Puget Sound Gateway Project

SR 509, I-5 and SR 167 Funding and Phasing Study: Strategic Corridor Design Review

509 5 167

Appendix G: Structures Summary

Washington State Department of Transportation

September 2013

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13-07-0002091

Contents

1. INTRODUCTION G-1

2. DESIGN REVIEW AND REFINEMENT G-1

2.1 Design Criteria G-1

2.2 Bridge Types and Layout G-2

2.3 Construction Methods G-3

3. SR 167 ..... G-4

3.1 Bridges G-4

3.2 Foundations and Ground Improvement G-14

3.3 Construction Staging G-14

4. I-5 EXPRESS TOLL LANES G-15

4.1 Bridges G-15
4.1.1 Bridge Widenings G-15
4.1.2 Bridge Replacements G-18
4.1.2.1 South 375th Street Bridge Undercrossing G-18
4.1.2.2 SR 161 Undercrossing G-18
4.1.2.3 South 320th Street Undercrossing G-18

4.2 Foundations G-19

4.3 Construction Staging G-19
4.3.1 Bridge Widenings G-19
4.3.2 Bridge Replacements G-19

5. SR 509 EXTENSION G-20

5.1 Bridges G-20
5.1.1 I-5 Overcrossing SR 516 (South Kent Des Moines Road) G-20
5.1.2 New I-5 Overcrossing South 231st Street G-20
5.1.3 South 216th Street Overcrossing (Replacement) G-20

5.1.4 I-5 Southbound Overcrossing SR 509 HOV G-21
5.1.5 I-5 NB Overcrossing SR 509 Northbound G-21
5.1.6 South 211th Street Overcrossing SR 509 ..... G-21
5.1.7 SR 99 (Pacific Highway South) Overcrossing SR 509 ..... G-21
5.1.8 28th/24th Ave. South Overcrossing SR 509 ..... G-21
5.1.9 SR 509 Overcrossing Wetland A G-22
5.1.10 SR 509 Overcrossing South 200th Street G-22
5.1.11 SR 509 Overcrossing Des Moines Memorial Drive G-22
5.1.12 S 192nd Street Overcrossing SR 509 ..... G-23
5.1.13 SR 509 Overcrossing Wetland B G-23
5.1.14 SR 509 Overcrossing South 188th Street G-23

5.2 Foundations and Ground Improvement G-23

5.3 Construction Staging G-24
5.3.1 South 216th Street Bridge G-24
5.3.2 SR 509/I-5 Connection G-24

6. CONCLUSIONS G-25

APPENDIX G.1: SR 167 EXTENSION, REVISED BASELINE BRIDGE PLANS G.1-1

APPENDIX G.2: SR 509 EXTENSION, BASELINE BRIDGE PLAN MARKUPS G.2-1

APPENDIX G.3: SR 509 EXTENSION, I-5/SR 509 CONNECTION PHASING CONCEPT . G.3-1

Tables

Table G- 1 Structure Types and Estimated Cost Ranges G-2

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges G-5

Table G- 3 Express Toll Lane Widenings G-16

Appendix

Appendix G.1: SR 167 Extension, Revised Baseline Bridge Plans

Appendix G.2: SR 509 Extension, Baseline Bridge Plan Markups

Appendix G.3: SR 509 Extension, I-5/SR 509 Connection Phasing Concept

1. INTRODUCTION

The Puget Sound Gateway Project consists of three connected corridors which will receive a variety of improvements over multiple phases of construction. The three corridors are the SR 167 extension to I-5/SR 509, the SR 509 extension to I-5, and the I-5 Express Toll Lanes (ETL) between SR 16 and the I-5 Express Lanes in downtown Seattle. Prior to this study, the Washington State Department of Transportation (WSDOT) had prepared baseline conceptual designs for most of the SR 167 and SR 509 corridors. The I-5 ETL is a new project and preliminary concepts are being developed as part of this study.

As part of this study, we evaluated the conceptual bridge designs prepared by the Washington State Department of Transportation (WSDOT) to identify opportunities to reduce the total project cost and evaluate options for phased construction of the Puget Sound Gateway project. For bridges without previously completed conceptual designs, we have identified possible bridge type and size in order to develop costs estimates and evaluate construction phasing as part of the larger study.

This memo documents the review of the bridges within the Puget Sound Gateway project and identifies opportunities to reduce structure costs from the conceptual design.

2. DESIGN REVIEW AND REFINEMENT

2.1 Design Criteria

The design criteria for the structures on the Puget Sound Gateway project are anticipated to be in accordance with the requirements of the WSDOT Bridge Design Manual, M23-50.12 (BDM) and Geotechnical Design Manual, M46-03.06 (GDM). The BDM and GDM specify the required AASHTO design codes, loadings to be used, and design procedures to be followed. For the structures under consideration, deviations from the BDM are not anticipated at this time. As the design of the individual structures progress further, it may be prudent to use design procedures that are less common that, per the BDM, require approval by the WSDOT Bridge Design Engineer. These procedures include options such as in-ground hinging of drilled shafts, isolation bearings, columns with reduced moment sections and others. Justification and approval of these methods should be evaluated on a case-by-case basis as the project is advanced during preliminary and final design.

The criteria used to determine the feasibility of the structure type selected for the Puget Sound Gateway project were based on the following:

1. Structure type span range capacity per BDM Appendices 2-B and 5.6-A1, as shown in Table G- 1 below.

2. Prestressed concrete girders on curved spans were considered feasible on curved spans provided the anticipated deck overhang at the exterior girder was less than half of the required girder spacing per BDM Appendix 5.6-A1.
3. Curved post-tensioned concrete box girders were considered feasible provide they had minimum inside radius of 200-feet or larger.
4. Falsework for a concrete box girder bridge over an existing roadway is not preferred. However, if it is required, full legal clearance to the bottom of the falsework must be provided.

