File No. 13926 Task 3.0PB
***Draft** Technical Memorandum*

Date:	September 28, 2001
To:	Jay Lyman, David Evans and Associates
From:	Connie Kratovil
Subject:	ODOT Contract No. 16902- I-5 Trade Corridor Study Phase II **Conceptual Engineering for Option Package 6: Express Bus with Corridor-Wide Capacity Increase**

GENERAL FUNCTIONAL DESCRIPTION

Option Package 6 includes directional express bus transit service in I-5 HOV lanes between Clark County and downtown Portland. It also includes widening I-5 to have a fourth travel lane in each direction between I-405 and I-205, and would require additional Columbia River Bridge crossing capacity. As currently proposed, Option Package 6 is designed and evaluated as an HOV system and not as a reversible lane system.

Key features of this option package include:

- Widens I-5 from 134th Street to approximately I-405 to support operation of three general purpose lanes and one HOV lane in each direction
- Results in a directional corridor HOV system from 134th Street to approximately I-405
- Includes additional Columbia River crossing capacity compatible with 4-lane tunnel, 6-lane bridge and 10-lane bridge crossing concepts

The general description of Option Package 6 is schematically depicted in **Figures 6-1 through 6-6** at the end of this memo.

TECHNICAL DESCRIPTION OF OPTION

General Description I-405 to Going Street

Roadways

The proposed design is depicted in **Figure 6-1.** The southerly beginning and terminus of the proposed HOV lanes would be at the I-405 connection with I-5. The northbound HOV lane would have a 'direct connect' from the I-405 northbound entrance ramp. This would be accomplished by exiting HOV traffic from the ramp and constructing a 'fly-over' structure over the northbound I-5 lanes and dropping the HOV lane down into the middle of the freeway. Northbound traffic on I-5 wanting to use the HOV lane would merge with the lane created by the direct connect ramp. Locations for merging and diverging in and out of the HOV lane where not identified. There may also be additional impacts created by the widths necessary to locate these areas.

The southbound HOV lane would terminate from I-5 with a 'direct connect' ramp to the southbound exit ramp from I-5 to I-405. The HOV lane profile grade would rise up from the middle of the freeway and 'fly-over' the southbound I-5 lanes on a structure and then connect into, and merge with, the I-405 southbound ramp.

Additional width in the median of the freeway was assumed to provide minimal shoulder width offsets to the proposed fly-over structures.

The proposed layout for this section includes a southbound auxiliary lane between the Going St. entrance and the I-405 exit. The I-405 exit ramp would be a two-lane exit with a drop lane to terminate the auxiliary lane. The northbound section assumes a two-lane entrance ramp from I-405 with one auxiliary lane extending to Going St. and the additional lane extending north to Portland Blvd. This section has not been shown to provide adequate capacity for operations. Further study will be necessary to determine the lane requirements and ramp configuration needed to accommodate projected traffic.

The existing 'trumpet' interchange style was selected for the Going St. interchange. The heavy northbound to westbound movement appears to require a free-flow style connection. The ramps were reconnected to fit the widened freeway cross-section. Access control will be necessary along Going St. up to Interstate Ave. to preserve the operation and safety of the ramp terminals.

Structures

The Going St. and Skidmore St. under crossing structures would need to be replaced with this option. Retaining walls would be continuous on both the east and west sides of the freeway between Going St. and I-405. These retaining walls would need to extend westerly along the north and south side of Going St. Soundwalls would be impacted, and would likely be relocated on top of the proposed walls.

The existing pedestrian structure between Going St. and I-405 would be impacted and would need to be relocated to provide pedestrian accommodation east and west.

The direct connect HOV ramps would require extended walls in the median to effect the grade change to clear the freeway lanes. The fly-over structures would likely require 'straddle' bents for support over the freeway. Some widening of the southbound I-405 ramp structure appears necessary to merge the HOV traffic.

Deviations from Standards
The direct connect HOV ramps may require minimal acceptable vertical and horizontal geometry. The NCHRP Report 'HOV Systems Manual' was used for much of the planning elements of the HOV layout. Some of the recommendations from this manual differ from standard freeway designs due to the exclusive nature of the HOV lanes. Some of the recommended values would need to be approved for use on Oregon state highways. As noted above, access management, Oregon Highway Plan and federal policies would also pertain.

General Description Going Street to Portland Blvd.

Roadways
The proposed design is depicted in **Figure 6-1.** This existing section has a partial, local access interchange to Alberta St. between the Portland Blvd. interchange and the Going St. interchange. The proposal for this section of freeway is to remove the partial interchange at Alberta St., create a southbound auxiliary lane between Portland Blvd. and Going St. and better define the southbound exit to Going St. The new southbound ramp would intersect directly into Going St. just west of the under-crossing structure. The Alberta St. under-crossing would be retained for local movements. The northbound freeway section would have an acceleration lane from the Going St. entrance loop that would merge into the additional lane created at the I-405 entrance ramp (described subsequently). The additional northbound lane from I-405 would drop at the new braided ramp exit to Lombard St.

Structures
The Ainsworth St., Killingsworth St. and Alberta St. under crossings would need to be replaced with this option. Retaining walls would be continuous on both the east and west sides of the freeway. Soundwalls would be impacted, and would likely be relocated on top of the proposed walls.

Deviations from Standards
No roadway design deviations were identified. Access management and federal policies were one of the main reasons for the proposal to remove the Alberta St. ramps. Federal reviews and approvals would still be required for this section. Deviations from access management and Highway Plan policies may be necessary.

General Description Portland Blvd. to Lombard Street

Roadways
The proposed design is depicted in **Figure 6-1.** The existing northbound and southbound freeway section between Lombard St. and Portland Blvd. is currently failing due to the close proximity of the entrance and exit ramps. This option would remove the weaving section from the freeway by grade separating ('braiding') the ramps. The southbound exit for Portland Blvd. would be moved to a point under the Lombard St. structure, with the southbound entrance ramp from Lombard 'braiding' over the modified exit ramp. The existing Lombard St. entrance loop would be removed and replaced with a double left turn, westbound to southbound ramp on Lombard St. The additional left turn lanes on Lombard St. would require widening both east and west of the freeway. Access control and closure of some street approaches would be necessary on Lombard St. to preserve the operation of the ramp signals.

A similar configuration would be used in the northbound section, with the Portland Blvd. entrance ramp 'braiding' over the northbound exit to Lombard St. The exit loop to Lombard St. would also be removed with this configuration. The ramp terminals on Lombard St. would be moved closer together to minimize impacts to adjacent properties.

