MEMO

Date: February 22, 2020~~January 13, 2020~~

To: Nelson Davis, Anne Carr, Josh Fedora

From: Aaron Olson, PE; Leonardos Tsellos

Subject: Confluence Parkway Bridge Feasibility Study

The purpose of this memo is to provide a summary of the results of a bridge feasibility study performed in support of the larger SR 285/N Wenatchee Ave Bypass (Confluence Parkway) project for the City of Wenatchee.

Introduction

In support of the larger SR 285/N Wenatchee Ave Bypass (Confluence Parkway) project for the City of Wenatchee, KPFF contracted with KPG to perform a bridge feasibility study for a proposed bridge crossing of the Wenatchee River. Five bridge alternatives were evaluated including three long-span structures that are able to clear span the river and two conventional structures that will require supports within the waterway. Each alternative is evaluated for how it fits within the proposed project site, constructability and preliminary construction costs.

Basis of Design & Design Data

The following design criterion were used as references in the development of this bridge feasibility study:

- Washington State Department of Transportation Bridge Design Manual (WSDOT BDM) M 23-50, latest edition
- American Association of Transportation and Highway Officials LRFD Bridge Design Specifications (AASHTO LRFD), latest edition
- AASHTO Guide Specifications for LRFD Seismic Bridge Design (AASHTO Seismic), latest edition
- WSDOT Geotechnical Design Manual (WSDOT GDM) M 46-03, latest edition

In addition to the aforementioned design criterion, the following reference documents were used to help inform the results of the study:

- Wenatchee River Crossing SR 285/North Wenatchee Avenue Bypass Geotechnical Report Permitting and Preliminary Engineering by GeoEngineers, dated April 26, 2019

- Proposed Confluence Parks Pedestrian Bridge Plans by Converse Consultants, dated October 1987
- Elwha River Bridge Replacement Plans (CRP No. C1190), dated June 2007

Other design data that was not available at the time of the study but that could significantly affect the results of this study include:

- Critical area delineation/mapping including, but not limited to, wetlands, ordinary high water mark (OHWM), archaeological resources, etc.
- Site specific hydrologic and hydraulic analyses including floodplain and floodway mapping, 100-year flood elevations including required structure clearances, no-rise analysis, 100-year and 500-year scour elevations, channel migration, etc.
- Site specific geotechnical explorations and analyses including foundation design parameters, seismic design parameters, seismic induced lateral spreading, liquefaction and downdrag loads, global stability of abutments and retaining wall structures, and construction considerations.

Further discussion of the potential impacts on this lack of design data on the results of this study is included in the Next Steps section of this memo.

Site Constraints

The proposed Confluence Parkway roadway is located in Wenatchee, WA and runs in a north-south direction. As shown in Figure 1, the proposed roadway and bridge crosses the Wenatchee River just north of downtown. The proposed roadway is bounded to the east by the existing Confluence Parks Pedestrian Bridge and to the west by the existing BNSF railroad bridge. Further west of the BNSF crossing is a bridge crossing that carries State Route 285.

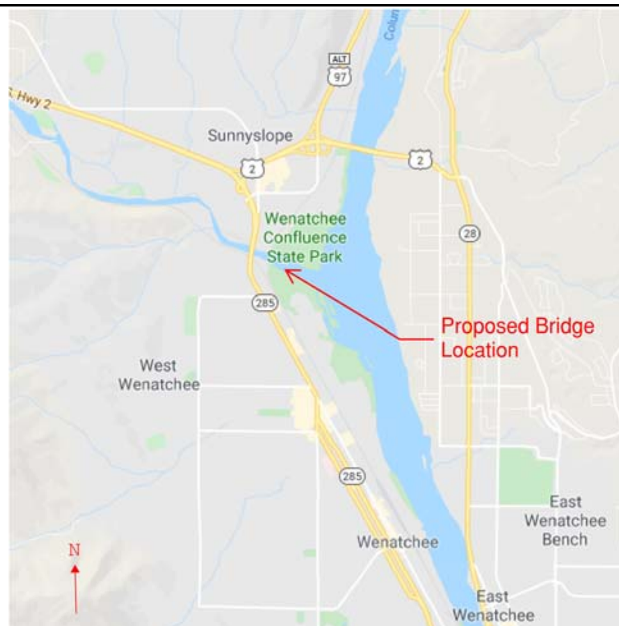

Figure 1: Proposed Bridge & Roadway Site Map

Figure 2 shows the proposed roadway in the vicinity of the Wenatchee River. The western edge of the roadway is approximately 75 feet east of the existing BNSF bridge and the eastern edge of the roadway is approximately 90 feet west of the existing pedestrian bridge. These horizontal clearances should provide adequate room to construct the proposed bridge crossing. It is recommended that the major construction activities and staging be performed as far as possible away from the BNSF right-of-way (ROW) and existing bridge crossing. BNSF coordination and permitting can be a time consuming and costly process which should be avoided or minimized whenever possible.