2.2 Bridge Types and Layout

For this study, the bridge type, size and layout that were prepared by WSDOT during the conceptual design of the baseline SR 167 and SR 509 corridors were evaluated for optimizations to reduce cost. The primary method used to reduce cost involved a change in structure type to a more cost-effective structure. Table G- 1 below lists the common structure types, in order of preference, anticipated for the Puget Sound Gateway project along with their span capacity, structural advantages, and estimated cost per square foot. The structure types and cost ranges in Table G- 1 were used to select bridge alternatives for the I-5 ETL project where conceptual designs were not previously prepared. These cost ranges were also where baseline designs have been revised.

Table G- 1 Structure Types and Estimated Cost Ranges

Superstructure Type	Span Range (Feet)	Advantages	Estimated Cost Range $/SF (WSDOT BDM August, 2012)
Widening Existing Concrete Bridges (Including Removal)	N/A	Often cost effective when compared to complete replacement	$175 - $300
Prestressed Concrete (Typically Girders)	20 - 190	Most Cost Effective, Low Maintenance	$110 -$200
Spliced Prestressed Concrete Girder	140 - 240	Cost Effective, Low Maintenance Medium Span	$160 - $250
Post-Tensioned Concrete Box Girder	140 –300*	Medium Span, Low Maintenance Moderate Curved Construction	$150 - $300
Steel Plate Girder	60 - 400	Long Span, Moderate Curved Construction	$150 - $250
Steel Box Girder	60 - 400	Long Span, Curved Construction	$250

* The BDM recommends a range of up to 200-feet. However, 450 feet is achievable with advanced methods of construction and variable depth spans. A maximum span of 300 feet has been considered for this report.

When selecting the appropriate structure type and looking for optimizations, a number of factors play a role. These factors include cost, required span length, future widening of streets being crossed, available right-of-way, available foundation locations, structure framing,

curvature, and depth, and skew with respect to supports. The aesthetics of changing from one type of bridge superstructure to another within the length of the bridge was not considered when selecting the appropriate structure type.

2.3 Construction Methods

For all of the bridges within the project, conventional bridge construction methods can be used. However, for the bridges crossing I-5 and other bridges that will significantly impact the public, the use of Accelerated Bridge Construction (ABC) should be considered as a method of reducing impacts to the traveling public and local businesses.

ABC consists of a variety of construction techniques from the use of precast beams, to forming techniques, to moving a completed bridge superstructure into place. Regardless of the technique, the overarching goal of ABC is to speed up construction and reduce the impact of construction on the public. One thing that ABC does not inherently bring is reduced construction costs. While ABC can reduce the duration of construction and associated costs, such as overhead and maintenance of traffic, it does not always result in reduced bridge costs and can often increase them. As a result, ABC should not be viewed as a construction cost savings measure but rather as a means to reduce impacts that are directly tied to the duration of construction.

In evaluating the options for ABC and comparing them to conventional construction methods, a typical framework for decision making consists of the following process. First, the need for ABC is considered based on traffic volume, immediacy of replacement need, use of the route for emergency access, lane closures or detours required and impacts on the total project critical path. Then other factors such as worker safety, environmental concerns, community impact, repetition within the project and site access are considered. If a combination of these factors indicates that rapid bridge construction methods might be beneficial, costs are analyzed to determine the best solution. In addition to construction costs, costs required for maintaining traffic, contractor's operations and owner agency's operations would also be considered. After service life and future maintenance costs are factored in, the design best suited to the site can be determined.

For this project, we recommend evaluating methods of ABC as part of the next phase of design. The use of precast bridge elements, including footings, columns, crossbeams and abutments, should be considered as a method of accelerating construction and reducing impact. Secondly, the option to prefabricate entire bridge spans adjacent to the bridge and roll them into place should be looked at to determine if it is a cost-effective method of reducing impacts to the traveling public.

3. SR 167

3.1 Bridges

The bridges proposed as part of the WSDOT baseline designs were evaluated based on the criteria in Section 2 and Table G- 1. Table G- 2 below coupled with the revised concept plans in Appendix G.1 provides a list of proposed design revisions, notes relating to the revision and future design refinements that should be considered as part of the preliminary design for each structure.

Following the December 2012 Initial Design Workshop, an interim construction phasing alternative was developed for the I-5/SR 167 interchange which involves construction of a half-diamond interchange with signalized intersections on SR 167. As a result of this alternative, the southbound SR 167 bridge across I-5 was modified and three bridges, two carrying the half-diamond ramps and one for the HOV direct connect, were added to the project which are also shown in Table G- 2 below.

Moving forward, a type, size and location (TS&L) report for the more complicated structures and a preliminary design for the remaining structures should be prepared in order to refine the design of the structure and to identify foundation elements.

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				Appx. G.1 Plan Sheet No.
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	
SR 167 Baseline Concept Design							
12 / Hylebos#	Concrete	150	PC Conc. Girder	150			
167 / 12	Concrete	150	PC Conc. Girder	150	Assumed proposed bridge spans City/County R/W.	Evaluate shortening span to the minimum necessary to span 12th Street.	ST5*
167 / 54	Concrete	160	PC Conc. Girder	142	Shortened bridge to accommodate 6-foot clear (2' Barrier, 3' Bridge, 1' Shy) to existing & proposed curb line.	Evaluate shortening span to the minimum necessary to span 54th Street. Verify impact of bridge shortening on potential future plans for improvements to 54th Street. Verify that shortening of bridge will not adversely affect the ditch near the west abutment.	ST4*
70 / 5	Steel Box	170	PC Conc. Girder & Reinf. Conc. Box	170	Use reinf. conc. box around the tight corner east of I-5 with added pier mid curve if necessary. Use PC Conc. girders before and after the curve. See Royal Brougham Bridge (SR519 design build project) over BNSF Tracks in Seattle as an example.		ST12*
N167 / 161	PT Conc. Box	210	Spliced PT Girder	210	Use spliced post-tensioned precast concrete girder in place of post-tensioned box girder.		ST50*
N167 / 26	Concrete	110	PC Conc. Girder	110	Assumed proposed bridge spans City/County R/W.	Evaluate shortening span to the minimum necessary to span 26th Street. Verify	ST39*

