Deliver a bridge that embodies the Portland aesthetic, is functional and affordable

- **Aesthetic** – the right bridge for the context
- **Function** – the right bridge for the use, site and environment
- **Cost** – the right bridge for the budget
- **Viable solutions must balance all three**
Risks

- Fabrication – Erection
- Material – Superstructure
- Design
- Schedule
## Draft Risk Analysis Summary

### Willamette River Transit Bridge

<table>
<thead>
<tr>
<th>Major Risk Categories</th>
<th>Wave frame</th>
<th>Tied Arch</th>
<th>Thru Arch</th>
<th>4 Pier Cable Stayed</th>
<th>2 Pier Cable Stayed</th>
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<tr>
<td>Center-to-center Span Width</td>
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</tr>
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</table>

**Legend**

- Higher Risk
- Moderate Risk
- Lower Risk

### Wave Frame

### 2 Pier Cable Stayed

### 4 Pier Cable Stayed
## Draft Risk Analysis Summary

### Willamette River Transit Bridge

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### Legend
- Higher Risk
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- Lower Risk

**Wave Frame**

**2 Pier Cable Stayed**

**4 Pier Cable Stayed**
## Draft Risk Analysis Summary

**Willamette River Transit Bridge**

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**Legend**

- Higher Risk: Red
- Moderate Risk: Yellow
- Lower Risk: Green

### 2 Pier Cable Stayed

### 4 Pier Cable Stayed
## Draft Risk Analysis Summary

### Willamette River Transit Bridge

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- Lower Risk: Green

### Wave Frame

2 Pier Cable Stayed

4 Pier Cable Stayed
### Draft Risk Analysis Summary

**Willamette River Transit Bridge**

#### Wave Frame

**Team’s Charge**

Develop methods to reduce risk profile of Wave Frame

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**Legend**

- Higher Risk
- Moderate Risk
- Lower Risk

**Images:**

- Wave Frame
- 2 Pier Cable Stayed
- 4 Pier Cable Stayed
Risks

- **Fabrication - Erection**
  - High performance steel at superstructure
  - Option A: In place on temporary work platform
    - Restrict navigation to 150’ 3 - 4 month
    - Helps manage construction risks
    - Lowers labor cost
    - Reduces schedule

![Wave Frame](image)

2 Pier Cable Stayed

4 Pier Cable Stayed
**Risks**

- **Fabrication - Erection**
  - High performance steel *at superstructure*
  - Option B: *Balanced cantilever method*
    - Higher construction risk
    - Jones Act – Increase labor cost 10%

---

Wave Frame

2 Pier Cable Stayed

4 Pier Cable Stayed
Risks

• Fabrication - Erection
  – Both Options Require
  – High performance steel at superstructure
  – Complex – highly technical welding
  – Higher cost and schedule risk
  – One has HP steel superstructure
Wave Frame

Construction Sequence - Revised

Willamette River Transit Bridge
Lifting of heavy prefabricated segments (400 ton)
Wave Frame
Willamette River Transit Bridge
Construction Sequence - Revised

Advantages:
• Reduce construction cost – less in-water work (Jones Act)
• Reduce on-site field welding
• Comparable construction schedule as Cable Stay bridge type
Risks

Willamette River Transit Bridge

- **Material - Superstructure**
  - High performance steel
  - Available from only one source
  - Volatile pricing
  - Special run - availability limited
  - Material sizes at upper limit of availability
  - Higher cost and schedule risk
  - One has HP steel superstructure
Revised Design:

- **High Performance Steel** only for top chord of wave
- Normal steel for **remainder** of bridge steel elements
Wave Frame

Willamette River Transit Bridge

Use of High Performance Steel

Advantages:

• **Excellent structural properties** (high yield strength – fracture toughness)
• Ease of welding
Wave Frame

Use of High Performance Steel

Disadvantages:

- Available from two sources
- Volatile pricing
- Special run – limited availability
Risks

Willamette River Transit Bridge

- Design – Wave Frame
  - Prototype design
  - Complex steel to concrete connections
  - Non redundant structure
  - Higher cost and schedule risk
Wave Frame