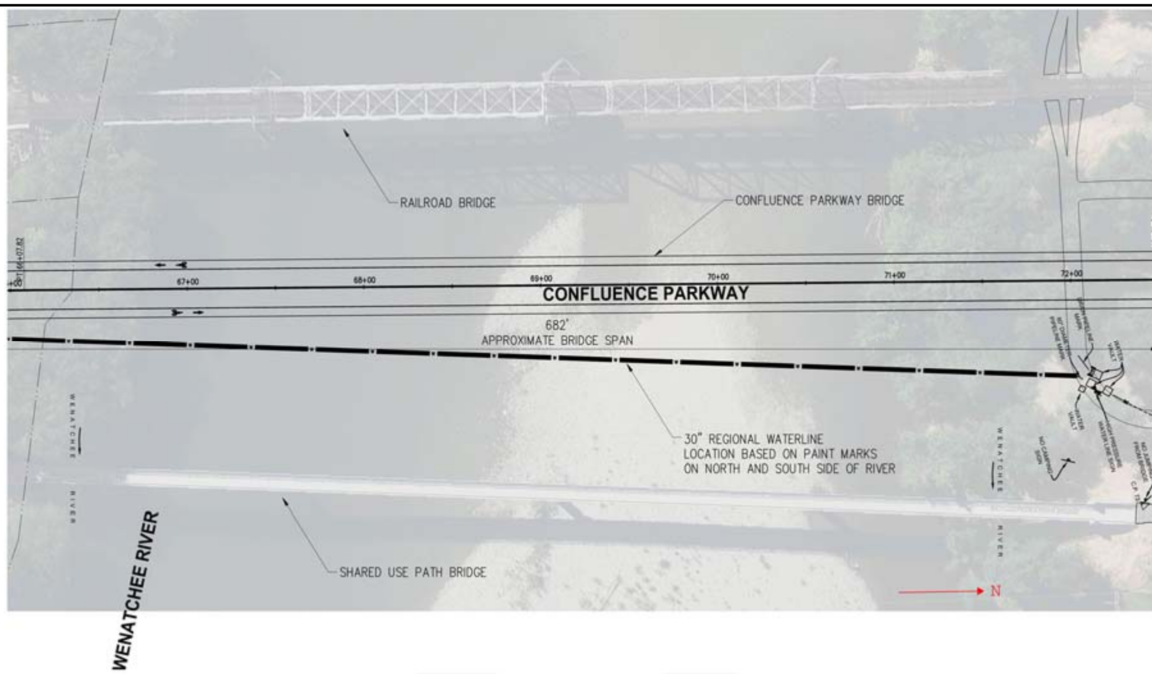

Figure 2: Site Plan at Proposed Bridge Crossing

In addition to the existing BNSF and pedestrian bridges, there is a 30-inch diameter regional waterline in the immediate vicinity of the proposed bridge. The exact location of this waterline is unknown at this time due to limited survey information. For the purposes of this study, it is assumed that the waterline is either not in conflict with the proposed bridge crossing or that it can be relocated to the proposed structure.

Bridge Alternatives

For the purposes of this study, the following common assumptions were used for all bridge configurations:

- Roadway Width = 32 feet consisting of (2) 11ft lanes and (2) 5ft bike lanes
- Main Span Bridge Length = 682 feet.
  - This bridge length was provided by KPG and is a conservative estimate of what would be required to clear-span the river based on aerial images and approximate limits of vegetation.
  - The overall bridge length can vary depending on structural requirements.
- Clearance to 100-year flood elevation = 3 feet minimum
  - The flood elevation shown on plans is taken from the Confluence Parks Pedestrian Bridge Plans. This elevation would need to be verified along with the minimum clearance to the structure. The 3ft clearance is typically a regulatory minimum.