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				Appx. G.1 Plan Sheet No.
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	
						impact of bridge shortening on potential future plans for improvements to 26th Street.	
N167 / 5	Concrete	200	PC Conc. Girder	Approx. 165	Reconfigure bridge span layout and use concrete for the full length of the bridge.	Evaluate pier locations & span layout for more efficient configuration.	ST17*, ST23*, & ST35*
N167 / MWK	Concrete	130	PC Conc. Girder	130	Assumed proposed bridge spans City/County R/W.	Evaluate shorting span to the minimum necessary to span Milwaukee Ave. Verify impact of bridge shortening on potential future plans for improvements to Milwuakee Avenue.	ST51*
N167 / VA (A)#	Steel Plate	250	PC Conc. Girder	185	Reconfigure layout. Assume RR R/W (~100') governs steel span over RR. Outside of RR R/W use PC Conc. Girder.	Consider the impact of structure weight on the straddle bents.	ST41*
N167 / VA (B)#	Steel Plate	250	Steel Plate	240	Reconfigure layout. Assume RR R/W (~100') governs steel span over RR. Outside of RR R/W use PC Conc. Girder.	Evaluate pier skew at RR R/W and, if possible, eliminate the skewed piers adjacent to the R/W. The short variable spans should be lengthened if possible to eliminate uplift.	ST41* & ST42*
N167 / VA (C)#	Steel Plate	250	PC Conc. Girder	160	Reconfigure layout. Assume RR R/W (~100') governs steel span over RR. Outside of RR R/W use PC Conc. Girder.		ST42*

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	Appx. G.1 Plan Sheet No.
N167 / VALE#	Concrete	155	PC Conc. Girder	155	Assumed proposed bridge spans City/County R/W.	Evaluate shortening span to the minimum necessary to span Valley Ave. Verify impact of bridge shortening on potential future plans for improvements to Valley Avenue.	ST48*
N167-N5	Concrete	170	PC Conc. Girder	170		Evaluate pier locations & span layout for more efficient configuration.	ST10*
N5 / HYL	Concrete	40	Concrete Widening	40			ST30*
N5 / HCR	Concrete	120	PC Conc. Girder	130			ST20*
N5-N167	Concrete	150	PC Conc. Girder	150			ST25 *
N5-N167 (HOV)#	Concrete	210	PC Conc. Girder	150	Break Span 1 (210-ft) into two spans.	Evaluate pier locations & span layout for more efficient configuration.	ST15*
N5-N167(HOVCTR)#	Steel Box	290	Steel Box	290		Evaluate shorter spans and straddle bents to allow for the use of PC Conc. girder with PT conc. box where necessary.	ST14*
PORTER / 5	Concrete	165	PC Conc. Girder	165		Verify applicability of PC concrete girder on vertical curve and 165' span.	ST28

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	Appx. G.1 Plan Sheet No.
S167 / 161#	PT Conc. Box	210	Spliced PT Girder	210	Use spliced post-tensioned precast concrete girder in place of post-tensioned box girder.		ST49*
S167 / 26	Concrete	110	PC Conc. Girder	110	Assumed proposed bridge spans City/County R/W.	Evaluate shortening span to the minimum necessary to span 26th Street. Verify impact of bridge shortening on potential future plans for improvements to 26th Street.	ST40*
S167 / 5	Concrete & Steel	200	PC Conc. Girder	Approx. 175	Reconfigure bridge span layout and use concrete for the full length of the bridge.	Evaluate pier locations & span layout for more efficient configuration.	ST16*, ST24*, & ST34*
S167 / 509	Post Tension	186	PT Conc. Box	186		Evaluate PC Conc. girder with overbuilt deck as necessary to accommodate the required curve and three-sided box culverts over SR 509 with ground improvement and fill walls between the boxes.	ST1
167 / FIFE DITCH	Concrete	90	PC Conc. Girder	90	Can span be shortened? Can a 3-sided box be used?	Evaluate shortening the span length to minimum necessary. Evaluate the option of using a three-sided box culvert over Fife Ditch if the span can be shortened.	ST3
S167 / MWK	Concrete	130	PC Conc. Girder	130	Assumed proposed bridge spans City/County R/W.	Evaluate shortening span to the minimum necessary to span Milwaukee Ave. Verify	ST52*

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	Appx. G.1 Plan Sheet No.
						impact of bridge shortening on potential future plans for improvements to Milwuakee Avenue.	
S167 / VA (A)	Steel Plate	250	PC Conc. Girder	170	Reconfigured layout. Assume RR R/W (~100') governs steel span over RR. Outside of RR R/W use PC Conc. Girder.		ST31 *
S167 / VA (B)	Steel Plate	250	Steel Plate	280	Reconfigure layout. Assume RR R/W (~100') governs steel span over RR. Outside of RR R/W use PC Conc. Girder. Last 170 feet of Bridge VA-N167 was incorporated into Bridge N167/VA (B) as part of the span over the RR.	Evaluate pier skew at RR R/W and, if possible, eliminate the skewed piers adjacent to the R/W followed by the short variable spans.	ST31* & ST32*
S167 / VA (C)	Steel Plate	250	PC Conc. Girder	170	Reconfigure layout. Assume RR R/W (~100') governs steel span over RR. Outside of RR R/W use PC Conc. Girder.		ST32 *
S167 / VALE#	Concrete	155	PC Conc. Girder	155	Assumed proposed bridge spans City/County R/W.	Evaluate shortening span to the minimum necessary to span Valley Ave. Verify impact of bridge shortening on potential future plans for improvements to Valley Avenue.	ST47*
S167-N5 (HOV) (A)	Steel	230	PT Conc. Box	230	Span length and curve radius makes PT conc. box feasible.	Evaluate shorter spans and straddle bents as required to allow for the use of PC Conc. Girder. Consider vertical clearances to	ST22