Willamette River Transit Bridge

Structural Analysis Model
Wave Frame
Structural Analysis Model

Willamette River Transit Bridge
Wave Frame

Structural Analysis Model

Willamette River Transit Bridge
Wave Frame

Structural Analysis Model

Willamette River Transit Bridge
Willamette River Transit Bridge

Complex Steel to Concrete Connection

Initial Design
Concrete “T” section with shear stud connection

Revised Design
Composite cross section with continuous I-Beam
Wave Frame

Willamette River Transit Bridge

Complex Steel to Concrete Connection

Advantages:

- Simplification of pedestrian walkway construction
- Avoidance of shear studs (shrinkage – creep – concrete consolidation)
- Avoidance of post tensioning ducts
- Better strut to concrete beam connection
Wave Frame

Willamette River Transit Bridge

Redundancy of Bridge Elements – Tension Members

Initial Design:
4-inch thick plate
Box configuration

Revised Design:
Thinner plates
Double “C” configuration

Top Chord Cross Section
Wave Frame

Willamette River Transit Bridge

Redundancy of Bridge Elements – Tension Members

Advantages:
- Top chord section with redundancy
- Elimination of 4” steel plates
Risk Summary – Wave Frame

• High Performance Steel remains fundamental
• Lowered use of HPS
• Increased use of standard steel
• Simplified construction details and methods
## Draft Risk Analysis Summary

### Willamette River Transit Bridge

#### Team’s Charge

Develop methods to reduce risk profile of Wave Frame

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**Legend**

- Higher Risk
- Moderate Risk
- Lower Risk

**Images:**

- Wave Frame
- 2 Pier Cable Stayed
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Revised Risk Summary

Willamette River Transit Bridge

High Performance Steel remains fundamental to this bridge type

Risk profile lowered for wave frame

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Legend:
- Higher Risk
- Moderate (+) Risk
- Moderate Risk
- Lower Risk
Revised Risk Summary

Willamette River Transit Bridge

Questions?

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Legend:
- Higher Risk
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- Moderate Risk
- Lower Risk

Wave Frame

2 Pier Cable Stayed

4 Pier Cable Stayed
Opportunities and Challenges

Willamette River Transit Bridge
Evaluation Criteria

Willamette River Transit Bridge

- Cost
- Risk
- Fundamental Performance
- Architectural
- Urban Context
- Greenway
- Environmental – Sustainability
- Bridge Operations
- Miscellaneous
- Opportunities
Each alternative has opportunities and challenges
Opportunities and Challenges

Willamette River Transit Bridge

**Cable Stayed 2 Pier**
Cable Stayed – 2 Pier

Greenway

Opportunity

Willamette River Transit Bridge

More open – no landside piers
Cable Stayed – 2 Pier

Lifecycle cost

Willamette River Transit Bridge

Opportunity

Low lifecycle cost - more concrete and less steel
Cable Stayed – 2 Pier

Willamette River Transit Bridge

Navigation

Opportunity

Largest horizontal clearance

760’ Clear
Cable Stayed – 2 Pier

Environmental

Willamette River Transit Bridge

Challenge

Piers closest to shallow water
Cable Stayed – 2 Pier

Navigation

Willamette River Transit Bridge

Challenge

Lowest vertical clearance (still exceeds 75’)

Cable Stayed – 2 Pier

Accommodation of curved spans at greenway

Willamette River Transit Bridge

Challenge

Stay Cables – Overhead Catenary Wire
Opportunities and Challenges

Willamette River Transit Bridge

Cable Stayed 4 Pier
Cable Stayed – 4 Pier

Lifecyle cost

Willamette River Transit Bridge

Opportunity

Low lifecycle cost - more concrete and less steel
Cable Stayed – 4 Pier
Willamette River Transit Bridge

Risk Profile

Opportunity

Lowest risk profile for schedule and budget
Cable Stayed – 4 Pier

Willamette River Transit Bridge

Navigation

Opportunity

Second largest horizontal clearance

700’ Clear
Willamette River Transit Bridge

Cable Stayed – 4 Pier

Mode Flexibility

Opportunity

Accommodates various bike/ped – train/bus configurations
Cable Stayed – 4 Pier
Willamette River Transit Bridge
Greenway
Challenge
Landside pier closest to greenway
Cable Stayed – 4 Pier