The southbound and northbound 'braided' ramps would need to be two lanes wide due to their length. The northbound exit and southbound entrances from Portland Blvd. would be modified to reconnect into the widened cross section of I-5. An additional left turn lane on Portland Blvd. appears to be necessary to accommodate future traffic volumes. Access control and closure of some street approaches would also be necessary on Portland Blvd.

Some streets adjacent to the freeway between Lombard St. and Portland Blvd. would need to be cul-de-saced or realigned due to direct impacts from the ramps or to reconnect circulation cut off by the ramps .

Structures
Both the Lombard St. and Portland Blvd. freeway crossings would be replaced under this option. Both streets would need to be widened over the structure to provide for double left turns at the ramp terminals. Both structures would include bike and pedestrian accommodations.

The 'braided' ramp structure southbound could be either a rigid frame or 'regular' structure. The southbound ramps would require extensive walls between the ramps and along the R/W. Tie-back or cantilever type walls appear to be necessary. There may some difficulty in constructing these walls due to the close proximity of several residences. Soundwalls would be impacted, and would likely be relocated on top of the proposed walls.

The northbound 'braided' structure would be very long and would need to 'straddle' over the exit ramp. For feasibility, it was assumed that supports would need to be integrated into the proposed wall along the R/W. Profile grades would be very tight with this option.

The pedestrian structure across I-5 in this section would need to be removed due to conflicts with the braided ramps. Pedestrian movements would need to be accommodated via the Lombard St. and Portland Blvd. structures.

General Description Lombard St. to Victory Blvd.

Roadways
The roadway in this segment would be very similar to Option package 1, utilizing the same 'split diamond' configuration for the Victory – Columbia interchange and having similar exit and entrance points as previously described. The main difference under this option is the wider I-5 cross section that would be required to provide room for the HOV lanes and the proposed alignment shift of I-5 south of Columbia Blvd. The alignment shift is proposed to better utilize the existing freeway right of way and minimize residential impacts. The centerline alignment of I-5 would be moved east between Lombard St. and through the Columbia Blvd. area. This would be done using a series of horizontal curves that would keep the west edge of the pavement at approximately the same location.

Structures
The structures through this section would be similar to the structure details in Option Package 1. Additional widening would be necessary along the westerly and easterly side of the Columbia Slough structure due to the widened cross section of I-5. The easterly side of the Columbia Slough structure would also be wider, including some extension of the northbound exit ramp to Columbia Blvd. onto the structure.

Retaining walls and relocated soundwalls would be necessary along the easterly side of the freeway between Lombard St. and Columbia Blvd. Additional retaining walls to retain the fill from the widened roadway would be required along the easterly side of I-5 north of the Columbia Slough. All other walls for this isolated section would be similar to those described in Option Package 1.

Deviations from Standards
Access management and Oregon Highway Plan policies include recommended distances for the separation of freeway interchanges. The close proximity of the existing interchanges may require deviations from these policies. Federal Highway policies pertaining to modified freeway access would need to be followed, and would require formal approval of these proposals.

The area between Victory Blvd/Marine Drive to Mill Plain is discussed in COLUMBIA RIVER CROSSING section

General Description Mill Plain to SR-500

Between Mill Plain Blvd. and SR 500 in Vancouver, the proposed design is depicted in **Figure 6-3** and includes widening of the mainline to provide a total section of four through lanes (1 HOV and 3 general purpose). Additional lanes were added as auxiliary lanes between interchanges where the space between ramps was inadequate to provide for a merge and a diverge from the highway. Widening of the highway would require replacement of the existing overpasses for 29th St., 33rd St., and SR 500, and widening of the Mill Plain and McLaughlin overcrossings.

Interchanges were modified based upon the schematic design developed at a workshop held with DOT and consultant team members on June 29, 2001. The design concept included braiding most of the ramps to and from the existing interchanges. Ramps to be braided include:

Northbound

- Fourth Plain on-ramp with SR 500 off-ramp: The new diverge point for the SR 500 off-ramp would begin on the north side of the Fourth Plain overpass. The Fourth Plain on-ramp would pass over the SR 500 off-ramp, merging with the highway near the 29th Street overpass. The Fourth Plain on-ramp would also have an split to allow traffic to access I-5 northbound or SR 500 eastbound. Braiding of these ramps would require reconstruction of the 29th St. and 33rd St. overpasses.

Southbound

- SR 500 on-ramp with Fourth Plain off-ramp: The diverge point for the Fourth Plain off-ramp would be moved to the area between the 39th St. off-ramp and the SR 500 overpass. The new ramp would align to the west side of the SR 500 on-ramp, cross under the 39th St. on-ramp, and parallel the highway to connect to the existing interchange area. The design currently includes a connection between SR 500 and Fourth Plain Blvd. via a short weaving area. This weave takes place within the same zone that includes the SR 500-to-mainline weave and may negate the advantages of braiding the ramps. As a result, further study of the ramp configuration is recommended during subsequent alternatives analysis to determine the need for this connection and, if warranted, whether the correct design approach is to braid the ramps at this location.

- Fourth Plain on-ramp with Mill Plain off-ramp: The diverge point for the Mill Plain off-ramp would be moved to approximately the same location as the existing Fourth Plain off-ramp diverge. The Mill Plain ramp would rise and cross over both the Fourth Plain on-ramp, which is left mostly unchanged from the existing configuration, and Fourth Plain Blvd. Much of this ramp would be on structure because of the need to clear Fourth Plain.

- Mill Plain on-ramp with Downtown Vancouver/SR 14 off-ramp: To mitigate an existing short weave distance between the Mill Plain on-ramp and the Downtown Vancouver/SR 14 off-ramp, the off-ramp diverge point would be move to the north edge of the Mill Plain underpass, braid over the Mill Plain on-ramp and make a connection to SR 14 via the ramp included in the design for each of the river crossing options. The Mill Plain on-ramp would offer the option, via a mid-ramp split, to go to either I-5 southbound or SR 14 eastbound.

This design segment also includes a connector between SR 500 westbound and the 39th St. northbound on-ramp, providing a direct connection between SR 500 and I-5 northbound.

During the I-5 HOV study completed by Parsons Brinckerhoff, it was noted that in Vancouver, I-5 functions as both a regional and local connector. To improve the performance of I-5, these two traffic types could be separated via a barrier, effectively creating a bypass system through Vancouver for regional traffic. This option would require additional widening of the freeway to accommodate all the lanes, but would eliminate the need to extensively braid the interchanges. Separation of the freeway would occur north of SR 500 and south of SR 14, although the river crossing options that include a bypass bridge could connect into the regional route. Lane configurations would likely include 2 lanes in each direction on the bypass (1 HOV and 1 general purpose) and 2 lanes on the "local" system, plus any necessary auxiliary lanes between interchanges. It is recommended that this option be revisited in future studies along with the braided ramp option shown.

