Hood River-White Salmon Interstate Bridge

Seismic Vulnerability Assessment

Final Report

Port of Hood River, Oregon

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Abbreviations

ADT	average daily traffic
ARS	acceleration response spectrum
Bridge	Hood River-White Salmon Interstate Bridge
CSZ	Cascadia Subduction Zone
DSL	Department of State Lands
ERS	Earthquake Resisting System
FHWA	Federal Highway Administration
LL	lower level ground motion
ODOT	Oregon Department of Transportation
PL	Performance Level
POHR/Port	Port of Hood River
UL	upper level ground motion
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

1 Purpose and Need

The Hood River-White Salmon Interstate Bridge (Bridge) is a vital infrastructure link for the economic viability of the region's industries, community livability, and access for public health and safety. To protect and maintain the Bridge, the Port of Hood River (POHR) seeks to understand the existing structure vulnerabilities, including seismic vulnerability, in order to make an informed decision for seismic retrofit. One of the key vulnerabilities of the Bridge is damage and loss of function in the event of an earthquake. The overarching goal is to improve community resiliency.

A 2012 study of Pacific Northwest earthquake hazards published by the USGS determined that the odds are greater than one in three for a partial rupture of the Cascadia Subduction Zone fault occurring within the next 50 years, and greater than one in ten for a full rupture of the Cascadia Subduction Zone fault within the next 50 years. In addition, according to a 2015 statewide natural hazard risk assessment study, nearby local seismic faults along the Hood River present a closer potential source of earthquakes. Distance from the epicenter of an earthquake tends to dissipate the intensity and duration of ground shaking, and Hood River is not in the area of highest anticipated ground shaking for either Cascadia Event. However, the soil properties surrounding the Bridge and the age of the structure itself make it highly susceptible to ground shaking.

Since the Bridge was constructed before the region's seismic activity history was known and before seismic resiliency was considered in bridge design, it has a number of seismic deficiencies. The POHR conducted this study because the Hood River-White Salmon Interstate Bridge is not only an important local connection, but is also a vital regional and bi-state connection for post-earthquake recovery.

1.1 Port Goals

This report was authorized by the POHR to better understand:

- The seismic hazard at the site and the related consequences to this bridge depending on the type of earthquake;
- How to mitigate the potential seismic vulnerabilities of the Bridge;
- The steps and possible sequencing of seismic retrofit work that would improve the Bridge's performance in an earthquake and improve community resiliency; and
- The related costs, timeline, impacts, and processes for implementing seismic retrofit strategies for use in short- and long-term planning.

1.2 Project Objectives and Scope

Project specific objectives to meet the stated goals above are to:

- Provide meaningful but summarized information to the Port to understand and weigh the benefits of making a seismic retrofit investment for the aging bridge structure;

- Formulate concept seismic retrofits consistent with federal and state guidelines that are reasonable, achievable, and fundable; and
- Estimate the project cost, next steps for engineering analysis and project development, and an understanding of key impacts;

The following project scope that achieves the above goals and objectives includes:

- A general survey of the structure and supporting elements to identify deficiencies that would prevent bridge use after a seismic event;
- A high level summary of local seismicity, seismic design criteria, vulnerability, analysis methodology, and seismic retrofit alternatives which are often referred to as Earthquake Resisting Systems (ERSs); and
- Technical guidance, planning level recommendations, and estimates for bridge seismic retrofit including sequencing of work.

1.3 Importance of the Bridge

The Bridge connects the City of Hood River in Oregon to State Route 14 on the Washington side. This bridge is a connection that is important both locally and regionally. Residents cross the Bridge frequently for work, commerce, education, healthcare, and pleasure. Local emergency services rely on the Bridge as the only cross-river connection within many miles in each direction, with the Bridge of the Gods in Cascade Locks located 32 miles to the West, and The Dalles Bridge located 22 miles to the East.

