2018
Construction Complete	October 2018
Group 3 Bridges (Glacier Key and Lower Skagit Key)	
Final Design	January–December 2018
State and City Permits Issued	December 2018
Construction Contract Advertised	January 2019
Construction Starts	May 2019
In-Water Construction	July–September 2019
Construction Complete	October 2019

2. EXISTING SITE CONDITIONS

The Coal Creek channel in Newport Shores extends 4,000 feet from I-405 to Lake Washington. It passes through two types of culverts in this neighborhood (see Table 2):

- **Concrete box structures**—Concrete box structures 10-feet wide by 6-feet high are installed at Cascade Key, upper Skagit Key, and Glacier Key. These structures have 6-foot long wing walls with concrete aprons on their upstream and downstream faces. The Cascade Key culvert (Figure 2) is constructed at a 27-degree skew and is 62 feet long (with wing walls). The upper Skagit Key and Glacier Key culverts (Figure 3 and Figure 4) are 55 and 56 feet long, respectively, with no skew.
- **Corrugated metal pipe arches**—The culverts at Newport Key and lower Skagit Key are 13.5-foot wide by 6.7-foot high corrugated metal pipe arch culverts. The Newport Key culvert (Figure 5) is 60 feet long. The lower Skagit Key culvert (Figure 6) is 62 feet long and is skewed 20 degrees to the road.

Table 2. Existing Culverts in the Project Area

Crossing	Material and Shape	Size and Material	Culvert Length	Skew
Cascade Key	Concrete Box	10' W x 6' H	62 feet	27°
Upper Skagit Key	Concrete Box	10' W x 6' H	55 feet	0°
Glacier Key	Concrete Box	10' W x 6' H	56 feet	0°
Newport Key	Corrugated Metal Pipe Arch	13.5 W x 6.7' H	60 feet	0°
Lower Skagit Key	Corrugated Metal Pipe Arch	13.5 W x 6.7' H	62 feet	20°

The road at all crossings is 32 feet wide with an 18-inch rolled curb. Cascade Key has a 3-foot-wide sidewalk on the east (upstream) side of the road and no sidewalk on the west side of the road. Upper Skagit has a 3-foot-wide sidewalk on the west (downstream) side of the road and no sidewalk on the east side of the road. At Glacier Key, Newport key, and lower Skagit Key, a 3-foot-wide sidewalk is located on both sides of the street.

A 36-inch high pedestrian handrail is located on the headwall at both ends of the culvert at Cascade Key and upper Skagit Key, and Glacier Key. The culverts at Newport Key and lower Skagit Key have a 30-inch high guard rail next to the sidewalk. Lower Skagit Key also has a 36-inch high pedestrian hand rail at both ends of the culvert.

Storm drain outfalls discharge to the creek downstream of all the culverts except the Cascade Key culvert.

A wood timber trestle structure between Cascade Key and I-405 carries an abandoned railroad (future recreation trail) over the creek. Work or modification of this structure is not part of the flood hazard reduction project.

Figure 2. Downstream Face of the Existing Culvert at Cascade Key

Figure 3. Upstream Face of the Existing Culvert at Upper Skagit Key

Figure 4. Upstream Face of the Existing Culvert at Glacier Key

Figure 5. Downstream Face of the Existing Culvert at Newport Key

Figure 6. Upstream Face of the Existing Culvert at Lower Skagit Key

3. DESIGN REFERENCES

The following publications will be used for guidance for bridge, stream channel, and roadway design for the Lower Coal Creek Flood Hazard Reduction project:

- City of Bellevue
  - *Storm and Surface Water Engineering Standards*, January 2016
  - *Transportation Department Design Manual* (TDDM), March 2015
- Washington State Administrative Code
  - Hydraulic Code Section 220-110-070
- Washington Department of Ecology
  - *2012 Stormwater Management Manual for Western Washington* (required by City of Bellevue as of January 1, 2017)
- Washington Department of Transportation
  - *Bridge Design Manual (LRFD [Load and Resistance Factor Design]) (M23-50)*, June 2016
  - *Washington State Department of Transportation Standard Specifications for Road, Bridge, and Municipal Construction (M41-10)* 2016
  - *Standard Plans for Road, Bridge and Municipal Construction (M21-01)*
- Washington Department of Fish and Wildlife
  - *Water Crossing Design Guidelines*, draft January 2013 (Barnard, et. al)
- King County
  - *2007 Road Design and Construction Standards*, May 2007
  - *Surface Water Design Manual*, 2016
- American Association of State Highway and Transportation Officials (AASHTO)
  - *Guide Specification for LRFD Seismic Bridge Design, Second Edition*, 2011
  - *LRFD Bridge Design Specifications, Sixth Edition*, 2012 and the current Interims
  - *A Policy on Geometric Design of Highways and Streets (Green Book), 6th Edition*, 2011
- U.S. Department of Transportation, Federal Highway Administration
  - *Manual on Uniform Traffic Control Devices*, as amended and approved by the Washington Department of Transportation

4. Bridge Structures

The replacement structures will need to have a 24-foot wide span to meet current guideline for fish passage (see Section 9.2.1) to meet the stream simulation methodology outlined in the WDFW Water Crossing Design Guidelines (Bernard, et. al., 2013). A structure with a span greater than 20 feet is considered to be a bridge (WSDOT, 2015) as defined in Title 23 of the Code of Federal Regulations, Section 650.305 (23 CFR 650). Compared to culvert crossings, bridge structures have more restrictive design criteria for freeboard, seismic stability, traffic safety, and other design parameters. According to Chapter 10 of the City of Bellevue Transportation Design Manual, all bridges, whether on public streets or private roads, shall meet the minimum requirements set forth in the latest edition of the AASHTO LRFD Bridge Design Specifications (2012), the AASHTO Guide Specifications for LRFD Seismic Bridge Design (2011), and the WSDOT Bridge Design Manual (2016). Furthermore, all bridges shall match the full width and configuration of the street, private road, or path being served (traveled way plus curb, sidewalk, walkway, bike lane, equestrian lane, and shoulder on one or both sides).

4.1 BRIDGE SELECTION EVALUATION CRITERIA

The general location of each bridge will be set primarily by the roadway alignment and Coal Creek. Bridge type, size and other options will be evaluated using the following criteria:

- **Functionality**—Meeting the intent of the proposed culvert removal and the design criteria described in this section.
- **Constructability**—Ease of construction of the bridge, including equipment access, hydraulics, environmental impacts, and public impacts.
- **Construction Cost—**Project cost of the bridge, based on preliminary quantity takeoffs and current unit costs.