Deviations from Standards
The improvements were designed to the standards in the WSDOT Highway Design Manual. No deviations are noted.

General Description SR-500 to I-205

Roadways
This option creates 4 lanes (1 HOV and 3 general purpose) each direction on I-5 between SR 500 and just prior to the merge with I-205 at 134th Street. Traffic analysis for this segment warrants auxiliary lanes between the 39th and Highway 99/Main Street interchanges, and also between the 78th and 99th street interchanges. This would effectively create 5 lanes in each direction at these locations. The team was charged with minimizing impacts to existing structures that are currently in construction or which were recently constructed. In order to accomplish this, some design exceptions would be necessary. This option also includes widening I-5 for Express Bus and HOV bypass lanes at the Highway 99/Main Street and 99th Street south bound on-ramps.

Structures
Walls retaining the highway fill would be required on both sides of I-5 between the 39th Street Interchange and the Highway 99/Main Street interchange to minimize impacts to the natural resource area adjacent to

I-5. At the pedestrian bridge south of the interchange, retaining walls or modifications to the abutments would be required to accommodate the re-alignment of the southbound on ramp and the northbound off-ramps at the Highway 99/ Main Street Interchange. For the northbound on-ramp from the Highway 99/Main Street Interchange, cut retaining walls would be needed against a steep slope adjacent to the re-aligned ramp.

The widening between the 78th Street and 99th Street interchanges would force the sound walls on both sides of I-5 to be relocated. Additionally, new retaining walls near the north bound off-ramp at the 99th Street interchange would be required.

Deviations from Standards
The newly constructed Highway 99/Main Street, 78th Street and 99th Street interchanges, and the CCRR bridge are locations where the typical section does not meet WSDOT standards. The design varies from standards in order to keep from impacting those structures. The distance from the center travel lane to the center barrier would be 2 feet where 12 foot minimum is required by WSDOT standards. Additionally, in these same locations the outside shoulder widths would be 6-7 feet. WSDOT standards call for 10 foot minimum shoulders. In the section from the Highway 99/Main Street interchange to the CCRR bridge, the non-standard section length is approximately 1000' on the southbound side and approximately 2800' on the northbound side. At the 78th Street interchange the non-standard section runs for approximately 3100' and approximately 3000' at the 99th Street interchange.

COLUMBIA RIVER CROSSING OPTIONS

6-LANE BRIDGE OPTION

Roadway
The proposed design is depicted in **Figure 6-2.** At Marine Drive, the southbound on-ramp and off-ramp to Interstate Avenue would be braided. Due to the future light rail line planned for the area, the location of the Interstate Avenue diverge would remain in its existing location, requiring the southbound Marine Drive on-ramp to be on-structure through the wetland area to the west of Expo Road and merging with the mainline near Victory Boulevard. Northbound connections from the mainline to Marine Drive would largely remain the same.

The new 6-lane bridge concept is depicted in **Figure 6-2**. As shown, this concept provides a new eastern mainline express bypass facility with no interchange access between Marine Drive and SR 14. Access to Marine Drive, Hayden island, and SR 14 would continue to be provided from the I-5 mainline across the existing I-5 Columbia River Bridges.

The mainline of the 6-lane bridge section is designed with three lanes in each direction (1 HOV and 2 general purpose) between Marine Drive and Mill Plain in both directions. This provides a total of 6 lanes for the new river crossing, and 8 lanes elsewhere in the corridor. Operation of the existing I-5 bridges is maintained, resulting in 12 total roadway lanes (6 in each direction) over the river. On the Vancouver side of the river, the developed downtown and the Fort Vancouver Historical Reserve constrain the corridor. As a result, the northbound Mill Plain access ramp (from I-5 and SR 14) would have to be cantilevered over the freeway between SR 14 and Mill Plain if these connections are to be accommodated on the widened freeway with minimal impacts to adjacent properties.

By maintaining the existing I-5 bridge structures, connections to Hayden Island would remain in their current locations. There would be no impacts to the existing circulation system in this area.

The northbound connection to SR 14 as well as the southbound connection to I-5 from SR 14 would also remain in their current locations. However, to alleviate weaving between Mill Plain and SR14, the southbound off-ramp to SR14 and the Mill Plain on-ramp would be braided. For safety reasons, the Mill Plain on-ramp merges with the mainline south of the new 6-lane bridge touchdown point (approx. 7th Street). Northbound, a structure separate from the existing SR14 to I-5 structure is used for a direct SR 14 to Mill Plain/Fourth Plain connection. This connection merges with the relocated I-5 off-ramp to Mill Plain/Fourth Plain which is the result of braiding this ramp with the SR14 northbound on-ramp.

Additionally a southbound slip ramp connecting to 6th St. could be provided if warranted.

Direct HOV connections are provided (northbound and southbound) between the new 6-lane structure and SR 14 to eliminate the need for northbound HOVs to change lanes south of the southern touchdown point (approx. 1500' south of Marine Drive) to access the general purpose SR 14 connection, which requires use of the existing bridge structures. Accommodating these connections requires a split in the new 6-lane structure at SR 14, as they are left-hand merge/diverges.

Bicycle/Pedestrian Facilities

This memorandum does not include bicycle/pedestrian facilities on the proposed bridge section. The existing I-5 bridges accommodate pedestrian access. It is recommended that bicycle/pedestrian access be revisited in the future and that access be improved on the proposed or existing structures.

Structures

The 6 Lane Bridge alternative is conceptualized as a concrete segmental type with a bascule moveable span over the navigation channel. The span layout could be comprised of (south bank to north bank) 260'-540'-270'-540'-540'-280'(Bascule Draw Span)-320' spans. Currently, the existing dual bridges provide a horizontal clearance of 263 feet between the lift spans piers over the main navigation channel. The lift span provides a 39-foot vertical clearance above the Columbia River Datum (also referred to as zero gage or low water) when closed, and a maximum of 178 feet when fully raised. An increased vertical clearance of 58 feet is provided at the alternate barge channel beneath the bridge's fixed 531-foot truss span. South of the 531-foot span, a vertical clearance of 72 feet is provided between piers 6 and 7 and piers 7 and 8; these spans are outside of the maintained channel limits. The assumed profile of the 6-lane bridge has the bridge deck elevation over the navigation channel at 145 feet in the closed position. This is compared to the existing twin I-5 bridges which have a deck elevation of 45'feet (+-) in the closed position. The 6 lane bridge would function with the exiting I-5 bridges in operation. The new bridge is conceptualized to have a bascule moveable span, that when open, provides unlimited vertical clearance. The deck elevation of 145 feet was assumed based on the vertical restriction associated with Pearson Airpark. The airpark airspace height restriction is approximately at 175 feet; a deck at 145 feet should allow lights, signs and trucks to pass without infringing into the airspace.