Five bridge alternatives were considered for this study. Three of the bridge alternatives are considered to be long-span structures that do not have permanent structure within the limits of the river. These alternatives include a tied arch bridge, truss bridge and cable-stayed bridge. Two of the bridge alternatives are considered to be conventional structure types that will require permanent foundations within the river.

In general, the long-span bridges are considered specialty structures that require more advanced construction techniques/equipment and that typically require areas of expertise that may not be readily available to local contractors. The more conventional bridge types do not typically require the same level of specialization and are more commonplace and familiar to local contractors. Additional discussion of these construction techniques is provided within the descriptions of each bridge type.

Option 1 – Tied Arch Bridge

Bridge Description

As shown in drawing S-101, the tied-arch bridge is classified as a long-span structure as it can span across the river without the need for permanent structure within the river. The tied arch is comprised of four main components: the arch ribs, tie beams, hangers and floorbeams. These components are typically comprised of steel although, in some cases, concrete can be used.

For the proposed span length, the height of the arch rib is estimated to be approximately 136 feet above the roadway surface. The total structure width measured from outside face of the tie beam to outside face of tie beam is estimated to be approximately 45 feet. This results in a very narrow structure considering its overall height. The structure may need to be widened further to increase its stability under lateral loads (e.g. wind and seismic). This would need to be determined via further analysis during design. One advantage of a tied arch bridge is that it has a relatively shallow structural depth below the roadway surface. This allows for the roadway profile to remain lower which reduces approach fills and/or retaining wall heights.

Tied arch bridges are considered to be non-redundant structures. This means that the loss of one of the arch ribs, tie beams or hanger cables could result in the collapse of the structure. While this non-redundancy does not preclude the use of this structure type, it adds additional complexity and cost during design, construction and future maintenance of the bridge. Inspection and maintenance requirements for non-redundant structures are more stringent which increases their life cycle costs when compared to redundant structures.

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Construction Techniques

Techniques used for the construction of tied arch bridges can vary significantly depending on site conditions and the means and methods of the contractor. In general, construction methods fall into two categories: in-situ construction and offsite pre-assembly.

In-situ construction typically involves a significant amount of falsework and temporary structures in order to support both the bridge and the heavy equipment required to assemble the structure. An example of in-situ construction is shown in Figure 3 below. These temporary structures would need to be located within the river below throughout construction. The length of time that these temporary structures would need to be in place would likely exceed the fish window for the Wenatchee River. Permitting conditions for these structures would need to be negotiated with all authorities having jurisdiction.

Figure 3:Example of In-Situ Tied Arch Bridge Construction

Offsite pre-assembly involves fabrication and construction of the majority of the bridge structure in a location that is more accessible for the heavy equipment that is required for construction. The assembled bridge is then transported by barge to the bridge site and then lifted into place. Figure 4 below shows an example of this style of construction. In order for this technique to be feasible in this setting, it would need to be determined whether the depth of the Wenatchee River is adequate to allow transport of the bridge and the heavy lift cranes required. Additionally, a temporary dry dock structure would need to be constructed to facilitate assembly of the bridge prior to transport. This facility would be costly to construct and may be challenging to permit.

Figure 4: Example of Pre-assembly Erection of Tied Arch Bridge

Pros and Cons

Below is a list of pros and cons for the tied arch bridge option:

Pros:

- Clear span of the river
- Shallow structure depth, lower roadway profile
- Aesthetically pleasing

Cons:

- Specialized construction techniques/contractor
- Non-redundant structure
- Increased maintenance/life cycle costs
- High construction costs

Construction Costs

Below are the estimated construction costs for the tied arch bridge option. These costs are based on total square footage of the bridge deck area. Costs for the approach structures and/or roadway fill are not included.

Preliminary Cost Estimate:

- Structure Cost = $20M
- Design Costs = $3M
- Construction Management = $5M
- **Total Costs = $28M**

Design and construction management costs are assumed to be 15% and 25% of the estimated structure cost, respectively.

Option 2 – Truss Bridge

Bridge Description

As shown in drawing S-102, the truss bridge is classified as a long-span structure as it can span across the river without the need for permanent structure within the river. The truss is comprised of four main components: the top chords, bottom chords, diagonal/vertical members and floorbeams. All of these components are steel.