4.2 BRIDGE DESIGN

4.2.1 Dead Loads

The weight of the structure and the soil over substructure components will be determined using the following unit weights:

- Concrete: 160 pounds per cubic foot
- Asphalt concrete pavement overlay (if applicable): 150 pounds per cubic foot
- Structural steel: 490 pounds per cubic foot
- Soil: 120 pounds per cubic foot
- Utility attachments: As recommended by utility companies and approved by the City.

4.2.2 Live Loads

Design live loading will be HL-93 as prescribed by *AASHTO LRFD Bridge Design Specifications*. Multiple lane live load reduction factors will be used for the superstructure and substructure design.

4.2.3 Earth Pressures

The weight of soil and equivalent lateral fluid pressures are found in the geotechnical report in Appendix A.

4.2.4 Seismic Forces

Bridge seismic design will be in accordance with the *AASHTO LRFD Bridge Design Specifications*. Site-specific seismic design parameters such as peak bedrock acceleration, site factors, and short and long period accelerations are found in the geotechnical report in Appendix A.

4.2.5 Stream Flow

The effect of flowing water on portions of the substructure and buoyancy will be calculated in accordance with the provisions of *AASHTO LRFD Bridge Design Specifications*. Section D4-04.4 (B) of the Surface Water Design Standards (COB, 2016) specifies the 100-year peak flow rate as the design level of service for conveyance.

Scour protection measures should be installed to a depth at least two times the potential scour depth.

4.2.6 Vertical Clearance

A vertical clearance of 6 feet from the channel thalweg and the low chord of the bridge and minimum 1 foot clearance between the bottom of the bridge superstructure and the 100-year water surface elevation is required. Section D4-04.4 (B) of the Surface Water Design Standards (COB, 2016) specifies the 100-year peak flow rate as the design level of service for conveyance. Section D4-04.6 (B) requires one-foot of freeboard below the low-chord of the bridge for the 100-year peak flow event. Additional discussion on clearance and freeboard is provided in Section 9.4.

4.3 BRIDGE FOUNDATION EVALUATION

The geotechnical investigation (see Chapter 6 and Appendix A) revealed very poor soil conditions under each bridge location. The project area consists of about 5 feet of fill over 25 to 55 feet of very soft and liquefiable material, which is compounded by a high water table about 6 feet below existing grade. The poor soil conditions prompted the evaluation of foundation options beyond the typical spread footing approach commonly used for precast culverts. This evaluation is documented in the memo *Lower Coal Creek Culvert Replacement Alternative Concepts*, provided in Appendix B. After weighing the seismic performance, ease of construction, neighborhood impacts, and costs associated with each option, a pile-supported structure was recommended as the preferred foundation support for the bridge crossings. This option was determined to have the best seismic performance, fewer constructability issues, and the lowest risk of impacting adjacent residential structures from dewatering and vibration.

A subsequent analysis evaluated the feasibility of two pile foundation options: helical piles and drilled shaft. This evaluation is documented in the memo *Lower Coal Creek Culvert Foundation to Support Earthquake Loads*, also provided in Appendix B. This evaluation recommended the drilled shaft option because it is expected to be less expensive and its design provides a more robust foundation system that will perform better during a seismic event and normal vehicular loading. It was also recommended that the structure be a precast or cast in pace concrete flat slab bridge. The concrete flat slab bridge will consist of four drilled shafts (one at each corner of the bridge), a substantial (5-foot deep) cap beam between the shafts parallel to the stream, and either a 12-thick precast pre-stressed concrete deck panels or 16-inch cast-in-place concrete slab between the cap beams to form the bridge deck.

5. ROADWAY DESIGN

The project will restore each road crossing to match existing conditions to the greatest extent possible. Existing sidewalks will be upgraded to meet requirements of the Americans with Disabilities Act. Crossings without sidewalks will be designed to accommodate future sidewalk width. The road profile of upper Skagit Key, Glacier Key, and Newport Key will be raised to meet minimum hydraulic clearance design criteria (see Sections 4.2.6 and 9.4) using a double tangent profile. Table 3 summarizes roadway design criteria.

Table 3. Roadway Design Criteria

Design Element	Standard	Citation	Design Criteria
Posted Speed	25 mph	Match existing	Per standard
Design Speed	25 mph	Match existing	Per standard
Lane Width	12 feet	Match existing	Per standard
Maximum angle point without vertical curve	1%	2011 AASHTO Green Book	4% to 5%[a] Low Speed Roadway
Vertical curve length	K=12.0	2011 AASHTO Green Book	Not applicable for tangent design
Tangent Slope	4 – 10%		Per Bellevue Transportation Dept. recommendation
Shoulder Width	4 feet	Match existing	Per standard
Curb Type	Vertical	TDDM Standard 11	Per standard
Sidewalk Width	5 feet	TDDM Standard 14	Per standard
Barrier Type		TDDM Standard 10, Traffic rated with railing	Oregon style with pedestrian rail

a. Design criteria deviation from the standard is justified for the maximum angle point without vertical curve because the roadways are low speed.

5.1 HORIZONTAL ALIGNMENT AND BRIDGE SECTION

The current horizontal alignment will be maintained. For all road crossings, the proposed roadway section (see Figure 7) will be sized to match the existing roadway, at 32 feet wide (curb to curb). This will include two 12-foot-wide travel lanes and a 4-foot shoulder. A 5-foot sidewalk is proposed on both sides of the street, except at Cascade Key and upper Skagit Key. At these locations, 5-foot sidewalk will only be provided where sidewalk currently exists. Sidewalk will be provided on the east side of Cascade Key and the west side of upper Skagit Key. This section will be held through the entire length of new roadway.

A 54-inch-high open rail TL-1 traffic barrier with pedestrian rail will be provided at each end of the bridge (see Figure 8). Residents in the Newport Shores neighborhood have requested a traffic barrier that would allow them to see the stream as they drove and walked over the bridge. The residents have also requested a decorative feature on the concrete tapers at the bridge ends.

5.2 VERTICAL ALIGNMENT

The road profile at the gutter line will need to be a minimum of 2.17 feet above the 100-year water surface elevation to accommodate vertical clearance requirements and the proposed deck configuration (1 foot freeboard, 12” bridge deck, minimum 2” asphalt). The existing road profile at Cascade Key and lower Skagit Key is sufficiently high enough and will be maintained. At upper Skagit Key, Glacier Key, and Newport Key, the road profile will be raised to accommodate the higher low chord needed to provide 1 foot of clearance above the 100-year water surface elevation. This will require raising the road profile 1 to 1.5 feet at the center of the structure. A raised section will be constructed as a double-tangent profile with 4 to 5 % approaches and a level grade over the bridge. Table 4 shows the low-chord and top of road elevation required at each structure.