Construction Considerations

- *Superstructure Type* - The superstructure section could be a multi-cell trapezoidal concrete box girder built by the balanced cantilever method. The cross section varies in depth from maximum depths over the interior piers to 10' at midspan. A suggested depth to span ratio would be 1/20 at the pier, and 1/50 at midspan (but no less than 10 feet). The parabolic soffit resulting from the variable structure depth coupled with the sloping webs of the box girder provides a dramatic aesthetic appearance, similar to the Glenn Jackson (I-205) Columbia River Bridge.

- *Column Type* - The river pier columns could consist of two 6' by 20' shafts spaced longitudinally 24' on center. The purpose of these twin wall shafts is to provide longitudinal stability during balanced cantilever erection, and then to provide longitudinal flexibility for the large time-dependent displacements experienced by this type of bridge in the final service condition. The piers for the moveable span would be solid 20' X 120' rectangles, housing the bascule lift span drive motors. If a vertical lift span is utilized, the bridge would most likely be two bridges with 4 towers to lift the large deck section.

- *Foundations* - The two end transition piers are on land at the riverbanks, and the remaining interior piers are all in the river. For the river piers, a footing size of approximately 36' by 36' (non-moveable piers) is required. Deep foundation elements may be either driven piles or drilled shafts. Larger diameter drilled shafts may be preferable to limit noise and vibration construction impacts.

- *Construction Procedures* - The river piers could be constructed by conventional methods using cofferdams. This features braced sheet piling walls, driven piles, underwater tremie concrete pours, and extensive pumping of the water inside the cofferdam to allow construction of the remainder of the pier footing and columns in the dry. This foundation type features footings that are founded below the river bottom. Because contractors assume significant risk with this type of foundation construction, costs are generally high.

  The river piers could also be constructed as water level foundations. This foundation makes use of a precast concrete lost footing form. The form has a bottom and four sides approximately 15' high. The bottom has holes for piling or in this case, large diameter drilled shafts. The drilled shafts are installed with permanent casings from the water level down below the bottom of the river. The precast footing form is lifted and placed over the top of the shaft casings and supported by hangers from the casings. Underwater tremie concrete is placed in the bottom of the form to allow pumping out the water to construct the remainder of the footing in the dry. However, in this configuration, the bottom of footing is at a much higher elevation, requiring a smaller tremie pour due to the reduced hydrostatic head. This type of foundation is generally less costly, because contractor risk is reduced.

  Superstructure construction could be by the balanced cantilever method. The concrete superstructure could be either cast-in-place or precast, however for the 500' span range (anticipated for this crossing), cast-in-place has been more widely used and is the recommended construction type. Segments are cast in pairs using form travelers, and typically two segments are cast per one week cycle. Segment lengths may vary between 10' and 15', with shorter lengths occurring near the piers where the sections are heavier.

- *Construction Duration* - Substructure construction could be expected to take about 3 months per main river pier. Construction of the land-based piers could overlap with the construction of the river piers. Therefore substructure construction would be dependant on the actual type of bridge selected and the spans over Columbia River. Superstructure construction is dependent on the number of form travelers utilized (overhead erection equipment). With an average segment length of 12', one would calculate the numbers of segment pairs comprising each cantilever (½ span). Assuming a one-week cycle per segment pair, superstructure construction could be approximated with only one pair of travelers. Total construction time with mobilization and demobilization could be readily calculated once a conceptual span arrangement is determined. This schedule could be accelerated with the use of additional travelers.

Deviations from Standards
None noted.

10-LANE BRIDGE OPTION

Roadway
The new 10-lane bridge concept is depicted in **Figures 6-4 and 6-5**. The mainline of the 10-lane bridge section is designed with four lanes in each direction (1 HOV and 3 general purpose) plus an auxiliary lane between Hayden Island and SR 14 in both directions. This provides a total of 10 lanes for the river crossing, and 8 lanes elsewhere in the corridor. On the Vancouver side of the river, the developed downtown and the Fort Vancouver Historical Reserve constrain the corridor. As a result, the freeway would have to be double-decked between SR 14 and Mill Plain if all the ramp connections are to be accommodated on the widened freeway with minimal impacts to the adjacent properties. Construction of the 10-lane bridge assumes full replacement of the existing I-5 bridges. As a result, connections to Hayden Island and SR 14 would need to be reestablished.

On Hayden Island, the ramps would not be able to connect at their current locations. As a result, the existing circulation system for the Hayden Island area would need to be modified extensively.

The northbound connection to SR 14 would diverge from the bridge onto an independent structure. This ramp would then split, with one ramp going to downtown Vancouver via a loop and the other connecting to SR 14 eastbound. The ramp to SR 14 would begin at such a high elevation that it cannot connect to SR 14 without conflicting with the existing Columbia Way interchange. Therefore, it is assumed a braided ramp would be constructed at Columbia Way to accommodate both ramps.

In the southbound direction, the SR 14 ramp would diverge north of Mill Plain, braiding with the Mill Plain on-ramp (discussed below). This ramp would connect to SR 14 at approximately the same location as the existing ramp but would be lowered to the current the elevation of I-5 (approximately). Additionally, a slip ramp connecting to 6th St. could be provided if warranted.

From SR 14, the northbound connector would braid with the Mill Plain/Fourth Plain off-ramp, providing a split to optionally exit to Mill Plain/Fourth Plain instead of entering the freeway. The southbound connector would cross under the I-5 mainline then rise to connect to the mainline at approximately the location of the ship navigation channel. This ramp is two lanes to incorporate an HOV bypass of the ramp meter.

Due to the high elevation of the bridge, a connection from downtown Vancouver to I-5 is not possible. Vehicles needing to go southbound would access I-5 at Mill Plain Blvd.

Structures
The 10 lane bridge is conceptualized as a concrete segmental type without a lift or a bascule moveable span over the navigation channel. The span layout could be comprised of (south bank to north bank) 260'-540'-270'-540'-540'-280'minimum -320' spans (280' horizontal clearance is documented to be deficient, therefore Coast Guard and river users should be consulted regarding a preferred horizontal clearance). Currently, the existing dual bridges provide a horizontal clearance of 263 feet between the lift spans piers over the main navigation channel. The lift span provides a 39-foot vertical clearance above the Columbia

River Datum (also referred to as zero gage or low water) when closed, and a maximum of 178 feet when fully raised. An increased vertical clearance of 58 feet is provided at the alternate barge channel beneath the bridge's fixed 531-foot truss span. South of the 531-foot span, a vertical clearance of 72 feet is provided between piers 6 and 7 and piers 7 and 8; these spans are outside of the maintained channel limits. The assumed profile of the 10-lane fixed span bridge has the bridge soffit (underside of bridge) elevation over the current main navigation channel at 178 feet. This is compared to the existing twin I-5 bridges which have a deck elevation of 45'feet (+-) in the closed position. When the moveable span is open, the maximum vertical clearance is 178 feet.