In addition to the main span, there is a back span on either side of the river. These are required to balance out the main span of the structure in order to minimize the depth of the truss. This style of truss is often referred to as a cantilever truss. For the proposed main span length, the maximum depth of the truss at the piers is approximately 75 feet.

The total structure width measured from outside face of the bottom chord to outside face of bottom chord is estimated to be approximately 45 feet. One advantage of a truss bridge is that it has a relatively shallow structural depth below the roadway surface. This allows for the roadway profile to remain lower which reduces approach fills and/or retaining wall heights.

Construction Techniques

One advantage of a cantilever truss is that it can be constructed without having temporary falsework or structures in the river below. The back spans of the structure are constructed first and then the main span is advanced in a piecemeal fashion from both sides of the river until it meets in the middle where it is permanently joined together. This construction technique is demonstrated in Figure 5 below. It should be noted that in this figure the bridge is being deconstructed, however, the principle remains the same.

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Figure 5: Example of Cantilever Truss Bridge Construction

Similar to the tied arch bridge, truss bridges are considered non-redundant structures. This increases their life-cycle costs due to their more stringent maintenance and inspection requirements.

Pros and Cons

Below is a list of pros and cons for the truss bridge option:

Pros:

- Clear span of the river
- Shallow structure depth, lower roadway profile
- Aesthetically pleasing

Cons:

- Specialized construction techniques/contractor
- Non-redundant structure
- Increased maintenance/life cycle costs
- High construction costs

Construction Costs

Below are the estimated construction costs for the tied arch bridge option. These costs are based on total square footage of the bridge deck area. Costs for the approach structures and/or roadway fill are not included.

Preliminary Cost Estimate:

- Structure Cost = $21.5M

- Design Costs = $3.2M
- Construction Management = $5.4M
- **Total Costs = $30.1M**

Design and construction management costs are assumed to be 15% and 25% of the estimated structure cost, respectively.

Option 3 – Cable Stayed Bridge

Bridge Description

As shown in drawing S-103, the cable-stayed bridge is classified as a long-span structure as it can span across the river without the need for permanent structure within the river. The cable stayed bridge is comprised of five main components: the towers, cable stays, edge girder and floorbeams. The towers are typically comprised of concrete while the edge girder can be either concrete or steel. The cable stays are comprised of steel cables.

Similar to the truss bridge, cable stayed bridges often consist of a main span that is anchored to the back spans of the structure. The main span can also be anchored directly into the ground.

The total structure width measured from outside face of the bottom chord to outside face of bottom chord is estimated to be approximately 42 feet. One advantage of a cable-stayed bridge is that it has a relatively shallow structural depth below the roadway surface. This allows for the roadway profile to remain lower which reduces approach fills and/or retaining wall heights

Cable stayed bridges are typically considered to be redundant structures.

Construction Techniques

One advantage of a cable stayed bridge is that it can often be constructed without having temporary falsework or structures in the river below. The back spans of the structure are constructed first and then the main span is advanced in a piecemeal fashion from both sides of the river until it meets in the middle where it is permanently joined together. This construction technique is demonstrated in Figure 6 below.


Figure 6: Example of Cable-Stayed Bridge Construction

Pros and Cons

Below is a list of pros and cons for the cable-stayed bridge option:

Pros:

- Clear span of the river
- Shallow structure depth, lower roadway profile
- Redundant structure
- Aesthetically pleasing

Cons:

- Specialized construction techniques/contractor
- Non-redundant structure
- Increased maintenance/life cycle costs
- High construction costs

Construction Costs

Below are the estimated construction costs for the cable-stayed bridge option. These costs are based on total square footage of the bridge deck area. Costs for the approach structures and/or roadway fill are not included.

Preliminary Cost Estimate:

- Structure Cost = $31M
- Design Costs = $4.7M
- Construction Management = $7.8M
- **Total Costs = $43.4M**

Design and construction management costs are assumed to be 15% and 25% of the estimated structure cost, respectively.

Option 4 – Steel Plate Girder Bridge

Bridge Description

As shown in drawing S-104, the steel plate girder bridge is classified as a conventional structure as it requires intermediate supports within the river. This bridge is comprised of two primary components: the steel plate girders and the concrete bridge deck. Each foundation within the river consists of a single, reinforced concrete column supported on a concrete drilled shaft.

The total structure width measured from outside face of the bottom chord to outside face of bottom chord is equal to the roadway width as the girders are inset from the edge of the bridge deck. Because the girders are below the roadway, the roadway profile may need to be increased in order to maintain required clearances to the 100-year flood elevation or other obstructions below.