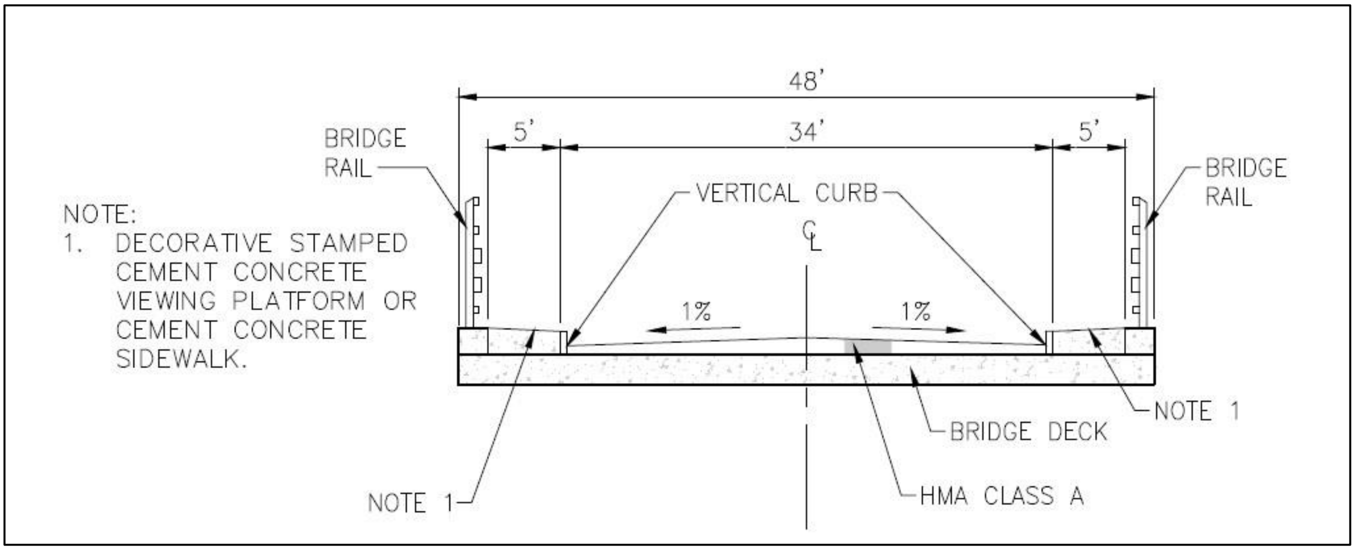

Figure 7. Typical Roadway Cross Section

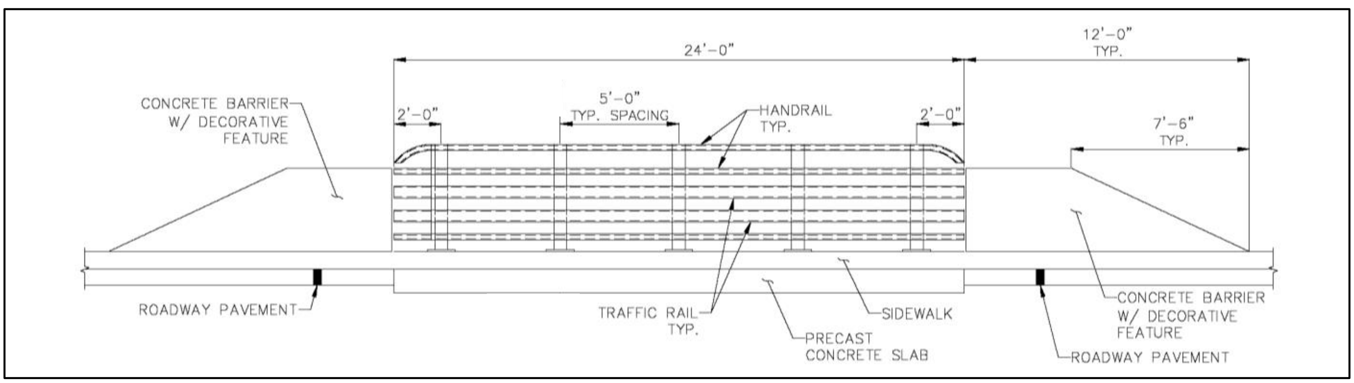

Figure 8. Open Rail Traffic Barrier with Pedestrian Rail

Table 4. Vertical Profile at Upper Skagit, Glacier and Newport Key

Design Element	Upper Skagit Key	Glacier Key	Newport Key
Proposed Low-Chord Elevation (feet NAVD88)	40.7	31.2	27.8
Existing Road Profile Elevation (feet NAVD88)	40.4	30.9	27.9
Proposed Road Profile Elevation (feet NAVD88)	41.9	32.4	29.0
Area of Roadway Replaced (square feet)	3,900	4,700	3,800
Length of Roadway Replaced (feet)	122	148	119

Note: NAVD88 = North American Vertical Datum of 1988

5.3 TRAFFIC MANAGEMENT

Except at the Cascade Key crossing, the network of roads in the neighborhood provides easy alternative driving routes, so the road in the vicinity of each crossing will be closed to all through traffic during construction of the bridge. A detour route will be posted indicating an alternative route for drivers.

Cascade Key is the only access to the southern half of the neighborhood, so the bridge at that crossing will be constructed in halves, leaving a single lane open to traffic throughout construction. This crossing will be signed to indicate a speed reduction, lane width reduction and yield to oncoming traffic. This will be a bidding requirement of the contractor so access to the neighborhood is maintained.

6. GEOTECHNICAL INVESTIGATION

A preliminary geotechnical investigation for this project included review of previous geotechnical investigations in the area, field explorations and laboratory testing of subsurface samples, and assessment of site soil and groundwater conditions. The field explorations consisted of five borings completed in 2015 at each road crossing. A conceptual geologic cross section developed from this information generally follows the creek alignment from I-405 to Lake Washington.

The local geology consists of fill material from the ground surface to a depth of 5 to 9 feet. A 15- to 45-foot thick weak, compressible layer of organic rich sediments and lake deposits underlie the fill layer. Glacial recessional deposits of dense sand and gravel are found at depths ranging from 20 feet below ground surface near Cascade Key and Upper Skagit Key to 50 feet below ground surface at Newport Key and Lower Skagit Key. Groundwater level ranges from 5 to 7 feet below the ground surface, at about the same level as stream flow in Coal Creek.