Figure 1-1. View of the Hood River-White Salmon Interstate Bridge

Source/Note: https://upload.wikimedia.org/wikipedia/commons/d/d1/Hood_River_Bridge.jpg. Washington on the left and Hood River, Oregon, on the right.

The Bridge is an essential emergency detour route for highway and interstate traffic. This fact was exemplified when an oil train derailment and subsequent oil car fire in Mosier, Oregon in June 2016, required I-84 closures and traffic detours to Washington SR14 and onto the Bridge. This recent event highlighted the vital importance of the Bridge as a critical link for the broader region and local area; the Bridge effectively became part of the Interstate System as an emergency detour route. Maintaining the Bridge’s viability for vehicular and truck traffic is essential for the safety, vitality, and resiliency both locally and regionally.

The Oregon Resilience Plan (Oregon, Fig. 5.23) specifically addresses the need to prepare for a Cascadia Subduction Zone event and has designated U.S. 97 combined with a loop created by I-84, I-5, and OR 58 near Eugene-Springfield as post-earthquake transportation backbone lifeline routes. As emergency supplies move east-west along I-84 and north-south along U.S. 97, the Hood River-White Salmon Bridge could also provide important access between states for freight mobility, emergency supplies delivery, and reconstruction assistance.

The Columbia River itself must also remain navigable after an earthquake to deliver goods and services on the river system; the Bridge must not block navigation. The regions ports and river traffic will play an important role in recovery after an earthquake as points of goods exchange, storage, equipment delivery and transfer, and response operations.

2 Seismic Hazard

Until the 1980s, the Pacific Northwest was generally believed to be seismically inactive despite its place along the Ring of Fire, the perimeter of the Pacific Ocean marked by historic and current volcanic activity. Relatively small local faults along the Hood River were believed to pose the greatest risk with potential to cause ground shaking up to magnitude 6 in the Hood River area. Recent historic and physical evidence compiled in the last 30 years led to greater awareness of different and possibly more catastrophic seismic events. An earthquake event is scientifically predicted to occur along the Cascadia Subduction Zone (CSZ), where the Juan de Fuca tectonic plate off the west coast is slowly pushing beneath the continental North American tectonic plate.

Seismic hazard is generally greater in areas to the west of the Cascade Mountain Range. Hood River is on the edge of the Cascades, but statewide emergency management coordination efforts have grouped Hood River County and its associated cities into a general region with other eastern Oregon counties that have relatively less seismic hazard. However, according to the Oregon Natural Hazards Mitigation Plan, Hood River and the Bridge have the soft soils and historical earthquakes that lead to greater damaging impacts compared to the rest of the region (State).

2.1 Seismic Scale

Earthquakes are measured on two scales: magnitude and intensity.

- Magnitude: The *Richter scale* was devised as a simple way to compare medium-sized earthquakes in Southern California in the 1930s. Over the years, other approaches were created to increase accuracy and account for very large, distant earthquakes. The current 1 to 10 scale used in the United States is the *Moment Magnitude scale* which compares the relative energy released by an earthquake. When earthquake numbers are reported today, it is typically the Moment Magnitude scale value although rarely identified as such.
- Intensity: The Modified Mercalli scale accounts for local effects, potential damage, and impact to humans, animals, structures, and natural objects. This scale uses Roman numerals I to XII.

Table 2-1. Modified Mercalli Scale Intensity

Level	Intensity
I	Not felt except by very few under especially favorable conditions
II	Felt only by a few persons at rest, especially on upper floors of buildings
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings; many people do not recognize it as an earthquake; standing motor cars may rock slightly; vibrations similar to the passing of a truck; duration estimated
IV	Felt indoors by many, outdoors by few during the day; at night, some awakened; dishes, windows, doors disturbed; walls make cracking sound; sensation like heavy truck striking building; standing motor cars rocked noticeably
V	Felt by nearly everyone; many awakened; some dishes, windows broken; unstable objects overturned; pendulum clocks may stop
VI	Felt by all, many frightened; some heavy furniture moved; a few instances of fallen plaster; damage slight
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VIII [a]	**Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse; damage great in poorly built structures; fall of chimneys, factory stacks, columns, monuments, walls; heavy furniture overturned**
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings with partial collapse; buildings shifted off foundations
X	Some well well-built wooden structures destroyed; most masonry and wood structures destroyed with foundations; rails bent
XI	Few, if any (masonry) structures standing; bridges destroyed; rails bent greatly
XII	Damage total; lines of sight and level are distorted; objects thrown into air

[a] Full CSZ event shaking anticipated at the Bridge site.