Steel plate girder bridges are considered to be redundant structures.

Construction Techniques

As previously mentioned, a steel plate girder bridge will require that foundations be placed within the river. This will require falsework and temporary structures be placed in the river in order to construct the bridge foundations and erect the plate girders. These temporary structures do not need to be in place in order to place the bridge deck concrete or traffic barriers. With careful planning and the use of prefabricated elements (e.g. columns and crossbeams), it is likely that all construction activities, including installation and removal of the temporary structures, could occur within the fish window.

This type of bridge construction does not otherwise require the use of specialty equipment or contractors.

Pros and Cons

Below is a list of pros and cons for the steel plate girder bridge option:

Pros:

- Common construction techniques
- Lower construction costs
- Redundant structure
- Lower maintenance/life cycle costs

Cons:

- Permanent structure within the river
- Deeper structure, increased roadway profile

Construction Costs

Below are the estimated construction costs for the steel plate girder bridge option. These costs are based on total square footage of the bridge deck area. Costs for the approach structures and/or fill are not included.

Preliminary Cost Estimate:

- Structure Cost = $9M
- Design Costs = $1.4M
- Construction Management = $2.3M
- **Total Costs = $12.6M**

Design and construction management costs are assumed to be 15% and 25% of the estimated structure cost, respectively.

Option 5 – Prestressed Concrete Girder Bridge

Bridge Description

As shown in drawing S-104, the prestressed concrete girder bridge is classified as a conventional structure as it requires intermediate supports within the river. This bridge is comprised of two primary components: the prestressed concrete girders and the concrete bridge deck. Each foundation within the river consists of a single, reinforced concrete column supported on a concrete drilled shaft.

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The total structure width measured from outside face of the bottom chord to outside face of bottom chord is equal to the roadway width as the girders are inset from the edge of the bridge deck. Because the girders are below the roadway, the roadway profile may need to be increased in order to maintain required clearances to the 100-year flood elevation or other obstructions below.

Prestressed concrete girder bridges are considered to be redundant structures.

Construction Techniques

As previously mentioned, a prestressed concrete girder bridge will require that foundations be placed within the river. This will require falsework and temporary structures be placed in the river in order to construct the bridge foundations and erect the girders. These temporary structures do not need to be in place in order to place the bridge deck concrete or traffic barriers. With careful planning and the use of prefabricated elements (e.g. columns and crossbeams), it is likely that all construction activities, including installation and removal of the temporary structures, could occur within the fish window.

This type of bridge construction does not otherwise require the use of specialty equipment or contractors.

Pros and Cons

Below is a list of pros and cons for the prestressed concrete girder bridge option:

Pros:

- Common construction techniques
- Lower construction costs
- Redundant structure
- Lower maintenance/life cycle costs

Cons:

- Permanent structure within the river
- Deeper structure, increased roadway profile

Construction Costs

Below are the estimated construction costs for the prestressed concrete girder bridge option. These costs are based on total square footage of the bridge deck area. Costs for the approach structures and/or roadway fill are not included.

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Preliminary Cost Estimate:

- Structure Cost = $9.5M
- Design Costs = $1.4M
- Construction Management = $2.3M
- **Total Costs = $13.3M**

Design and construction management costs are assumed to be 15% and 25% of the estimated structure cost, respectively.

Integrated Pedestrian Facility

As part of this feasibility study, KPFF was asked to evaluate the effects of integrating a pedestrian facility that would be suspended from below the proposed vehicular bridge. An example of this type of construction can be seen below in Figure 7 where a suspended pedestrian facility was implemented for the Elwha River Bridge Replacement Project.

Impacts to Bridge Alternatives

Suspending the pedestrian facility has two primary impacts to the bridge design. The first major impact is that the bridge/roadway profiles may need to increase in provide adequate clearance to the 100-year flood elevation. The AASHTO Guide for the Development of Bicycle Facilities recommends a 10-foot minimum vertical clearance for pedestrian/bicycle facilities to any overhead obstructions. In this case, the surface of the pedestrian/bicycle trail would need to be a minimum of 10ft clear to the soffit of the bridge superstructure. Assuming a 2-foot structural depth for the pedestrian facility, the total "depth" of the combined structure (i.e. vehicular bridge and pedestrian structure) would effectively be increased by 12 feet. The increase in total depth is more impactful to the steel plate girder and prestressed concrete girder bridge options where the structural depth is already greater than the other bridge options considered. Impacts to the approach fill/retaining wall design due to profile increases would need to be carefully evaluated.