Seismicity was assessed based on peak bedrock acceleration (PBA) using established seismic risk models. The selected design event for this project is the event with a 7-percent probability of exceedance in 75 years (approximately 1,000-year recurrence interval) per the AASHTO Guide Specifications for LRFD Seismic Bridge Design, section 3.2 (AASHTO, 2011). Based on USGS National Seismic Hazard Map data, the event magnitude is 6.99; the ground motion PBA is 0.44g. Site Class E should be assigned for the culvert replacements.

Liquefaction of the saturated fill, very loose to loose (porous) sand, and low-plasticity silt and organic deposits would occur at all five bridge locations during the design seismic event. The total ground surface induced settlement due to liquefaction is estimated to be as follows:

- Cascade Key—3 to 8 inches
- Upper Skagit Key—3 to 8 inches
- Glacier Key—9 to 12 inches
- Newport Key—6 to 12 inches
- Lower Skagit Key—12 to 13 inches.

When saturated, porous soil liquefies during an earthquake it loses almost all of its strength. Seismically induced lateral spreading and flow failures are anticipated throughout the Newport Shores neighborhood. Lateral spreading is characterized as area-wide vertical and horizontal ground deformations on the order of inches to feet of the Coal Creek delta complex toward Lake Washington. Lateral spreading would generally impose lateral loads in the direction of the creek alignment. Flow failure result in the movement of creek banks into the creek bed which would impose lateral loads on piles and abutments, generally in a direction perpendicular to the creek alignment. Deformations would result in significant damage to utilities, roadways, and structures.

Engineering properties of subsurface soils and seismic design parameters are found in the full geotechnical report in Appendix A.

7. STORMWATER

Stormwater conveyance, treatment, flow control and discharge will be designed in accordance with the City of Bellevue 2016 *Storm and Surface Water Standards*. Washington State Department of Ecology *Stormwater Management Manual for Western Washington* (2017) may apply with respect to water quality treatment, per Bellevue City Code Title 24.06.065.

8. UTILITIES

The following utilities are present in the project corridor:

- Underground power
- Phone and cable
- 8- and 6-inch ductile iron water main
- 6-inch ductile iron sanitary sewer force main
- 8-inch sanitary sewer.

The sanitary sewer is deep enough that relocation will not be needed for the installation of the bridges. However, the sanitary sewer will need to be considered during design and construction of the deep foundation system. It is anticipated that all other underground utilities will be attached to the bridge. Proposed alignments and details will be developed as design progresses.

Table 5 lists the size of the utilities, along with purveyor contact information.

Table 5. Utilities

Utility	Owner	Cascade Key	Upper Skagit Key	Glacier Key	Newport Key	Lower Skagit Key
Sanitary Sewer	City of Bellevue Utilities 450 110th Avenue NE Bellevue, WA 98009 425.452.6932 *Debbie Harris, DHarris@bellevuewa.gov*	8” GM[a]	8” GM	8” GM	8” GM and 6” FM	8” GM
Storm Drain	City of Bellevue Utilities 450 110th Avenue NE Bellevue, WA 98009 425.452.6932 *Debbie Harris, DHarris@bellevuewa.gov*	Not Present	12” DS (2 outfalls)	12” DS (2 outfalls)	12” DS (1 outfall)	12” DS (3 outfalls)
Water	City of Bellevue Utilities 450 110th Avenue NE Bellevue, WA 98009 425.452.6932 *Debbie Harris, DHarris@bellevuewa.gov*	8” DS	6” DS	6” DS	8” under road	8” US
Gas	Puget Sound Energy Bellevue, WA *Andy Swayne, andy.swayne@pse.com*	4” US	2” US and DS	2” US	2” US	2” US
Underground Power	Puget Sound Energy Bellevue, WA *Andy Swayne, andy.swayne@pse.com*	2 US & 1 DS	1 US and 1 DS	1 US	2 DS	4 conduits DS
Telecommunications	Century Link 800.283.4237	US and DS	US and DS	DS	DS	DS

GM = Gravity main, FM – Force main, DS = Downstream, US = Upstream
a. Sewer line terminates outside of project area

9. STREAM ELEMENTS

Design flows were developed to evaluate the performance of the existing structures and to size the culvert replacement structures and stream channel design elements. Structures and channel elements are sized to convey the 100-year peak flow rate as the design level of service. The supporting hydrologic and hydraulic analysis are described in Appendix C.

9.1 BASIN HYDROLOGY

The peak annual flood frequency, seasonal frequencies, and other statistics describing the stream flow in Coal Creek were estimated from an HSPF model of the entire Coal Creek basin.

9.1.1 Coal Creek Flood Frequency

Peak flood frequency for each crossing is shown in Table 6. For events up to the 100-year flood, the corresponding flow changes by less than 2 percent from the upper to lower end of the project area. This is logical because the change in drainage area from Cascade Key to lower Skagit Key is very small in proportion to the overall basin drainage area. Additionally, it was found that widening one or several of the existing culverts would not alter peak flood flows at any crossing due to a lack of flood storage along the creek within Newport Shores.

Table 6. Peak Flood Frequency

Crossing	2-Year Return Period	10-Year Return Period	25-Year Return Period	100-Year Return Period
Cascade Key	232 cfs	411 cfs	467 cfs	525 cfs
Upper Skagit Key	232 cfs	411 cfs	467 cfs	525 cfs
Glacier Key	232 cfs	412 cfs	469 cfs	529 cfs
Newport Key	232 cfs	413 cfs	470 cfs	531 cfs
Lower Skagit Key	234 cfs	415 cfs	472 cfs	535 cfs

9.1.2 Construction Season Flood Probability

The probability of Coal Creek flows of different magnitudes occurring during the construction season was investigated using seasonal flood frequency and high-flow-event duration analysis for the 3-month period from July through September and for each individual month in that period. As shown in Table 7, the flow with a 1-percent probability of being exceeded in the 3-month July–September period of any given year is 232 cubic feet per second (cfs), 43 percent of the full-year 100-year flow of 535 cfs.

9.2 STREAM HYDRAULICS

Culvert design, flood levels, and channel stability were evaluated using a one-dimensional, steady-state HEC-RAS hydraulic model of lower Coal Creek. The model was originally developed and calibrated as part of an earlier phase of this project (NHC, 2015), but it was subsequently updated using new channel survey data and updated flood frequency results to improve calibration and model performance at each crossing.