The 10 lane bridge would function without the exiting I-5 bridges in operation (they would be demolished). The resulting deck elevation of 200 feet over the current river navigation channel assumes a 300-foot span for the main river navigation channel and a structure depth of 20 feet at the piers (10 feet at midspan). A deviation to the Pearson Airpark airspace would be required under this bridge alternative. Alternative profiles could also be examined which would shift the navigation channel to the south, although this could adversely affect the ramp connections to Hayden Island. For all bridge alternatives, more detailed analysis of current and future river navigation needs is warranted to see if the 178 foot clearance could be reduced.

Construction Considerations

- *Superstructure Type* - The superstructure section could be a multi-cell trapezoidal concrete box girder built by the balanced cantilever method. The cross section would vary in depth from maximum depths over the interior piers to 10' at midspan. A suggested depth to span ratio would be 1/20 at the pier, and 1/50 at midspan (but no less than 10 feet). The parabolic soffit resulting from the variable structure depth coupled with the sloping webs of the box girder provides a dramatic aesthetic appearance, similar to the Glenn Jackson (I-205) Columbia River Bridge.

- *Column Type* - The river pier columns could consist of two 6' by 20' shafts spaced longitudinally 24' on center. The purpose of these twin wall shafts is to provide longitudinal stability during balanced cantilever erection, and then to provide longitudinal flexibility for the large time-dependent displacements experienced by this type of bridge in the final service condition.

- *Foundations* - The two end transition piers are on land at the riverbanks, and the remaining interior piers are all in the river. For the river piers, a footing size of approximately 36' by 36' is required. Deep foundation elements may be either driven piles or drilled shafts. Larger diameter drilled shafts may be preferable to limit noise and vibration construction impacts.

- *Construction Procedures* - The river piers could be constructed by conventional methods using cofferdams. This features braced sheet piling walls, driven piles, underwater tremie concrete pours, and extensive pumping of the water inside the cofferdam to allow construction of the remainder of the pier footing and columns in the dry. This foundation type features footings that are founded below the river bottom. Because contractors assume significant risk with this type of foundation construction, costs are generally high.

  The river piers could also be constructed as water level foundations. This foundation makes use of a precast concrete lost footing form. The form has a bottom and four sides approximately 15' high. The bottom has holes for piling or in this case, large diameter drilled shafts. The drilled shafts are installed with permanent casings from the water level down below the bottom of the river. The precast footing form is lifted and placed over the top of the shaft casings and supported by hangers from the casings. Underwater tremie concrete is placed in the bottom of the form to allow pumping out the water to construct the remainder of the footing in the dry. However, in this configuration, the bottom of footing is at a much higher elevation, requiring a smaller tremie pour due to the reduced hydrostatic head. This type of foundation is generally less costly, because contractor risk is reduced.

Superstructure construction could be by the balanced cantilever method. The concrete superstructure may be either cast-in-place or precast, however for the 500' span range, cast-in-place has been more widely used and is the recommended construction type. Segments are cast in pairs using form travelers, and typically two segments are cast per one-week cycle. Segment lengths may vary between 10' and 15', with shorter lengths occurring near the piers where the sections are heavier.

- *Construction Duration* - Substructure construction could be expected to take about 3 months per main river pier. Construction of the land-based piers could overlap with the construction of the river piers. Therefore substructure construction would be dependant on the actual type of bridge selected and the spans over Columbia River. Superstructure construction is dependent on the number of form travelers utilized (overhead erection equipment). With an average segment length of 12', one would calculate the numbers of segment pairs comprising each cantilever (½ span). Assuming a one-week cycle per segment pair, superstructure construction could be approximated with only one pair of travelers. Total construction time with mobilization and demobilization could be readily calculated once a conceptual span arrangement is determined. This schedule could be accelerated with the use of additional travelers.

Deviations from Standards

The roadway improvements described were designed using the standards of the appropriate DOT jurisdiction. Two deviations from standard are noted. On the northbound off-ramp from I-5 to SR14/Downtown Vancouver, the downtown Vancouver leg of the ramp has a profile grade of 7%. On the SR 14 to southbound I-5 ramp, a profile grade of 6% is required to cross under the I-5 mainline and connect to the mainline at a reasonable distance from Hayden Island. A maximum of 5% is considered standard. There is limited opportunity to modify the I-5 to Vancouver ramp to accommodate a lesser slope. The 6% slope on the SR 14 to I-5 ramp could be reduced if either the ramp is extended south or I-5 is kept at a higher elevation in the proximity of the crossing.

TUNNEL OPTION

Roadway

The proposed design is depicted in **Figure 6-6.** The tunnel section is designed to provide a total of 4 lanes of capacity (1 HOV and 1 general purpose in each direction) to supplement the existing 6-lane freeway section between Marine Drive and Mill Plain Blvd. The south tunnel portal would be located approximately 800' south of the Marine Drive interchange. The north portal would be located approximately 500' north of the SR 14 interchange. The tunnel profile assumes the use of cut and cover box and immersed tube tunneling techniques. In the vicinity of the portals, the existing freeway would be flared to accommodate the tunnel approaches in the center of the freeway. The tunnel approaches extend 1000' south and 1600' north of the tunnel portals. Flaring of the freeway in the Marine Dr. vicinity would require reconstruction of the Marine Dr. northbound off-ramp and southbound on-ramp. The Marine Dr. overpass would also require reconstruction. Flaring the freeway in the SR 14 vicinity would require reconstruction of the southbound I-5 to SR14 off-ramp and SR 14 to northbound I-5 on-ramp. The Evergreen Blvd. overpass would also require reconstruction.

The HOV lane and the center most general purpose lane in each direction would be directed into the tunnel, bypassing the Marine Drive, Hayden Island, and SR14 interchanges. Access to these interchanges would remain on the existing surface system.

Bicycle/Pedestrian Facilities

This memorandum does not include bicycle/pedestrian facilities on the proposed tunnel section. The existing I-5 bridges accommodate pedestrian access.

Structures

The tunnel crossing could be immediately to the west or east of the existing I-5 bridges. At this location, the river is approximately one-half mile wide. There are a number of tunnel types distinguished by the method of tunneling. Three broad categories include, cut-and-cover, immersed tube, and bored tunnels. A profile for an immersed tube tunnel has been prepared, but alternatively a bored tunnel section could also be developed. Both types would utilize sections of cut-and-cover tunnels as transition tunnel segments across land for immersed tubes, or as portals for bored sections. For example, for an immersed tube, at grade segments of the alignment could transition to a cut-and-cover for land crossings, and then transitioning to immersed tube for water crossings. The U-shaped retained cut section would extend along the alignment from the area, which the highway starts a downward grade and reaching a depth below ground providing enough clearance for the highway traffic and cut-in-cover structure to be completely below ground. At this point, the tunnel would be cut-and-cover.