Greenway

Widest bridge over greenway – 69’ versus 66’
Opportunities and Challenges

Willamette River Transit Bridge

Wave Frame
Wave Frame
Innovative

Willamette River Transit Bridge
Opportunity

Portland known for innovation: Light Rail – Streetcar – Tram
Wave Frame

Environmental

Willamette River Transit Bridge

Opportunity

Piers closer to deeper water

600' Clear
Wave Frame
Environmental

Willamette River Transit Bridge
Opportunity

Piers farther away from contaminated media

600' Clear
Wave Frame

Navigation

Willamette River Transit Bridge

Challenge

Narrowest horizontal clearance

600’ Clear
Wave Frame

Prototype

Willamette River Transit Bridge

Challenge

Increase design and construction engineering costs
Willamette River Transit Bridge

Wave Frame Prototype

Challenge

Increase design and construction engineering costs

Bid risk

- Reduced competition for steel fabrication
Higher price volatility than concrete
Wave Frame
Steel

Willamette River Transit Bridge

Challenge

Higher price volatility than concrete
Increased lifecycle costs
- Weld inspections
- Impact to service for recoating (painting)
FTA – Hold contingency for high risk items

- Hold until high risk elements are 20% complete
- Funds held well into construction
- Opportunity to apply resources for other needs reduced
Opportunities and Challenges

Questions?
Cost: Baseline Quantity Estimate

Willamette River Transit Bridge

Process

Wave frame design was revised
Construction methodology was revised
Revised quantities were generated (all three)
Design, market and construction risks were removed

Result

Baseline Quantity Estimate
Willamette River Transit Bridge

**Cost: Risk Assessment**

**Process – Wave Frame**

- Risks and likelihood of occurrence were identified
- Impacts were assessed
- Mitigation strategies were developed
- Cost for mitigation estimated

**Result**

- Cost range for design, market and construction risks
Cost: Risk Assessment

Result – Wave Frame

Cost range for design, market and construction risks

Potential Maximum Risk Value ............... $16,900,000
Potential Minimum Risk Value ............... $4,200,000
Recommended Risk Value ....................... $8,000,000

Result

Conceptual Cost Estimate Ranges
<table>
<thead>
<tr>
<th>NCG Recommended Design-Build Contract Contingencies</th>
<th>Cable Stayed 4 Pier 700' Clear</th>
<th>Cable Stayed 2 Pier 760' Clear</th>
<th>Wave Frame Girder 600' Clear</th>
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**Difference between estimating what is shown today versus Contractor bid prior to contract award**

**Design, Market and Construction Risk**
Cost to advance design from preliminary engineering to final design

Plus

Cost for construction engineering and inspection

Wave Frame has a range

Potential for higher design cost - prototype
### Conceptual Design Estimate

**December 11, 2008**

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**Unforeseen Conditions**

**Change Orders**
National Constructors Group Estimates (NCG)

Developed using labor costs, production rates, equipment costs, permanent and temporary material costs and contractor margin

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**December 11, 2008**

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**Difference between estimating what is shown today versus Contractor bid prior to contract award**

**Design, Market and Construction Risk**
### Conceptual Design Estimate
December 11, 2008

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<tr>
<td>Design Contingency Cost (2)</td>
<td>$5,490,000</td>
<td>$7,137,000</td>
<td>$8,000,000</td>
</tr>
</tbody>
</table>

Cost for the Wave Frame established during Risk Workshop - **$8,000,000**
Cost to advance design from preliminary engineering to final design

Plus

Cost for construction engineering and inspection
## Conceptual Design Estimate

**December 11, 2008**

<table>
<thead>
<tr>
<th>NCG Recommended Design-Build Contract Contingencies</th>
<th>NCG (1)</th>
<th>NCG (1)</th>
<th>NCG (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Contingency</td>
<td>10.0%</td>
<td>13.0%</td>
<td>10.1%</td>
</tr>
<tr>
<td>Design - Build Final Eng, Const, Inspection</td>
<td>22.0%</td>
<td>22.0%</td>
<td>22.0%</td>
</tr>
<tr>
<td>Construction Reserve</td>
<td>5.0%</td>
<td>8.0%</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>National Constructors Group</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity Based Construction Estimate</td>
<td>$54,900,000</td>
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<tr>
<td>Construction Reserve Cost</td>
<td>$3,020,000</td>
<td>$4,970,000</td>
<td>$3,280,000</td>
</tr>
</tbody>
</table>