Table 7. Annual Exceedance Probability by Month and Season

Annual Probability of Exceedance	Coal Creek Flow at Corresponding Exceedance Probability (cfs)			
	July	August	September	July–September
50%	19	19	40	62
10%	68	103	113	144
4%	112	157	157	190
1%	162	232	200	232

9.2.1 Modeled Bridge Configuration for Proposed Conditions

A standard bridge configuration was assumed, to model proposed conditions on Coal Creek after completion of this project. Bridges were sized to meet fish passage requirements according to the stream simulation methodology outlined in the Water Crossing Design Guidelines (Barnard, et. al., 2013). A letter report documenting the bank-full width investigation is provided in Appendix C.

Average bank-full widths above the five culverts ranges from 15 to 17 feet, with a minimum of 12.3 feet and a maximum of 20.3 feet. Washington Department of Fish and Wildlife design guidance suggests that the culvert bed width be 20 percent larger than the bank-full width plus 2 feet (Barnard et al., 2013, Equation 3.2). Based on the observed bank-full width values, the computed minimum width for the culverts would range from 20.0 to 22.4 feet at the various culvert crossings. A single width is proposed for all five crossings in the project, so a width of 24 feet was assumed for the analysis of replacement bridges.

The proposed-condition HEC-RAS modeling assumed regrading of surrounding banks at culvert faces (within the right of way) and bridge structures modeled as 24-foot-wide openings with the low-chord above the 100-year water surface elevation. The Manning’s ‘n’ values, representing friction, was uniformly set to 0.04 through the structures.

9.2.2 Existing and Proposed Flood Profiles

The recalibrated HEC-RAS model was used to estimate the water surface profiles for the 2-, 10-, 25-, and 100-year events under existing conditions. Proposed-condition water surface profiles were then computed to assess flood reduction benefits of the culvert replacements. Figure 9 compares the computed existing and proposed condition water surface profiles for the 100-year peak flood event.

The largest flood event recorded on lower Coal Creek (2007) had a peak flow of about 460 cfs, slightly less than the 25-year event at all project crossings. During this event, overtopping of the road surface did not occur except at Cascade Key, where a piece of wood blocked the culvert entrance. These observations are consistent with modeling of existing conditions, which does not predict overtopping of the culverts for flows below a 100-year event; at the 100-year event, the existing-conditions modeling predicts overtopping at all but the lower Skagit Key crossing.

Under proposed conditions, with 24-foot wide bridge structures, overtopping during a 100-year event is not predicted at any crossing, and flood level reductions upstream of the crossings are on the order of 1.5 to 3 feet.

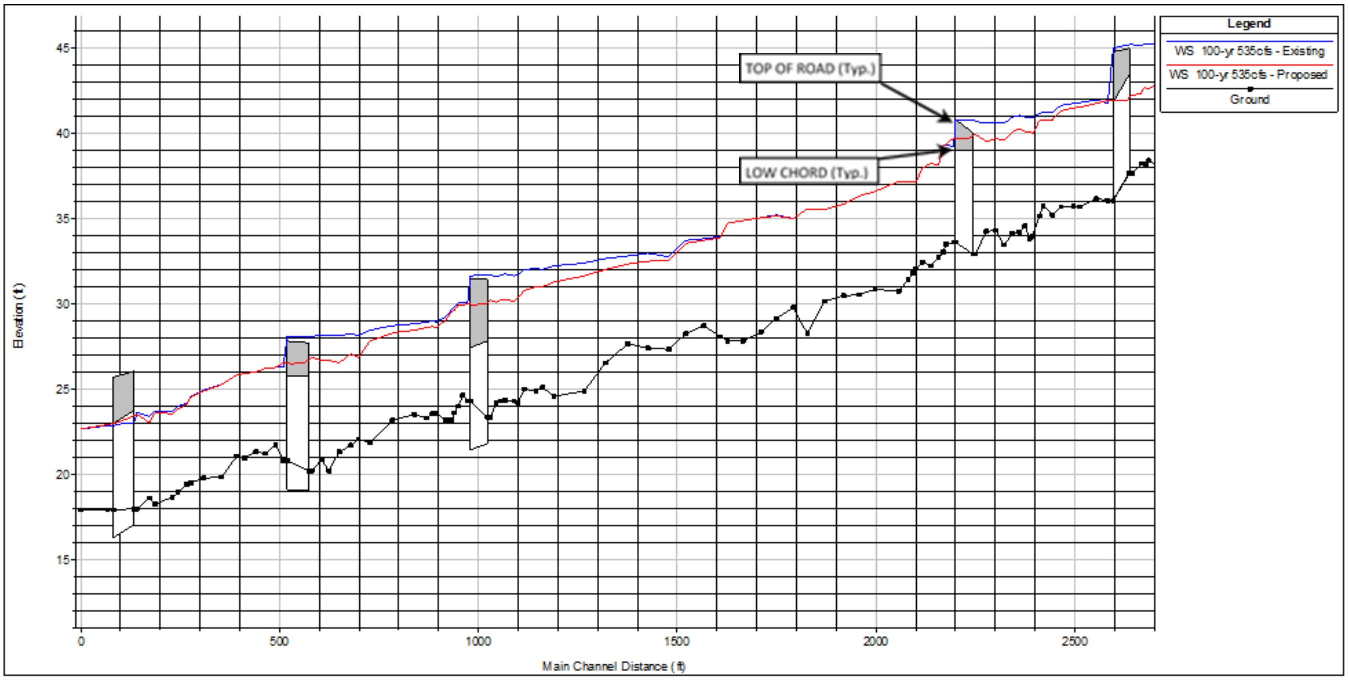

Figure 9. 100-Year Water Surface Profile for Existing and Proposed Conditions

9.3 STREAMBED DESIGN

9.3.1 Channel Bed Scour

Channel stability and scour were evaluated using field data, HEC-RAS modeling, and standard bed scour relations. Field data consisted of streambed sampling in fall 2015 to determine grainsize composition at each crossing.

Localized scour at each crossing was estimated using the "competent velocity" method outlined in TAC (2004). This method assumes that scour within a constricted waterway (e.g. bottomless culvert) will occur until the mean velocity is lower than the competent velocity, defined as the velocity that is able to mobilize bed material. The procedure was implemented iteratively using the HEC-RAS model. Assuming a 100-year flow, the bed level in the culvert was manually lowered until computed velocities within the barrel did not exceed the competent velocity for the existing surface and subsurface D50 particle diameters measured upstream at each crossing. Table 8 summarizes the results.