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				Appx. G.1 Plan Sheet No.
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	
						falsework of PT Conc. Box.	
S167-N5 (HOV) (B)	Concrete	220	PC Conc. Girder	150	Reconfigure pier layout and span lengths to accommodate PC Conc. girder.		ST22 & ST22A
S5-N167 (HOVCTR) (A)	Concrete	250	PC Conc. Girder	170	Reconfigure pier layout and span lengths to accommodate PC Conc. girder.	Evaluate center pier locations & span layout for more efficient configuration.	ST21
S5-N167 (HOVCTR) (B)	Steel Box	250	PC Conc. Girder	275		Consider effect of curved alignment and superstructure torsion with single column bents. Also evaluate potential for uplift on short end spans.	ST21
S5-N167 (HOVCTR) (C)	Concrete	230	PC Conc. Girder	190	Adjust center pier location to accommodate PC Conc. Girder.		ST21
S167-N5 / 20	Concrete	170	PC Conc. Girder	170	Assumed proposed bridge spans City/County R/W.	Evaluate single span bridge and shortening span to the minimum necessary to span 20th Street. Verify that 20th Street meets full standards. Verify impact of bridge shortening on potential future plans for improvements to Valley Avenue.	ST36
S167-N5 / HCR			PC Conc. Girder	130	Assumed clearance to Hylebos is not an issue.	Evaluate clearance to Hylebos Creek and use shorter spans with PS Slabs if necessary to achieve	ST53*

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				Appx. G.1 Plan Sheet No.
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	
						required clearance.	
S167-S5 (A)	PT Conc. Box	190	PT Conc. Box	190	Move break between Bridge Sections A & B ahead one span and change span over I-5 to PC Conc. Girder.	PT Box is required for tight curve on Section A. Evaluate shortening spans and using PC Conc. Girder for full bridge length.	ST8* & ST9*
S167-S5 (B)	Steel	180	PC Conc. Girder	130	Move break between Bridge Sections A & B ahead one span and change span over I-5 to PC Conc. Girder.		ST9*
S167-S5 (HOV)#	Concrete	200	PC Conc. Girder	Approx. 160	Reconfigure pier layout and span lengths to accommodate PC Conc. girder.		ST33
S167-VA	Concrete	195	PC Conc. Girder	185	Reconfigure pier layout and span lengths to accommodate PC Conc. girder.	Evaluate pier locations & span layout for more efficient configuration. This may require redesign of Valley Avenue. Also consider weight of concrete girders on straddle bents.	ST45
S5 / HYL	Concrete	40	Concrete Widening	40			ST29
S5 / HCR	Concrete	120	PC Conc. Girder	130			ST19*
S5-N167 (HOV)	Concrete	230	PC Conc. Girder	170	Reconfigure pier layout and span lengths to accommodate PC Conc. Girder.	Evaluate pier locations & span layout for more efficient configuration.	ST13 * & ST13A*

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				Appx. G.1 Plan Sheet No.
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	
S5-N167 (A)	Concrete	230	PC Conc. Girder	150	Reconfigure pier layout and span lengths to accommodate PC Conc. Girder.	Evaluate pier locations & span layout for more efficient configuration.	ST18
S5-N167 (B)	Steel Box	240	Steel Plate	240	Span length and curve radius makes steel plate girder feasible.	Verify that the single pier bents can support plate girders. Steel box allows greater cantilever at the pier bent.	ST18 & ST18A
S5-N167 (C)	Concrete	200	PC Conc. Girder	165	Reconfigure pier layout and span lengths to accommodate PC Conc. Girder.	Evaluate pier locations & span layout for more efficient configuration.	ST18A
S5-N167 (HOV)			PC Conc. Girder				ST13* & ST13A*
S5-S167 (A)	Steel Plate	170	PC Conc. Girder	170	Bridge broken into Sections A & B before span over SR 99. Use PC Conc. girder for Section A and steel plate girder for Section B.		ST26*
S5-S167 (B)	Steel Plate	200	Steel Plate	200	Bridge broken into Sections A & B before span over SR 99. Use PC Conc. girder for Section A and steel plate girder for Section B.	Evaluate straddle bent over SR 99 to accommodate shorter span and the use of PC Conc. Girder. Consider added cost of straddle bent and weight of concrete girders on straddle bent.	ST26* & ST27*
SFR1	Conc. Widening	60	Conc. Widening	60	Initial design consisted of uniform widening. Widening tapered to accommodate only required widening.		ST2

Table G- 2 Revisions to SR 167 Baseline Conceptual Design Bridges

Structure Name (ID)	Baseline Design		Gateway Revised Design				
	Structure Type	Maximum Span (ft)	Structure Type	Maximum Span (ft)	Design Revision Notes	Potential Future Design Refinements	Appx. G.1 Plan Sheet No.
SR99 / Hylebos#	Concrete	40	PC Conc. Girder	40	Bridge area revised to match 120' x 57.5' (LxW) bridge.		ST37*
VA-N167	Concrete	150	PC Conc. Girder	150	Eliminated last 170 feet of the bridge and incorporated it into Bridge N167/VA (B) as part of the span over the RR.	Verify that section incorporated into Bridge N167/VA(B) is acceptable without a continuous backspan.	ST46*
SR 167 Half-Diamond Concept							
S167 / 5	-	-	PC Conc. Girder	170			ST54, ST55, & ST56
S5-167	-	-	PC Conc. Girder	120			ST57
5-167 (HOV)	-	-	PC Conc. Girder	160			ST58
167-N5	-	-	PC Conc. Girder	150			ST59

* Plan sheet showing proposed revision to WSDOT baseline design.
# Structure included in EIS 6-lane concept but not included in either Gateway Phase 1 construction or Full Gateway Vision construction.

3.2 Foundations and Ground Improvement

Based on the soils information available along the corridor combined with the flat topography in the valley and the proximity of the Puyallup River to the project it is anticipated that poor soil conditions will exist for most, if not all, of the structures within the corridor. As a result, careful evaluation of soil conditions and corresponding geotechnical design recommendations will be required as part of the next phase of design. This geotechnical information could be included in a geotechnical baseline report (GBR) for the corridor. As part of that report, it is recommended that the benefits of generating site-specific response spectrum for the structures be evaluated as a means of reducing foundation costs. It would also be beneficial to conduct a parametric evaluation of ground improvements versus deep foundations to determine cost-effective methods of addressing the poor soil conditions for the design of the bridges.