### Unforeseen Conditions

**Change Orders**

1. **Wave Frame Girder**
   - 600' Clear
   - NCG (1) 37.1% 42.1%

2. **Cable Stayed 2 Pier**
   - 760' Clear
   - NCG (1) 37.0% 43.0%

3. **Cable Stayed 4 Pier**
   - 700' Clear
   - NCG (1) 37.0% 43.0%
<table>
<thead>
<tr>
<th>NCG Recommended Design-Build Contract Contingencies</th>
<th>Cable Stayed 4 Pier 700' Clear</th>
<th>Cable Stayed 2 Pier 760' Clear</th>
<th>Wave Frame Girder 600' Clear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Contingency</td>
<td>10.0% 13.0%</td>
<td>10.0% 13.0%</td>
<td>10.1% 10.1%</td>
</tr>
<tr>
<td>Design - Build Final Eng, Const, Inspection</td>
<td>22.0% 22.0%</td>
<td>22.0% 22.0%</td>
<td>22.0% 24.0%</td>
</tr>
<tr>
<td>Construction Reserve</td>
<td>5.0% 8.0%</td>
<td>5.0% 8.0%</td>
<td>5.0% 8.0%</td>
</tr>
</tbody>
</table>

| National Constructors Group                      |                               |                               |                             |
|--------------------------------------------------|                               |                               |                             |
| Quantity Based Construction Estimate             | $54,900,000                   | $59,500,000                   | $79,600,000                 |
| Design Contingency Cost                         | $5,490,000                    | $5,950,000                    | $8,000,000                  |
| Design - Build Final Eng, Const, Inspection     | $12,078,000                   | $13,090,000                   | $17,512,000                 |
| Construction Reserve Cost                       | $3,020,000                    | $3,280,000                    | $4,380,000                  |

| Total - National Constructors Group             | $75,488,000                   | $81,820,000                   | $109,492,000                |
## Willamette River Transit Bridge

### Cost Estimate

#### Greenway grading
- Address subsurface utilities
- Pier protection

#### Conceptual Design Estimate

<table>
<thead>
<tr>
<th>NCG Recommended Design-Build Contract Contingencies</th>
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</thead>
<tbody>
<tr>
<td>NCG (1)</td>
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<td>43.0%</td>
<td>37.1%</td>
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<tr>
<td>Design Contingency</td>
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<td>Design - Build Final Eng, Const, Inspection</td>
<td>22.0%</td>
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<td>8.0%</td>
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<tr>
<th>Description</th>
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</tr>
<tr>
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<td>$17,512,000</td>
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<td>Construction Reserve Cost</td>
<td>$3,020,000</td>
<td>$4,970,000</td>
<td>$4,380,000</td>
</tr>
<tr>
<td>Total - National Constructors Group</td>
<td>$75,488,000</td>
<td>$79,085,000</td>
<td>$109,492,000</td>
</tr>
</tbody>
</table>

| Total - Other Risk Items                            | $6,300,000                    | $6,300,000                    | $5,100,000                    |
### Conceptual Design Estimate

**Willamette River Transit Bridge**

**Cost Estimate**

Cost range about $4M

<table>
<thead>
<tr>
<th>NCG Recommended Design-Build Contract Contingencies</th>
<th>NCG (%)</th>
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<tbody>
<tr>
<td>Design Contingency</td>
<td>37.0%</td>
<td>43.0%</td>
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<td>Design - Build Final Eng, Const, Inspection</td>
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<tr>
<td>Construction Reserve</td>
<td>22.0%</td>
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<td>22.0%</td>
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<tr>
<td></td>
<td>5.0%</td>
<td>8.0%</td>
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</table>

<table>
<thead>
<tr>
<th>National Constructors Group</th>
<th>NCG ($)</th>
<th>NCG ($)</th>
<th>NCG ($)</th>
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<tbody>
<tr>
<td>Quantity Based Construction Estimate</td>
<td>$54,900,000</td>
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<tr>
<td>Design Contingency Cost</td>
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<td>$5,950,000</td>
<td>$7,735,000</td>
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<td>$3,020,000</td>
<td>$4,970,000</td>
<td>$3,280,000</td>
<td>$5,380,000</td>
</tr>
</tbody>
</table>