Cut-and-cover construction would continue until water crossing sections are needed, at which time the tunnel would switch to an immersed tube section, transitioning back to cut-and-cover when reaching land again. Alternatively, a bored tunnel would start with a U-shape retained cut, transitioning to cut-and-cover, then to a bored section. The difference is that once a bored section is started, the tunnel boring equipment would continue from the south side of Portland Harbor until reaching Evergreen Blvd. in Vancouver. For this study, either tunnel alternative is viable, however an immersed tube was selected to profile due to its ability to daylight sooner, making the overall length shorter.

- *Construction Techniques-* Landside tunnels (on Hayden Island, south of Portland Harbor, and in Vancouver) could include cut-and-cover methods and bored or mined methods. The subqueous portion of the tunnel (below water) could be constructed by two different methods: boring, using Earth Pressure Balance Tunnel Boring Machines (EPB TBM), or by dredging a trench in the river bottom and placing prefabricated tunnel sections in the trench and backfilling over the tunnel. This method is referred to as "immersed tube". Immersed tube tunnels generally require less depth below the river bottom than bored tunnels. Since they are shallower, the immersed tube can transition back to an at grade alignment quicker that bored tunnels.
- *Typical Section-*
  - *Immersed Tube-* Immersed tube tunnels are tunnel sections, which are prefabricated in convenient lengths (usually 300 to 400 feet), floated to the site, and then placed into a pre-dredged trench, jointed, connected and protected by backfilling the excavation. The sections may be prefabricated with steel or concrete in temporary construction basins serving as dry docks. In the United States, immersed tubes have been used successfully for subaqueous transit and highway tunnels since the 1930's. As an alternative to dredging a trench with side slopes, the trench could be excavated and the tubes placed in a cofferdam in the river. However, the cofferdam could pose a serious obstacle to river traffic.

  - *Bored Tube-* Twin bores (drilled tunnels) have been successfully constructed with diameters from the teens, up to 50 feet. The cross-section that would be necessary for this alternative would be comprised of twin 35-foot diameter bores. This would provide the necessary clearance to provide two lanes of traffic, shoulders, and an emergency/maintenance walkway in each tunnel bore. The tunnel sections are constructed by first constructing an entrance portal tunnel or drop shaft, and then a tunnel boring machine is inserted to drill the section under the land obstructions and water. Since the minimum cover above a bored tunnel is approximately one tunnel diameter (a general "rule of thumb" for soft ground tunneling), the depth of the tunnel below the existing river bottom would increase as compared to an immersed tube tunnel. This, in turn, would increase the overall tunnel length since it will take longer to transition to an at-grade south of Portland Harbor and north into Vancouver. Generally speaking, larger tunnel diameters incur higher start up capital costs.

- *Property Sensitivity*- The conceptual tunnels could pass beneath businesses, highway overpasses and or private properties. Similar situations are in existence in San Francisco, Los Angeles, Chicago, New York, Boston, Baltimore, and Atlanta, just to name a few. One significant issue is the potential for ground settlement that can occur within the settlement tough around the tunneling operations. Many factors will affect whether a property is at risk of settling, some of which include: the tunnel techniques employed, the depth of tunnel below ground, soil types, and the foundation and design of the affected properties. Detailed investigation should occur to assess the risk and potential remedies to offset these potential tunneling impacts.
- *Benefits and Impacts*-
  - Immersed tube tunnels:
    - Shorter in length that a bored tunnel
    - Large in-water open excavation required
    - Could limit future river dredging
    - Large landside disruption in cut-and-cover section approaching water crossings
    - Would required open cut sections across Hayden Island, through Vancouver, and south of Portland Harbor.
  - Bored tunnels:
    - Would avoid all in-water construction in the Columbia River
    - Could result in significant construction impacts to tunnel portal areas in North Portland and Vancouver. Requires large tunnel staging areas, muck (tunnel waste) removal, and cut-and-cover transition areas.
    - Would probably not transition to at-grade section until north of Mill Plain Blvd. and south of Marine Drive.

RIGHT OF WAY

I-5 (less crossing section)

As discussed in the General Descriptions of each section, particularly through North Portland, weaving section proposed may not provide adequate capacity and operations. Some alternatives to the current design will likely require additional R/W and would impact homes adjacent to the freeway. Some modifications of the freeway alignment may reduce this potential, but there is not sufficient time to determine this in this phase of the study.

In an attempt to maximize the existing R/W and minimize impacts, the I-5 centerline was shifted to the east north of Lombard St. The shift avoided multiple impacts to the west side of the freeway, but three residences would be impacted on the east side. These appear to be direct impacts to buildings requiring three relocations, but further analysis is warranted.

Most of the right-of-way acquisition required between Mill Plain Blvd. and SR-500 results from the construction of the braided ramps. Northbound, the majority of the property takes would be north of Fourth Plain and would include the half block bounded by I-5 on the west and K St. on the east. In the southbound direction, the new off-ramp location at Fourth Plain would impact a number of residential properties.

Minimal ROW impacts are expected between the 78th Street and 99th Street interchanges. The frontage roads would be pushed out approximately 12' from their current location, which could require additional right-of-way and/or temporary construction easements.

6-lane bridge

Construction of the 6-lane bridge would require additional right-of-way for the main structure as well as for reconfigured ramps. Properties impacted include the Safeway Marketplace and Doubletree Hotel, both on Hayden Island.

The 6-lane bridge alternative requires a total commercial right-of-way take of approximately 292,100 sq. feet and open land right-of-way take of 96,600 sq. feet. Commercial takes are primarily concentrated east of the existing mainline at Hayden Island and Columbia Way. In addition, commercial right-of-way is necessary east and west of I-5 from SR 14 to Mill Plain due to mainline widening. Open land right-of-way is required for the Marine Drive southbound on-ramp structure west of Expo Road and SR 14 interchange improvements in the vicinity of the Burlington-Northern RR. No residential right-of-way is required.

10-lane Bridge

Construction of the 10-lane bridge would require limited additional right-of-way for the main structure. However, reconstruction of the many ramps would require the acquisition of additional right-of-way. Key impacts include a service station on Hayden Island and the parking lot for the Western Region headquarters of FHWA.