Table 8. Summary of Competent Velocity Scour Analysis

Crossing	Computed 100-Year Bridge Velocity, Existing Bed (feet/second)	Upstream D50 (mm)		Competent Velocity (feet/second)		Estimated Scour Depth Below Existing Bed (feet)	New Computed 100-Year Bridge Velocity, Existing Bed (feet/second)
		Surface	Subsurface	Surface	Subsurface		
Cascade Key	5.9	53	42	6.9	5.9	1	5.2
Upper Skagit Key	7.7	52	19	6.9	4.9	3.5	4.7
Glacier Key	6.0	40	32	5.9	4.6	3	4.0
Newport Key	6.4	43	13	4.6	3.9	4.5	3.9
Lower Skagit Key	5.5	41	24	4.6	4.3	3	4.1

Given that subsurface particle diameters are smaller and therefore mobilized at a lower competent velocity, they generally dictate the amount of scour predicted to occur at each culvert. For example, the smaller subsurface D50 of 13 mm at Newport Key results in the most significant scour depth of 4.5 feet below existing bed levels, whereas the coarsest subsurface D50 at Cascade Key results in a scour depth of 1 foot. With site-specific variation, scour depths for a 100-year design flow are expected to range from 3 to 4 feet along lower Coal Creek.

Sheet pile walls on the interior of the bridge abutment are proposed to protect he bridge structure from scour. The embedment depth of the sheet pile should be 1 to 2 times the scour depth.

Due to the potential for both reach-wide and local channel scour following culvert replacement, coarse sediment bands would be constructed within the channel of each bridge structure. In addition to providing grade control, the coarse sediment bands, spaced at minimum of one bank-full width, would prevent channel widening and help maintain definition of a low-flow channel. Following streambed sizing guidelines provided in the *Water Crossing Design Guidelines* (Barnard, et. al., 2013), the low flow channel bed material would be sized using the following ratios:

- D84/D100 = 0.4
- D84/D50 = 2.5
- D84/D16 = 8
- with 5 to 10% fines added to mixture.

These ratios, and measured D84 particle diameters in lower Coal Creek, yield streambed mixtures with D100 diameters of 160 to 230 mm, D50 diameters of 25 to 40 mm, and D16 diameters of approximately 10 mm. Coarse sediment band material would be sized to two times the D100 of the bed material (Barnard et al., 2013)—from 325 to 465 mm. The material used to construct bands within the culvert will be coarser than the neighboring bed material to protect against erosion and maintain established channel dimensions through the culvert.

9.3.2 Bank Stabilization

Lower Coal Creek is channelized and generally disconnected from adjacent floodplains, with much of the bank armored. A field investigation was conducted at the onset of this project phase to document the condition of the banks and identify instabilities. Bank conditions 200 feet upstream and downstream of each crossing were inventoried, except downstream of lower Skagit Key where access was not available. Numerous minor instabilities consisting of localized failures were observed along the reaches, but most were considered minor.

The most severe bank instability was observed on the left bank immediately upstream of upper Skagit Key. Here, a 4- to 5-foot high exposed vertical bank is eroding along the outside of a bend. Failure of past armoring is evident, as riprap lines the toe of the bank. Less severe bank instability was observed on the right bank 100 to 120 feet upstream of Cascade Key. Here, a 4- to 5-foot high rockery wall was observed to be undermined on the outside of an abrupt channel bend. The City of Bellevue will notify the property owner of the existing condition revealed during the field investigation of Coal Creek. Replacement of these culverts will increase the channel's conveyance capacity and reduce immediate flood risk, but also is expected to increase velocities. The potential for geomorphic change exists within the creek currently and will continue to exist after the culverts are replaced.

9.3.3 Large Wood for Bank Protection and Mitigation

Placement of large wood along lower Coal Creek will serve as bank protection as well as habitat mitigation. In total, 41 pieces of wood are being proposed for placement along Coal Creek. Preliminary design calculations have been completed for the log elements, to address buoyant and drag forces acting on the logs. The combined drag and buoyant force acting on an individual log is estimated to be 4.7 tons. To resist this force, non-embedded logs will be held in place with 2 to 4 mechanical anchors and one 2-ton boulder. Mechanical anchors will be secured to both ends of each log to limit movement. The 2-ton boulder (1.2 ton submerged weight) will allow settling and deformation of the structure as the channel adjusts following completion of construction.

Cascade Key

Two groups of wood structures are proposed immediately upstream of the Cascade Key crossing on the left bank and right bank. Three logs will be placed on both banks for flow redirection through the proposed bridge opening as well as for habitat mitigation. Each log will be individually ballasted with a combination of mechanical anchors and a 2-ton boulder. To minimize or eliminate loss of flow conveyance, the root end of these logs will be embedded into the channel and the stem placed in a shallow trench along the slope.

Upper Skagit Key

Severe bank instability on the left bank upstream of the Skagit Key crossing will be addressed with construction of a 35-foot log crib wall and bioengineered bank. The bank will be excavated to allow placement of the crib structure, composed of three layers of logs, with the lowest layer of logs placed below the current thalweg elevation. The logs will be lashed together with chain, and select logs secured with mechanical anchors. After backfilling the crib structure with native materials, the upper bank will be reconstructed with coir-wrapped soil lifts and live plantings. Three additional ballasted logs will be placed on the immediate opposite bank for flow redirection and habitat purposes. To eliminate loss of any significant flood conveyance capacity, the root end of these logs will be dug into the channel and the stem will be placed in a shallow trench along the slope. Each of the logs will be held in place with a combination of two mechanical anchors and a 2-ton boulder.

Newport Key

Although significant bank instability was not observed at Newport Key, large wood features are being proposed upstream and downstream of the crossing to create diversified habitat along the currently uniform, straight reach. Five structures upstream and four downstream, consisting of two ballasted anchored logs each, are proposed. To maintain flood conveyance capacity, the root end of these logs will be dug into the channel and the stems will be placed in a shallow trench along the slope. Each of the logs will be held in place with a combination of two mechanical anchors and a 2-ton boulder.

9.4 BRIDGE HEIGHT AND CLEARANCE

A vertical clearance of 6 feet from the channel thalweg and 1 foot of freeboard is recommended to pass submerged woody debris during the 100-year peak flood event. The recommendation is based on information on reach scale hydrology and sedimentation provided in the Alternatives Analysis Report (NHC, 2015) and an analysis of debris loading potential by NHC (see Appendix C) and summarized below.