3.3 Construction Staging

The construction staging and phasing of the SR 167 Extension will require careful analysis as the project progresses. Detailed construction phasing and staging plans will be a necessary part of the preliminary design for each structure. As part of our analysis, we have reviewed the proposed structures to identify construction staging challenges and potential fatal flaws that will exist with the construction of the project. No fatal flaws were identified.

There are a number of structures crossing existing roadways that will require the temporary closures and/or detours during select construction activities, such as setting girders. With only one exception, these structures are proposed to be prestressed concrete girder or steel girder bridges which are commonly used for such applications. The one exception is a post-tensioned, concrete box girder bridge (S167/509) over SR 509 for which additional clearance will need to be provided to accommodate false work during construction.

The largest staging challenge will be construction of the bridges over I-5 for which good detour routes do not exist. As a result, closures will need to be limited to nights when traffic is at a minimum. Fortunately, all of the proposed bridges have an intermediate pier centered between the northbound and southbound lanes of I-5 and the closures will likely be limited to one direction of I-5. This will accommodate a reduction of lanes with the shifting of traffic to the side of I-5 to remain open. It is our recommendation that further analysis and planning for the necessary closures of I-5 be conducted as the design of the project advances.

Other facilities, such as Valley Avenue E, 20th Street and the Union Pacific Railroad tracks, will require careful coordination with stakeholders in order to implement detours and temporary closures during construction.

4. I-5 EXPRESS TOLL LANES

The I-5 Express Toll Lane (I-5 ETL) corridor consists of constructing express toll lanes on I-5. The project is planned to be constructed in two phases. Phase 1 will convert the existing HOV lanes to express toll lanes between SR 16 and the reversible Express Lanes in downtown Seattle and will not require the modification or replacement of existing bridges. The full Gateway Vision will add a second express toll lane in each direction between the new SR 167 and SR 509 interchanges and will require the widening and/or replacement of a number of bridges along the corridor.

While the I-5 ETL full Gateway Vision for the second I-5 ETL toll lane phase extends from the SR 167 Extension to the SR 509 Extension, there are a number of bridges on I-5 that will be widened or replaced to accommodate the other two extension projects. These bridges are included in their respective projects and are not included in the I-5 ETL project. This includes the bridges from the Hylebos Creek undercrossing (Br. No. 5/546) south to SR 167 and the bridges from the proposed S 231st Bridge north to SR 509.

4.1 Bridges

Evaluation of the bridge widenings and replacements necessary for the additional lanes required as part of the Phase 2, I-5 ETL corridor was completed as part of this study. The bridges along this corridor fall into two categories, widenings or replacements, each of which are discussed in detail below.

Moving forward, a type, size and location (TS&L) report for the more complicated structures and a preliminary design for the remaining structures should be prepared in order to refine the design of the structure and to identify foundation elements.

4.1.1 Bridge Widenings

I-5 bridges overcrossing streets, waterways and other features were evaluated to determine if widening was required and feasible to accommodate the additional lanes. Based on a review of the existing as-built plans for the bridges to be widened, seismic retrofits have not been completed. All of the bridges to be widened (except Bridge No. 5/511W) are on the WSDOT Bridge Preservation P2 seismic retrofit 2009-2011 Biennium priority list. Costs for the seismic retrofits will be included in the cost estimates. The results of the evaluation of the bridge widenings along the I-5 ETL corridor along with notes and recommendations for future design can be seen in Table G- 3.

Table G- 3 Express Toll Lane Widenings

Bridge No.	Bridge Name	Bridge Length	Widening Width	Deck Area (SF)	Type	Notes
5/503W	I-5 Over SR 18	213.0	14.0	**2,982**	PS Conc. Girder Widening	Assumed 14' of widening, see Note 1.
5/503E	I-5 Over SR 18	206.0	14.0	**2,884**	PS Conc. Girder Widening	Assumed 14' of widening, see Note 1.
5/504W	I-5 Over S 336th Street	156.0	14.0	**2,184**	Reinf. Conc. Box Widening	Assumed 14' of widening, see Note 1
5/504E	I-5 Over S 336th Street	198.0	14.0	**2,772**	Reinf. Conc. Box Widening	Assumed 14' of widening, see Note 1
5/506W	I-5 Over Military Road	198.6	14.7	**2,925**	Reinf. Conc. Box Widening	
5/506E	I-5 Over Military Road	198.6	14.0	**2,782**	Reinf. Conc. Box Widening	Existing substandard shoulder, see Note 2
5/507W	I-5 Over S 288th Street	156.7	14.7	**2,307**	PS Conc. Girder Widening	
5/507E	I-5 Over S 288th Street	156.7	14.0	**2,194**	PS Conc. Girder Widening	Existing substandard shoulder, see Note 2
5/508W	I-5 Over Military Road	242.5	2.9	**707**	PS Conc. Girder Widening	Existing bridge is overbuilt on the inside shoulder
5/508E	I-5 Over Military Road	242.5	14.0	**3,396**	PS Conc. Girder Widening	Existing substandard shoulder, see Note 2
5/509W	I-5 Over S 272nd Street	150.6	32.5	**4,890**	PS Conc. Girder Widening	See Note 3
5/509E	I-5 Over S 272nd Street	150.6	14.5	**2,190**	PS Conc. Girder Widening	Existing substandard shoulder, see Note 2
5/510W	I-5 Over S 259th Place	161.5	14.7	**2,378**	Reinf. Conc. Slab Widening	See Note 3
5/510E	I-5 Over S 259th Place	161.5	22.0	**3,553**	Reinf. Conc. Slab Widening	Existing substandard shoulder, see Note 2
5/511W	I-5 Over SR 516	See Note 4			PS Conc. Girder Widening	Due to lack of separation between the east and west bridges, the widening will occur on the west side of the. In addition, an additional GP lane will be required for CD Lane as part of the SR 509 Extension.
5/511E	I-5 Over SR 516	268.9	9.5	**2,560**	PS Conc. Girder Widening	Existing substandard shoulder, see Note 2