The 10-lane bridge alternative requires a total commercial right-of-way take of approximately 224,700 sq. feet and open land right-of-way take of 167,200 sq. feet. Commercial takes are primarily concentrated east of the existing mainline at Hayden Island and Columbia Way. In addition, commercial right-of-way is necessary east and west of I-5 from SR 14 to Mill Plain due to mainline widening and along local roads requiring realignment on Hayden Island. Open land right-of-way is required in the vicinity of the SR 14 interchange and the Burlington-Northern RR. No residential right-of-way is required.

Tunnel
Assuming the use of cut-and-cover tunnel construction techniques, right-of-way impacts are expected on Hayden Island to perform excavation. Impacted properties on Hayden Island include Waddles Restaurant, Safeway Marketplace, and Doubletree Hotel. South of the Oregon Slough, a boat sales dealership would be impacted. North of the Columbia River, one developed parcel (building use unknown) is expected to be impacted by the tunnel construction. Most of the other work would take place within the existing public right of way.

The 4-lane tunnel alternative requires a total commercial right-of-way take of approximately 142,300 sq. feet and open land right-of-way take of 8,800 sq. feet. Commercial takes are concentrated east of the existing mainline at Hayden Island and Columbia Way. In addition, commercial right-of-way is necessary east and west of I-5 from SR 14 to Mill Plain due to mainline widening. Open land right-of-way is required south of the northern portal in the vicinity of the SR 14 interchange. No residential right-of-way is required.

Summary of ROW requirements

Section	Residential (Acres)	Commercial (Acres)	Open Land (Acres)	Residential Displacements
Going Street to Marine Drive Vicinity	0.44	1.23		11
Mill Plain to I-205	2.73		0.57	30
6-lane Bridge Option		6.71	2.22	
10-lane Bridge option		5.17	3.84	
Tunnel Option		3.27	0.20	

COSTS

All estimates are based on 2001 unit costs: These estimates do NOT include the cost to purchase any businesses on Hayden Island. The names of those businesses can be found under the ROW section of this memorandum. Commercial land value has been included in this estimate.

Segment estimates can be found in the following tables. In summary:

Option Package 6 with a 6-lane bridge	$.1,472,410,000
Option Package 6 with a 10-lane bridge	$.1,651,644,000
Option Package 6 with a 4-lane tunnel	$.1,341,585,000

4-lane from I-405 to Victory

Right of Way	$ 4,688,750
Utility Relocations	15,750,000
Excavation	1,184,000
Surfacing	20,470,912
Roadside Development	10,500,000
Traffic Services	6,188,950
Structures	176,141,895
Mobilization	19,058,861
Contingencies	82,334,278
Engineering and Administration	84,907,224
Total	$429,224,869

4-lane from Mill Plain to SR-500	
Right of Way	$ 10,020,351
Utility Relocations	6,150,000
Excavation	2,926,560
Surfacing	6,365,320
Roadside Development	4,100,000
Traffic Services	1,481,375
Structures	26,639,112
Mobilization	3,812,989
Contingencies	16,472,114
Engineering and Administration	16,986,868
Total	$94,954,689

4-lane from SR-500 to I-205	
Right of Way	$
Utility Relocations	
Excavation	
Surfacing	5,012,914
Roadside Development	2,390,000
Traffic Services	836,500
Structures	1,461,200
Mobilization	776,049
Contingencies	3,352,532
Engineering and Administration	3,457,299
Total	$17,286,494

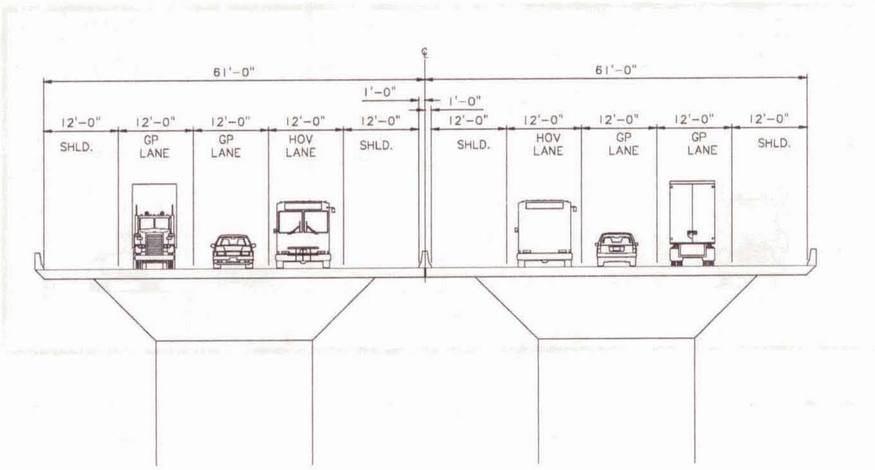
6-lane bridge (Victory to Mill Plain)	
Right of Way	$ 8,564,677

Utility Relocations	13,500,000
Excavation	844,480
Surfacing	7,166,965
Roadside Development	9,102,000
Traffic Services	3,263,950
Structures	483,730,785
Mobilization	41,408,654
Contingencies	178,885,387
Engineering and Administration	184,475,555
Total	$930,942,454

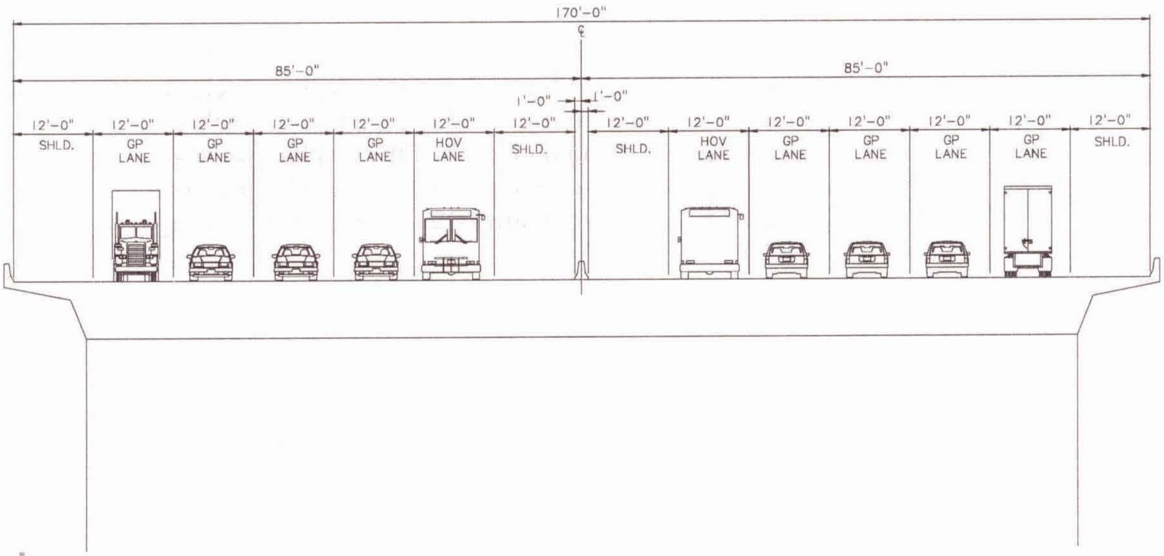
10-lane bridge (Victory to Mill Plain)	
Right of Way	$ 7,099,070
Utility Relocations	15,750,000
Excavation	5,383,840
Surfacing	11,811,930
Roadside Development	10,500,000
Traffic Services	4,967,750
Structures	570,597,936
Mobilization	49,520,916
Contingencies	213,930,359
Engineering and Administration	220,615,683
Total	$ 1,110,177,485