**Total - National Constructors Group**

- Cable Stayed 4 Pier 700' Clear: $75,488,000
- Cable Stayed 2 Pier 760' Clear: $79,085,000
- Wave Frame Girder 600' Clear: $81,820,000

**Total - Other Risk Items**

- Cable Stayed 4 Pier 700' Clear: $6,300,000
- Cable Stayed 2 Pier 760' Clear: $7,200,000
- Wave Frame Girder 600' Clear: $5,100,000

**Grand Total (Cost Range)**

- Cable Stayed 4 Pier 700' Clear: $81,788,000
- Cable Stayed 2 Pier 760' Clear: $85,385,000
- Wave Frame Girder 600' Clear: $89,020,000

- $3,597,000
- $3,885,000
- $4,222,000

Cost range about $4M
### Conceptual Design Estimate

**December 11, 2008**

<table>
<thead>
<tr>
<th>NCG Recommended Design-Build Contract Contingencies</th>
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<th>Cable Stayed 2 Pier 760' Clear</th>
<th>Wave Frame Girder 600' Clear</th>
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<td></td>
<td>NCG (1)</td>
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<tr>
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<tr>
<td></td>
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</tr>
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#### National Constructors Group

<table>
<thead>
<tr>
<th>Item</th>
<th>Cable Stayed 4 Pier 700' Clear</th>
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<td>$3,020,000</td>
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<td>$4,380,000</td>
</tr>
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</table>

Total - National Constructors Group: $75,488,000  $79,085,000  $81,820,000  $85,705,000  $109,492,000  $113,714,000

Total - Other Risk Items: $6,300,000  $6,300,000  $7,200,000  $7,200,000  $5,100,000  $5,100,000

Grand Total (Cost Range): $81,788,000  $85,385,000  $89,020,000  $92,905,000  $114,592,000  $118,814,000

$3,597,000  $3,885,000  $4,222,000

#### Budget Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Cable Stayed 4 Pier 700' Clear</th>
<th>Cable Stayed 2 Pier 760' Clear</th>
<th>Wave Frame Girder 600' Clear</th>
</tr>
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<tbody>
<tr>
<td>Budget Amount (1,720' x 66' x $725)</td>
<td>$82,302,000</td>
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<td>$82,302,000</td>
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<tr>
<td></td>
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# Conceptual Design Estimate

**December 11, 2008**

## Willamette River Transit Bridge

### Cost Estimate

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<td>5.0%</td>
</tr>
<tr>
<td>NCG (1)</td>
<td>43.0%</td>
<td>43.0%</td>
<td>42.1%</td>
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<td>$3,280,000</td>
</tr>
<tr>
<td>NCG (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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| Total - National Constructors Group                      | $75,488,000                    | $79,085,000                    | $81,820,000                   |
| Total - Other Risk Items                                 | $6,300,000                     | $6,300,000                     | $7,200,000                    |
| Grand Total (Cost Range)                                 | $81,788,000                    | $85,385,000                    | $89,020,000                   |
| Budget Summary                                           | $3,597,000                     | $3,885,000                     | $4,222,000                    |

|                   | Cable Stayed 4 Pier 700' Clear | Cable Stayed 2 Pier 760' Clear | Wave Frame Girder 600' Clear |
| Amount Over (+) /Under (+)                              | $514,000                       | ($3,083,000)                   | ($6,718,000)                  |
| Percentage Over /Under                                   | 0.6%                           | -3.7%                          | -8.2%                         |

1: National Constructors Group Estimates (NCG): Developed using labor costs, production rates, equipment costs, permanent and temporary material costs and contractor margin

2: Wave Frame Design Contingency Cost fixed based on 12/6/08 risk workshop
Discussion

Willamette River Transit Bridge
Next Steps

- WRBAC meeting for further deliberation of “few” viable types (January 13, 2009) ???

- WRBAC recommendation to Steering Committee (January 22, 2009) ???

- Additional design and process to refine vertical clearance (January to February 2009)

- Continued bridge design and refinement (Preliminary Engineering)
Thank you