Figure 7: Suspended Pedestrian Structure Below Elwha River Bridge

The other major impact that the suspended pedestrian facility will have on the design of the vehicular bridge is the increased load that the vehicular bridge will need to support. The AASHTO LRFD Guide Specification for the Design of Pedestrian Bridges recommends a minimum, uniform live load for pedestrian bridges of 90 pounds-per-square foot. When combined with the structural weight of a pedestrian facility, the increase in demands on the vehicular bridge is substantial.

It is likely that the increased demands from the suspended pedestrian facility would not appreciably change the overall configuration of the tied arch, truss and cable-stayed bridge options as these structures are capable of spanning longer distances than what is currently proposed. However, the addition of a suspended pedestrian facility on the steel plate girder and prestressed concrete girder bridge would likely require an additional pier support. This is because the proposed span arrangement for these structures is already nearing the upper limit of their capacity. The additional dead and live load from the pedestrian facility would effectively shorten the maximum span that these structural systems can accommodate.

In order to simplify the configuration of the pedestrian facility, it may be advisable to utilize two-column piers such that the trail can pass between the columns similar to what is shown in Figure 7 above. It may be feasible to split the trail around a single column pier, however, it may not be desirable from a pedestrian/bicycle user’s experience. The use of two-column piers doubles the number of permanent structures within the river.

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Construction Costs

Below are the estimated construction costs for the integrated pedestrian facility. These costs are based on total square footage of the pedestrian trail deck area and should be added to the vehicle bridge structure costs. Costs for the approach structures and/or fill are not included.

Preliminary Cost Estimate:

- Structure Cost = $2.2M
- Design Costs = $330,000
- Construction Management = $550,000
- **Total Costs = $3.1M**

Design and construction management costs are assumed to be 15% and 25% of the estimated structure cost, respectively.

Summary and Next Steps

Table 1 below provides a summary of the estimated design and construction costs for all bridge alternatives considered.

Table 1: Preliminary Cost Estimate for all Bridge Options

Bridge Type	Preliminary Cost Estimate			
	Construction	Engineering	Construction Management	Total
Option 1 - Tied Arch	$ 20,000,000	$ 3,000,000	$ 5,000,000	$ 28,000,000
Option 2 - Steel Truss	$ 21,500,000	$ 3,225,000	$ 5,375,000	$ 30,100,000
Option 3 - Cable Stayed	$ 31,000,000	$ 4,650,000	$ 7,750,000	$ 43,400,000
Option 4 - Steel Plate Girders	$ 9,000,000	$ 1,350,000	$ 2,250,000	$ 12,600,000
Option 5 - Precast Concrete Girders	$ 9,500,000	$ 1,425,000	$ 2,375,000	$ 13,300,000
Option 5 - Integrated Ped Facility*	$ 2,200,000	$ 330,000	$ 550,000	$ 3,080,000

*Integrated Pedestrian Facility Costs Should be Added to Vehicle Bridge Costs

In order to further validate the findings of this study, the following pieces of design data should be gathered prior to further advancing the bridge design. This data could appreciably affect the layout of the proposed structures as well as design and construction costs.

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Critical Area Delineations

Critical areas within the vicinity of the bridge should be determined and mapped in order to determine the impacts that the proposed structure will have on these elements. Limits of wetlands, OHWM, steep slopes, archeological resources, etc. could have significant impacts on the configuration of the proposed roadway and bridge.

Hydrologic and Hydraulic Analyses

A hydrologic and hydraulic analysis should be performed in order to determine key design criteria and to maintain compliance with regulatory requirements. Items like 100-year flood elevations, scour depths, channel migration, no-rise analysis could have significant impacts on the configuration of the proposed roadway and bridge. Establishing flood elevations and scour depth are especially important to the bridge design as they often affect the roadway profile and foundation depths, respectively.

Geotechnical Explorations

Site specific geotechnical explorations should be advanced in order to more accurately determine bridge foundation design parameters, seismic design parameters and wall design criteria. Bridge foundations can be costly depending on site conditions and seismicity. It is recommended that a geotechnical boring be advanced at all proposed bridge foundation locations.