Source: Oregon Natural Hazards Mitigation Plan, Table 2-13. An earthquake will be quantified with a magnitude value, but its surrounding impacts are gauged by a range of intensity values. For example, the CSZ event in Oregon is expected to be a magnitude value between 8 or 9 at the coast, but its intensity will range from VI to X across the state.

In the area of the Bridge, the Oregon Natural Hazards Mitigation Plan (cited here as a reference to its general statewide research into hazards; the purpose of the Plan was to identify and prioritize potential actions to reduce natural hazard vulnerability, and to satisfy requirements to be eligible for hazard mitigation and disaster assistance funds from the federal government) shows a Mercalli intensity value of Level VIII (State, Fig. 2-173) as highlighted in Table 2-1 and Table 2-2. This relates to an approximate Richter Scale of 6 to 7, as shown in Table 2-2. In terms of expected damage and loss relative to the rest of the state, the area around the Bridge is classified as a High Hazard location which indicates it is likely to experience more disturbance than the other areas (State, Fig. 2-175).

Table 2-2. Earthquake Scale Comparison

Intensity (Mercalli)	Observations (Mercalli)	Richter Scale Magnitude (approx. comparison)
I	No effect	1 to 2
II	Noticed only by sensitive people	2 to 3
III	Resembles vibrations caused by heavy traffic	3 to 4
IV	Felt by people walking; rocking of free standing objects	4
V	Sleepers awakened; bells ring	4 to 5
VI	Trees sway, some damage from falling objects	5 to 6
VII	General alarm, cracking of walls	6
VIII [a]	**Chimneys fall and some damage to building**	**6 to 7**
IX	Ground crack, houses begin to collapse, pipes break	7
X	Ground badly cracked, many buildings destroyed, some landslides	7 to 8
XI	Few buildings remain standing, bridges destroyed	8
XII	Total destruction, objects thrown in air, shaking and distortion of ground	8 or greater

[a] Full CSZ event shaking anticipated at the Bridge site.
Source: http://www.diffen.com/difference/Mercalli_Scale_vs_Richter_Scale

2.2 Sources of Seismic Hazard

The site that the Bridge is situated on has two main sources of seismic hazard which could produce two different types of earthquakes:

- Local Faults: The Hood River fault zone, located along the Hood River about 1 mile southeast of the Bridge and extending south. These are intra-crustal, near-surface faults having a localized impact. Ground shaking is likely to be of relative short duration, possibly high intensity, but will dissipate quickly away from the source.
- Large Plate Faults: The CSZ event, caused by movement along tectonic plates. Ground shaking is likely to be of extended duration with significant aftershocks. When these plates slip, the released energy will have an impact hundreds of miles inland.

A 2012 study of Pacific Northwest earthquake hazards published by the USGS determined that the odds are greater than one in three for a partial rupture of the Cascadia Subduction Zone fault occurring within the next 50 years, and greater than one in ten for a full rupture of the Cascadia Subduction Zone fault within the next 50 years. The most intense shaking from the CSZ event will be at the coast and will decrease with distance from the coast. Local soil conditions also contribute to the intensity of shaking at a site. For the full rupture CSZ event, the equivalent magnitude of shaking at the Bridge could be a magnitude 6 or more.