Table G- 3 Notes:

1. Assumed 14' of widening for additional 12' lane and 2' ETL separation
2. Widening was assumed to occur on the inside shoulder only without addressing the substandard shoulder on the outside of the bridge. It was assumed that addressing the shoulder Deviation would not be required because that side of the bridge is to remain untouched. However, this should be confirmed with the State Design Engineer and FHWA during the next phase of design.
3. Widening for the ETL is assumed to occur on the inside shoulder of the bridge. The existing bridge has adequate width on the outside shoulder to accommodate an additional lane without requiring widening. Shifting traffic north and south of the bridge to take advantage of this width and eliminate the need for widening should be evaluated during the next phase of design.
4. Bridge 5/511W is required to be widened to accommodate additional lanes for the southbound collector/distributer for the SR 509 Extension as well as I-5 ETL Phase 2. The cost associated with the widening was included in the SR 509 Extension because that is projected to occur before I-5 ETL Phase 2.

4.1.2 Bridge Replacements

Bridges overcrossing I-5 were evaluated to determine if the existing span configuration could accommodate an additional lane in each direction of I-5 without requiring a deviation of traffic around a pier or a reduction in shoulder widths. If it was determined that this was not feasible, the bridge was identified for replacement. The following are the bridges scheduled for replacement for I-5 ETL Phase 2.

4.1.2.1 South 375th Street Bridge Undercrossing

The existing bridge is a 5-span prestressed concrete girder bridge with the HOV lanes located under the center span and separated from the general purpose lanes by Piers 3 and 4. Due to the existing span configuration, the S 375th Street Bridge (Br. No. 5/501) must be replaced to accommodate additional lanes on I-5. The replacement bridge is proposed to be a two-span prestressed concrete girder bridge with a pier located between the northbound and southbound lanes of I-5. For cost-estimating purposes, the bridge was estimated to be 302-feet long by 48-feet wide.

4.1.2.2 SR 161 Undercrossing

The existing bridge is a 5-span prestressed concrete girder bridge with the HOV lanes located under the center span and separated from the general purpose lanes by Piers 3 and 4. The bridge is skewed at approximately 40-degrees with respect to I-5. Due to the existing span configuration the SR 161 Undercrossing Bridge (Br. No. 161/102) must be replaced to accommodate additional lanes on I-5. In order to accommodate the required span lengths (200+ feet) and torsion induced by the 40-degree skew, the replacement bridge is proposed to be a two-span steel box girder bridge with a pier located between the northbound and southbound lanes of I-5. A steel plate girder or a post-tensioned spliced girder bridge may be feasible and more cost-effective and should be evaluated during preparation of the TS&L report. For cost-estimating purposes, the bridge was estimated to be 407-feet long by 80-feet wide.

4.1.2.3 South 320th Street Undercrossing

The existing bridge is a 4-span prestressed concrete girder bridge with approximately a 15-degree skew with respect to I-5. Due to the existing span configuration, the S 320th Street Bridge (Br. No. 5/505) must be replaced to accommodate additional lanes on I-5. In the event that traffic analysis shows that the second ETL lane can be dropped at the S 317th Street direct access, the bridge would not need to be replaced because these access ramps and an HOV lane in each direction exist today. The replacement bridge is proposed to be a two-span prestressed concrete girder bridge with a pier located between the northbound and southbound lanes of I-5. For cost-estimating purposes, the bridge was estimated to be 332-feet long by 84-feet wide.

4.2 Foundations

All of the bridge work required for the I-5 ETL corridor is either a bridge widening or replacement. As a result adequate geotechnical information should be available for each structure for preparation of preliminary design. During the preparation of preliminary design/TS&L, the adequacy of the existing geotechnical information should be evaluated to determine where additional geotechnical information is needed.

4.3 Construction Staging

The construction staging and phasing of the I-5 ETL widening will require careful analysis as the project progresses. Detailed construction phasing and staging plans will be a necessary part of the preliminary design for each structure.

4.3.1 Bridge Widenings

There are a number of I-5 bridge widenings that will be required as part of the project. However, these widening are conventional and a majority of these bridges have been widened in the past.

4.3.2 Bridge Replacements

There are three (3) bridges overcrossing I-5 that must be replaced when the second ETL is constructed as part of the I-5 ETL full Gateway Vision construction: S 375th Street Undercrossing; SR 161 Undercrossing; and S 320th Street Undercrossing. These bridges will require careful consideration as the design progresses in order to minimize disruptions to the traveling public. Each of these proposed bridges are two-span structures with a pier located in the median of I-5. For each of these structures, a staging evaluation should be conducted during preliminary design. The evaluation should address how to maintain or detour traffic on the overcrossing street as well as how to maintain traffic on I-5 beneath the bridge during construction.

To maintain traffic on the overcrossing street the following options should be considered for each bridge:

- Complete closure with a detour during construction
- Staged construction and demolition, with traffic shifts and a reduction in the number of lanes in order to maintain connectivity across I-5
- Construction of the new bridge adjacent to the existing road

Replacement of the bridges will require the closure of I-5 for select construction activities such as setting girders and bridge demolition. These activities can be scheduled to occur during nights and weekends to minimize the impact to the traveling public. During these closures, the option to detour traffic around the bridge to local streets only exists for the S 320th Street Bridge. For this bridge traffic can be detoured around the bridge using the existing on and off

ramps. For the other two bridge replacements, it will be necessary to limit the closure of I-5 to one side of I-5 and shift all traffic to the other side.

5. SR 509 EXTENSION

5.1 Bridges

The bridges proposed for the WSDOT baseline project developed in a 2012 scoping study were evaluated based on the criteria in Section 2 of this report. For bridges and widenings that were not included in the scoping study, appropriate structure types and sizes have been determined and included in the cost estimate. The following are the results of this evaluation listed from south to north along the I-5 and SR509 Corridors.