4-lane tunnel (Victory to Mill Plain)	
Right of Way	$ 3,960,407
Utility Relocations	6,000,000
Excavation	2,999,640
Surfacing	10,975,770
Roadside Development	4,000,000
Traffic Services	1,438,425
Structures	18,610,779
Structures	402,753,000
Mobilization	35,742,209
Contingencies	154,406,343
Engineering and Administration	159,231,542
Total	$ 800,118,115

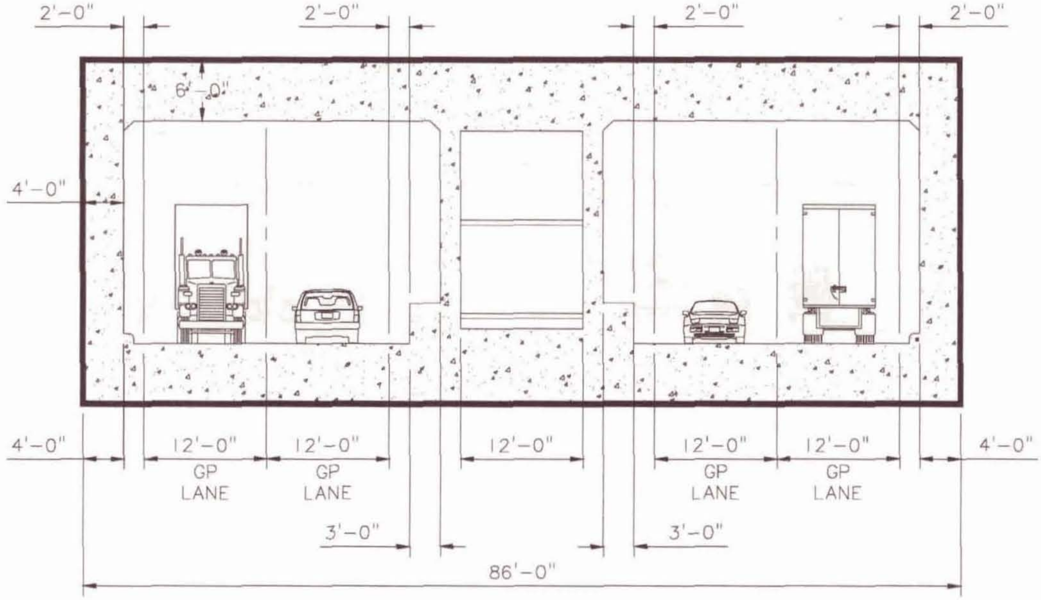
TYPICAL SECTIONS



6-LANE BRIDGE SECTION



10-LANE BRIDGE SECTION



TYPICAL TUNNEL SECTION

FIGURES

Note to reviewers:

Figure 6-1 would be similar to figure 4-2 of the graphics package.
Figure 6-2 would be similar to figure 5-4 of the graphics package.
Figure 6-3 would be similar to figure 5-5 of the graphics package.
Figure 6-4 would be similar to figure 5-8 of the graphics package.
Figure 6-5 would be similar to figure 5-9 of the graphics package.
Figure 6-6 would be similar to figure 5-12 of the graphics package.

I-5 Transportation and Trade corridor Partnership
Draft Costs by Option Package
October 16, 2001

Costs by Option Package	Unique Costs	Park and Ride Lots	Baseline Road Costs	Baseline Transit Costs	Rose Quarter Widening	Delta Park to Lombard	Vancouver Interchange Modifications	Add North Ramps to Columbia	No Bridge - Access to Hayden island through Marine Drive	LRT only Columbia River Bridge	4-lane supplemental Bridge	6-lane supplemental Bridge	10-lane supplemental Bridge	4-lane supplemental Tunnel	Total
Baseline					$300	$41	$93								$434
West Arterial	$947				$300	$41	$93								$1,381
3 Lanes (with a 4-lane Bridge)		$52			$300	$41	$93				$596				$1,083
Add a 4th Lane (with 6 lane bridge)	$465	$52			$300							$940			$1,757
Add a 4th Lane (with 10 lane bridge)	$465	$52			$300								$1,117		$1,933
Add a 4th Lane (with 4 lane tunnel)	$465	$52			$300									$807	$1,624
Light Rail Loop/3 lane [1, 2]	$1,082				$300	$41	$93			$140	$596				$2,252
Light Rail Loop/add a 4th lane [1,2]	$1,546				$300					$140		$940			$2,926

notes: 1. Assume separate LRT bridge
2. Park and Ride facilities inclused in "Unique costs"

I-5 Transportation and Trade corridor Partnership
Draft Costs by Decision Point
October 16, 2001

Costs by Decision Point	Unique Costs	Park and Ride	Baseline Road Costs	Baseline Transit Costs	Rose Quarter Widening	Delta Park to Lombard	Vancouver Interchange Modifications	Add North Ramps to Columbia	No Bridge - Access to Hayden island through Marine Drive	Total
Baseline					$300	$41	$93	$111	$76	$621
West Arterial	$947									$947
3 Lanes (with a 4-lane Bridge)	$596	$52			$300	$41	$93	$111		$1,193
Add a 4th Lane (with 6 lane bridge)	$1,405	$52			$300					$1,757
Light Rail Loop [1]	$1,222									$1,222
Express Bus - Short [2]	$199	$52				$41				$292
Express Bus- long [3]	$351	$52								$403
LRT only Columbia River Bridge	$140									$140
4-lane Supplemental Bridge (Victory to Mill Plain)	$596									$596
6-lane Supplemental Bridge (Victory to Mill Plain)	$940									$940
10-lane Supplemental Bridge (Victory to Mill Plain)	$1,117									$1,117
4-lane Supplemental Tunnel (Victory to Mill Plain)	$807									$807

Notes: 1. Park and Ride facilities included in "Unique costs"
2. Assume cost is 1/3 of 3-lane option
3. Assume cost is 1/4 of 4-lane option