- Low to moderate debris loading potential in the project reach due to:
    - Limited stream length available for recruitment of large woody debris and the size of observed woody material within the project area.
    - Limited potential for channel migration downstream of I-405 because of prevalence of bank revetments, and cohesive bank material.
- Relative flashiness of the peak flow hydrograph where high flow depths only occur for a few hours.
- Due to upstream sediment control measures and the current armored condition, the channel bed is stable and expected to remain stable in the future.
- Presence of the I-405 Pond control structure, located on Coal Creek upstream of the project site, includes a trash rack that traps large wood before it enters the I-405 box culvert. This structure limits wood recruitment to the project reach and the 600 foot long reach between I-405 and Cascade Key, cutting off delivery from over 97% of the upstream channel.

- Stream channel conditions would likely prohibit large woody material with attached rootwads from being mobile. The longest logs expected to be transported by the creek would be equivalent to the narrowest locations along the channel, which are typically around 12'. Considering that this is much shorter than height of trees with significant rootwads, this length should prohibit LWM with attached rootwads from being mobile in the creek.
- The largest diameter large woody material was found to be 36". If this log was mobilized with 2/3 submergence would require 1 foot of clearance at the bridge to safely pass the log during high flows.

The 100-year maximum water surface elevations at each crossing (see Figure 9) define the minimum soffit height required for clear flow through the crossing. Table 9 provides summary design parameters for each bridge based on the modeling results.

The existing road profiles at Cascade and lower Skagit Key are high enough to provide 1 foot of freeboard for the 100-year event and will not need to be raised. At upper Skagit, Glacier, and Newport Key, the road will need to be raised between 1.1 to 1.4 feet to obtain 1 foot of freeboard. The bridge opening height, defined as distance between the proposed bed level and soffit elevation, is in excess of 6 feet at all locations. A memorandum documenting the bridge clearance investigation is provided in Appendix C.

Table 9. Bridge Height and Clearance

Crossing	Cascade Key	Upper Skagit Key	Glacier Key	Newport Key	Lower Skagit Key
100-Year Flow (cfs)	525	527	529	533	535
Upstream 100-Year Water Surface Elevation (feet NAVD88)	42.2	39.7	30.2	26.8	23.3
Existing Top of Road Elevation (feet NAVD88)	44.7	40.4	30.9	27.9	26.1
Proposed Top of Road Elevation (feet NAVD88)	44.7	41.9	32.4	29.0	26.1
Low Chord Elevation (feet NAVD88)	43.5	40.7	31.2	27.8	24.9
Freeboard (feet)	1.3	1.0	1.0	1.0	1.6
Road Raise Height (feet)	0.0	1.5	1.5	1.1	0.0
Channel Thalweg (feet NAVD88)	37.3	33.0	24.7	20.9	18.5
Opening Height (feet)	6.3	7.7	6.5	6.9	6.4

Note: NAVD88 = North American Vertical Datum of 1988

9.5 STREAM BYPASS

The stream will be bypassed through the construction site during the culvert replacement. It is anticipated that a 42-inch smooth bore pipe will be used to route the creek through the construction zone. The creek will be temporarily dammed using sandbags or a sheet-pile cofferdam configuration at the upstream and downstream end of the bypass pipe, to a minimum height of 4.5 feet above the channel thalweg. The bypass flow will be about 62 cfs, which corresponds to the 2-year flow predicted by NHC for the July through September construction period. Summer flow characteristics are documented in Section 9.1.2.

Local groundwater seepage will be controlled by sump pumps strategically located and discharged into an approved disposal facility.

10. PERMITTING

This chapter reviews environmental and construction permits and approvals to identify those that are needed for the Lower Coal Creek Flood Hazard Reduction project.

10.1 FEDERAL AGENCY PERMITS AND APPROVALS

10.1.1 Section 404 Nationwide Permits

Section 404 Nationwide permits from the U.S. Army Corps of Engineers cover placement of fill material in wetlands or other waters of the United States. Specific permits required are based on the type of work being performed. For the Lower Coal Creek Flood Hazard Reduction project, the following nationwide permits would be required:

- NWP 14—For linear transportation projects, including bridges
- NWP 3—For maintenance projects
- NWP 27—For habitat restoration projects
- NWP 13—For bank stabilization projects.

This approval is prepared using Washington State’s Joint Aquatic Resource Project Application (JARPA) form.

10.1.2 Section 7 Endangered Species Act Consultation

Under Section 7 of the federal Endangered Species Act, if a project requires federal permits and may affect any species listed under the Endangered Species Act or its critical habitat, then consultation is required with the National Marine Fisheries Service to ensure that the project will not jeopardize the continued existence of the species or adversely modify the critical habitat. This requirement will be triggered for the Lower Coal Creek Flood Hazard Reduction project because of the required Section 404 permits. A biological evaluation will have to be prepared. This consultation is included in the JARPA process.

10.1.3 Section 10 Rivers and Harbors Act

Section 10 approval from the U.S. Army Corps of Engineers is required for construction in, over, under or near navigable waters of the United States. The approval is prepared using the JARPA form. It is not anticipated to be required for the Lower Coal Creek Flood Hazard Reduction project.

10.2 WASHINGTON STATE AGENCY PERMITS AND APPROVALS

10.2.1 Section 106 National Historic Preservation Act Consultation

Under Section 106 of the National Historic Preservation Act, consultation on potential impact on cultural or historic resources is required for projects that require a federal permit. This requirement will be triggered for the Lower Coal Creek Flood Hazard Reduction project because of the required Section 404 permits. Consultation will be with the Washington Department of Archaeology and Historic Preservation and potentially affected tribes. An area of potential effect letter/cultural resources report will have to be prepared for an initial consultation. Final submittal will depend on the outcome of initial consultation. This consultation is included in the JARPA process.

10.2.2 Hydraulic Project Approval

For this project, a Hydraulic Project Approval from the Washington Department of Fish and Wildlife is needed for work in or over the ordinary high water of a water of the state or waterway containing priority fish. The application is included in the JARPA form.

10.3 CITY OF BELLEVUE PERMITS, APPROVALS, AND REVIEWS

The permit process for the City of Bellevue is initiated by submitting an Application for Land Use Approval. City staff make the determination on the additional permits and approvals that are required for the project after review of the application. The permits and approvals listed below will be required for the culvert replacement projects.