5.1.1 I-5 Overcrossing SR 516 (South Kent Des Moines Road)

The existing bridge is a four-span precast concrete girder bridge with a total length of 259-feet. Widening of the west bridge (Bridge No. 5/511W) will be required to accommodate an additional lane for the southbound collector/distributor lane to be constructed as part of the SR 509/I-5 connection. In addition the bridge will need to be widened for the second express toll lane as part of the I-5 ETL Phase 2 project. The SR 509 Extension is expected to occur first and the bridge should be widened for the second express toll lane as part of that project. Due to the lack of separation between the existing east and west bridges and because the east bridge will require widening in the median, the bridge will be widened on the west side. The full build out will require approximately 27.5 feet of widening.

5.1.2 New I-5 Overcrossing South 231st Street

The bridge is a new structure proposed to consist of soldier pile or secant pile walls installed across I-5 supporting precast concrete slabs or girders with a cast-in-place deck slab. The lid of the structure can be used as the driving surface for I-5 in conjunction with approach slabs leading up to the bridge. Or, if profile depth is available, the lid of the structure can be placed a minimum of 2-feet below grade and a fill roadway section constructed over the structure, like a cut and cover tunnel. By burying the structure and eliminating the roadway deck and joints, long-term maintenance costs will be reduced. Staging of construction will be required in order to keep I-5 open at all times. The typical section will be similar to the new I-5 Overcrossing of SR 509, see Appendix G.3 for details. For cost-estimating purposes, the bridge was estimated to be 197-feet long by 70-feet wide.

5.1.3 South 216th Street Overcrossing (Replacement)

The replacement of the S 216th Overcrossing Bridge (Br. No. 5/513) is required to accommodate the new SR 509 access to I-5 and must be constructed prior to or in conjunction with the SR 509 to I-5 access. The proposed bridge is a precast concrete girder superstructure consisting of three (3) spans, approximately 170-feet each. Depending on the available bridge depth, the

bridge can be constructed with WF74G or WF83G girders. For cost-estimating purposes, the bridge was estimated to be 510-feet long by 48-feet wide.

5.1.4 I-5 Southbound Overcrossing SR 509 HOV

The proposed bridge will accommodate HOV direct access from northbound and southbound SR509. The proposed structure consists of soldier pile or secant pile walls installed across I-5 supporting precast concrete slabs or girders with a cast-in-place deck slab. For a typical section, layout, and staging details see Appendix G.2.

5.1.5 I-5 NB Overcrossing SR 509 Northbound

The new bridge will provide northbound I-5 access to northbound SR509. The proposed structure consists of soldier pile or secant pile walls installed across I-5 supporting precast concrete slabs or girders with a cast-in-place deck slab. For a typical section, layout, and staging details see Appendix C.

5.1.6 South 211th Street Overcrossing SR 509

This new bridge over SR 509 will provide local access to replace the loss of access at South 208th Street. The proposed bridge will be a single span bridge approximately 135-feet long using WF50G or WF58G girders. For cost-estimating purposes, the bridge was estimated to be 135-feet long by 44-feet wide.

5.1.7 SR 99 (Pacific Highway South) Overcrossing SR 509

The WSDOT baseline bridge layout consists of a two-span, cast-in-place, post-tensioned concrete box superstructure with a maximum span of 161 feet and a box depth of 6.0 feet. A potential design refinement is to use WF66G girders with a cast-in-place concrete deck to reduce cost assuming the bridge depth or profile can be increased by 6 inches. If a prestressed concrete girder bridge is used, the effect of skew on the unbalanced span lengths should be evaluated. A markup indicating the recommended revisions to the WSDOT baseline design can be seen in Appendix G.2.

Staged construction will be necessary to keep SR 99 open to traffic during construction. As discussed in Section 5.3 below, because SR 99 is a heavily used traffic corridor, the use of accelerated bridge construction (ABC) should be considered for this bridge during preliminary design.

5.1.8 28th/24th Ave. South Overcrossing SR 509

No preliminary bridge plan has been prepared by WSDOT. Based on the preliminary roadway layout, the bridge length is approximately 250-feet. Recommended bridge type is a two span prestressed concrete girder bridge with an intermediate pier located as close to center as can be

accommodated with the roadway layout. For cost-estimating purposes, the bridge was estimated to be 257-feet long by 92-feet wide.

5.1.9 SR 509 Overcrossing Wetland A

Wetland A is considered a Class II wetland which is difficult, to replace. Based on the conceptual estimates previously prepared for the corridor, the bridge spanning Wetland A is proposed to be a steel girder bridge. A visualization of the bridge was prepared for a prestressed concrete girder alternative and likely both a steel and concrete alternative have been considered in the past. Structurally either alternative is feasible; however, the concrete alternative will require an increased number of piers in the wetland and will result in larger wetland impacts. We recommend that a TS&L report be prepared to evaluate both alternatives from a structural as well as an environmental perspective. The TS&L report needs to evaluate:

- Long span precast concrete girders to minimize foundation costs and wetland impacts.
- Steel girders with spans in excess of 200-feet to further reduce wetland impacts.
- Wetland impacts and mitigation and permit requirements associated with the bridge construction.

For cost estimating purposes, a steel bridge was assumed to minimize wetland impacts and to satisfy permit requirements.

5.1.10 SR 509 Overcrossing South 200th Street

No preliminary bridge plan has been prepared by WSDOT. Based on the preliminary roadway layout, the bridge length is approximately 410-feet and crosses South 200th Street at nearly 63-degree skew. Due to the span length one or more intermediate piers will be required and will be in line with South 200th Street. Due to this span length and skew, a cast-in-place concrete box girder bridge is recommended to accommodate the torsion and local stresses that will be induced by the skew. During the TS&L preparation a prestressed concrete girder bridge should be considered with a straddle bent spanning South 200th Street as an intermediate support. For cost-estimating purposes, the bridge was estimated to be 418-feet long by 58-feet wide.