10.3.1 State Environmental Policy Act Threshold Determination

The State Environmental Policy Act (SEPA) requires all government agencies to consider the environmental impacts of a proposal before making decisions. Requirements for a SEPA review depend on the specific work proposed for each project and whether it includes impacts on critical areas. A SEPA environmental checklist will be prepared and submitted for the Lower Coal Creek Flood Hazard Reduction project. A checklist will provide information to help the agency identify impacts and decide whether an environmental impact statement is required. The City will issue a SEPA threshold determination based on the checklist. Environmental review is submitted as a Preliminary SEPA for the threshold determination and may need to be updated during design development. Preliminary SEPA is submitted with the Critical Areas Land Use Permit.

10.3.2 Critical Areas Land Use Permit

City of Bellevue critical areas land use permit is required if construction and related activities will cause disturbance within sensitive areas. A critical areas study must be prepared that identifies impacts on critical areas. All elements of the Lower Coal Creek Flood Hazard Reduction project beyond the road prism will occur within critical areas and will require a separate authorization from the City.

10.3.3 Clear and Grade Permit

A Clear and Grade permit is required for projects with infrastructure improvements including roads, streets, and utilities. The Clear and Grade permit draws primarily from information prepared for design. A construction stormwater pollution prevention plan must also be prepared.

10.3.4 Shoreline Substantial Development Permit

A Shoreline Substantial Development Permit is required for regulated activities within Bellevue’s designated Shoreline Management Zone. Requirements for the permit depend on the specific work proposed and the location of the work. Generally, bridge projects that do not change the use or configuration of the structure and that do not require filling or grading in the Shoreline Management Zone are exempt. Based on a meeting with the City of Bellevue Planning Department, a Shoreline Substantial Development Permit will not be required because the bridge projects are outside the Shoreline Management Zone jurisdiction.

10.4 CONSTRUCTION PERMITS

It is anticipated that the contractor will need to obtain the following permits prior to construction:

- King County Industrial Waste Discharge permit
- City of Bellevue Right-of-Way Use permit

- Washington State Department of Ecology Notice of Intent for Coverage under the NPDES Construction Stormwater General Permit.

11. 30-PERCENT DESIGN DOCUMENTS

11.1 PLANS

The 30-percent construction plans for this project are provided in Appendix D.

11.2 SPECIAL PROVISIONS TO STANDARD SPECIFICATION

Special provisions to the standard specification will be developed in subsequent design phases. Special provisions are anticipated for following:

- Clearing and grubbing (GSP)
- Removal of structure and obstruction (list of removal items) (GSP)
- Streambed sediment/cobbles/boulders (GSP)
- Temporary stream bypass system
- Utility relocation
- Log with root wad
- Crib wall
- Dewatering
- Survey
- Landscape restoration
- Pile foundation system
- Sheet piles
- Bridge decking system.

11.3 COST OPINION

The 30-percent level opinion of probable construction cost for each of the road crossings is shown in Table 10. Cost estimate detail sheets are provided in Appendix E. All costs are in 2016 dollars and include a 30-percent contingency. Construction cost represents the material cost directly associated with the construction of the bridge crossings, using material quantities from the 30-percent design plans. Unit costs are based on bid tabs for similar projects, Washington Department of Transportation unit bid analysis, and engineering judgement. Items with less certain or undefined quantities are based on a percentage of the material cost items. Construction cost includes sales tax of 9.5 percent.

Table 10. 30% Cost Estimate

Crossing	Cost Estimate
Cascade Key	$951,000
Upper Skagit Key	$1,035,000
Glacier Key	$1,110,000
Newport Key	$1,163,000
Lower Skagit Key	$1,041,000
Total Cost	**$5,300,000**

REFERENCES

American Association of State Highway and Transportation Officials. 2011. Guide Specification for LRFD Seismic Bridge Design, Second Edition. Washington, D.C.

American Association of State Highway and Transportation Officials. 2012. LRFD Bridge Design Specifications, Sixth Edition, and the current Interims. Washington, D.C.

American Association of State Highway and Transportation Officials.2011. A Policy on Geometric Design of Highways and Streets (Green Book), 6th Edition. Washington, D.C.

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 Crossing Design Guidelines. Washington Department of Fish and Wildlife. Olympia, WA. http://wdfw.wa.gov/hab/ahg/culverts.htm

City of Bellevue. 2013. Storm and Surface Water Engineering Standards. Bellevue, WA.

City of Bellevue. 2015. Transportation Department Design Manual. Bellevue. WA.

NHC. 2015. Lower Coal Creek Flood Hazard Reduction Alternatives Analysis Report. Prepared for the City of Bellevue and King County Flood Control District. Seattle, WA.

King County and City of Bellevue. 1987. Coal Creek Basin Plan and Final Environmental Impact Statement. Seattle, WA.

King County. 2007. Road Design and Construction Manual. Seattle, WA.

King County. 2016. Surface Water Design Manual. Seattle, WA.

Spearman Engineering. 1997. Sustainable Flood Prevention Plan for Skagit Key Reach of Coal Creek in Bellevue, Washington. Bellingham, WA

Transportation Association of Canada (TAC). 2004. Guide to Bridge Hydraulics. Second Edition.

Tetra Tech/KCM. 2006. Coal Creek Environmental Impact Statement. Prepared for the City of Bellevue. Seattle, WA.

U.S. Army Corps of Engineers (USACE), 1994. Channel Stability Assessment for Flood Control Projects. Engineer Manual (EM) 1110-2-1418. 31 October.

Washington State Department of Ecology. 2005. Stormwater Management Manual for Western Washington. Olympia, WA.

Washington State Department of Transportation. 2015. Bridge Inspection Manual (M36-64.06). Olympia, WA.

Washington State Department of Transportation. 2016. Bridge Design Manual (LRFD) (M23-50). Olympia, WA.

Washington State Department of Transportation. 2016. Standard Specifications for Road, Bridge, and Municipal Construction (M41-10). Olympia, WA.

Washington State Department of Transportation. 2016. Standard Plans for Road, Bridge and Municipal Construction (M21-01). Olympia, WA.

U.S. Department of Transportation. Manual on Uniform Traffic Control Devices. Federal Highway Administration. Washington D.C.

Coal Creek Bridges Preliminary Design Report

Appendix A. Geotechnical Report

A. Geotechnical Report

Appendix B. Preliminary Design Concepts

B. PRELIMINARY DESIGN CONCEPTS

Appendix C. Stream Design, Bank-Full Width and Debris Loading

C. STREAM DESIGN, BANK-FULL WIDTH AND DEBRIS LOADING

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Appendix D. 30% Plans

D. 30% PLANS

Coal Creek Bridges Preliminary Design Report

Appendix E. 30% Cost Opinion

E. 30% Cost Opinion