5.1.11 SR 509 Overcrossing Des Moines Memorial Drive

The WSDOT preliminary bridge layout consists of twin single span bridges. Each bridge consists of a cast-in-place post tensioned concrete box superstructure with a span of 150-feet and box depth of 7.0-feet. We recommend that a prestressed concrete girder bridge be used in place of the box structure, as it is a more cost effective structure. WF66G girders with a cast-in-place concrete deck can be used and will not increase the required structure depth. A markup indicating the recommended revisions to the WSDOT baseline design can be seen in Appendix G.2.

5.1.12 S 192nd Street Overcrossing SR 509

The WSDOT preliminary bridge layout consist of a two span cast-in-place post tensioned concrete box superstructure with equal spans of 120-feet and box depth of 5.0-feet. We recommend that a prestressed concrete girder bridge be used in place of the box structure, as it is a more cost effective structure. WF50G girders with a cast-in-place concrete deck can be used and will not increase the required structure depth. A markup indicating the recommended revisions to the WSDOT baseline design can be seen in Appendix G.2.

5.1.13 SR 509 Overcrossing Wetland B

The WSDOT preliminary bridge layout consists of two side by side bridges. The bridges are six (6) span precast concrete girder (WF74G) bridges with maximum total length of approximately 780-feet and individual spans of between 118 and 138 feet. While this is the most cost effective structure type and should remain for the purposes of this study, we recommend that at TS&L report be prepared to evaluate:

- Longer span precast concrete girders to reduce foundation costs and wetland impacts.
- Steel girders with spans in excess of 200-feet to further reduce wetland impacts.
- Wetland impacts and mitigation and permit requirements associated with the bridge construction.

5.1.14 SR 509 Overcrossing South 188th Street

The WSDOT preliminary bridge layout consists of twin side bridges consisting of a three (3) span structures with a maximum span of 186-feet. The bridges are proposed as precast post-tensioned trapezoidal tub girders. Prestressed concrete girders should be considered in place of the tub girders, as they are more cost effective. If prestressed concrete girders are used, it will be necessary to consider the additional columns that are required at each pier and if the piers will need to be skewed to fit the columns in the available space. If WF83G girders with a cast-in-place concrete deck are used the profile may need to be revised to accommodate an increase of up to 9-inches in the superstructure depth. A markup indicating the recommended revisions to the WSDOT baseline design can be seen in Appendix G.2.

5.2 Foundations and Ground Improvement

Based on the soils information available along the corridor combined with the topography and the presence of wetlands it is anticipated that a variety of soil conditions will exist along the corridor. As a result, evaluation of soil conditions and corresponding geotechnical design recommendations will be required as the design of the bridges is advanced to the TS&L Phase. This geotechnical information could be included in a geotechnical baseline report (GBR) for the corridor. At locations where poor soil conditions are expected, increased geotechnical exploration would be beneficial, to allow for detailed evaluation of foundation options and bridge configuration to minimize cost.

5.3 Construction Staging

The construction staging and phasing of the SR 509 Extension will require careful analysis as the project progresses. Detailed construction phasing and staging plans will be a necessary part of the preliminary design for each structure. There are a number of structures that will cross existing facilities that will require the temporary closures and/or detours during select construction activities, such as setting girders. There are also several existing facilities that cross over SR 509 that will require the overcrossing bridge to be constructed in stages or the existing road to be closed during construction.

Standard bridge construction methods can be used for all of the bridges within the project. However, the bridges over and under I-5 and the bridge on SR 99 will significantly impact the public, the use of Accelerated Bridge Construction (ABC) should be considered as method of reducing impacts to the traveling public and local businesses.

As part of our analysis, we have reviewed the proposed structures to identify construction staging challenges and potential fatal flaws that will exist with the construction of the project. Based on this review no fatal flaws were identified. The largest staging challenge will be construction of connections between I-5 and SR 509 and the S 216th Street Bridge.

5.3.1 South 216th Street Bridge

Prior to construction of the SR 509/I-5 connection, the S 216th Street Bridge must be replaced to accommodate the necessary lane shifts for construction of the connection. Given the 28-feet curb to curb width of the existing bridge, it is not feasible to phase construction of the replacement bridge on the same alignment while keeping two (2) lanes of traffic open. Options for construction of the bridge involve the following:

- Complete closure with a detour during construction
- Staged construction and demolition with while maintaining one lane of stop light controlled alternating traffic
- Construction of the new bridge adjacent to the existing bridge

As part of the next phase of design staging should be investigated further. The possibility of using ABC should also be evaluated as a means to reduce the duration of construction and impacts to the traveling public.

5.3.2 SR 509/I-5 Connection

The structures that will carry traffic between SR 509 and I-5 will place traffic under I-5 and will need to be constructed in phases in order to maintain traffic on I-5 throughout construction. In order to demonstrate proof of concept and that these structures can be built while traffic is maintained on I-5, the construction phasing option in Appendix G.3 has been prepared. This option assumes that a minimum of 63-feet of width (outside to outside of temporary barrier) is

adequate for I-5 in one direction during construction and it only evaluated traffic shifts at the SR 509/I-5 connection south to the S 216th Street Bridge. As part of the next phase of design, this concept should be studied further in greater detail to identify and resolve conflicts with lane and traffic shifts that may exist north and south of the connection.

6. CONCLUSIONS

Based on our review of the WSDOT existing baseline designs for the Puget Sound Gateway Project there are a number of opportunities to reduce the structures cost to the project through a variety of methods. The primary option is a change in structure type to a more cost effective alternative. There are also opportunities to revise the proposed bridge layouts that will in turn accommodate a change to a more cost effective structure type.

We have also identified a number of areas related to the bridges that should be studied and evaluated further as the design of the project progresses to preliminary design. These include:

- Developing TS&L reports and preliminary design for individual bridges within the project to better identify risk and cost.
- Conducting a geotechnical baseline report for the project along with foundation evaluations of the bridges to more accurately estimate foundation requirements and costs.
- Developing staging plans for bridges to be constructed over or under I-5 and other critical roadways.
- Evaluating options for Accelerated Bridge Construction for bridges associated with I-5 and SR 99 and elsewhere on the project as applicable.