In addition to the direct ground shaking, the Bridge may experience direct damage associated with ground movement and soil failures. As described in the Oregon Natural Hazards Mitigation Plan, the area around the Bridge has the following vulnerabilities:

- **Ground amplification hazard is very high** (State, Fig. 2-169). Seismic shaking effects dissipate with distance from the location of the event. However, soft soils, like those found around the Port, can magnify ground motions and create greater hazard.
- **Susceptibility to liquefaction hazard is very high** (State, Fig. 2-170). Loose and saturated sandy soils can essentially become liquefied during an earthquake, losing the ability to support its own weight and loads from a bridge.
- **Susceptibility to landslide hazard induced by earthquakes is moderate** (State, Fig. 2-171). Strong ground shaking can cause new landslides or reactivate dormant ones. The Bridge is located on and surrounded by historically large landslides on both sides of the Columbia River, although the Oregon side may appear to be more vulnerable. These large landslides pose a sizeable hazard for the Bridge.

3 Bridge Configuration

The Bridge today consists of several segments of different structure types, characterized mostly by the deck truss spans, but also the iconic through-truss lift span and towers, reinforced concrete spans, and steel girder spans. Each of the structure types will respond differently to an earthquake. Segments of the Bridge are grouped together for this vulnerability study, as follows and shown in the aerial view in Figure 3-1:

- <u>Approach Spans</u>: There are two unique approach structure types on the two ends of the bridge which connect the Bridge to Oregon and Washington. Top down, the Oregon Approach spans are concrete deck supported on two continuous steel girders, which are supported on reinforced concrete pile substructures spliced to steel pile foundations. The Washington Approach spans are longer than the Oregon Approach and consist of concrete deck supported by eight reinforced concrete deck girder spans, which are supported on two-column bent substructures founded on spread footings. The Oregon and Washington Approach spans are relatively short and stiff compared to the flexible Steel Truss Spans. Their response to earthquakes and the associated retrofit costs will be minor compared to the Bridge as a whole.
- <u>Steel Truss Spans</u>: The majority of the Bridge consists of an open grid steel decking on steel beams, which are supported by a steel truss that spans between concrete pier substructures, which then have variable foundation types below the water across the length of the bridge. Starting at the Oregon Approach spans, there are two pony trusses, eight deck trusses, and eight more deck trusses on the Washington side of the lift span. The steel through-truss on the lift span is included in the lift span discussion below. Given this type of structure is the longest, it most significantly characterizes the bridge response to earthquakes.

- Lift Span: The vertical lift span over the navigation channel includes a deck truss span, steel towers on each side with large concrete counterweights, and auxiliary trusses mounted outboard of the adjacent Steel Truss Spans on either side of the lift span. This span includes electrical and mechanical movable bridge systems that require specific discussion later in the report. The massive counterweights suspended high in the air will have a profound effect on the structure response in an earthquake.

Figure 3-1. Bridge Segments for Discussion of Seismic Vulnerability

4 Site Conditions

For this seismic vulnerability study, a desktop study of foundation soil conditions was conducted based on information currently available. All information shown for the site soils and geology was obtained from previously written documents. If the POHR advances the seismic retrofit design, then additional site soils investigation, geotechnical engineering, and site-specific geologic hazard characterizations are necessary. The depth of investigation will depend on the selected level of retrofit effort. The characteristics of foundation soils and slopes will have a marked impact on the structure response during an earthquake. *Soft soils can often amplify ground shaking; loose sandy soils are known to liquefy during an earthquake and can settle downward, lose capacity to support bridge foundations, and often result in slope instability causing landslides*.

The 1924 plans for the original bridge show approximately 40 feet of sandy alluvial deposits that make up the river bed of the Columbia River at the Bridge. Below these loose sandy soils is bedrock at about 40-foot below the mud line. Starting at the existing bridge foundation just north of the navigation channel and moving north towards the Washington shore, this bedrock rises quickly and is exposed in one nearby location. From the lift span, approaching the Oregon mainland toward the south, the bedrock below the sand does not rise as quickly.

In 2011, a geotechnical data report was produced for the SR35 Columbia River Crossing Project (which looked at bridge replacement alternatives) in which three borings were taken west/downstream of the existing Bridge and generally confirmed the bedrock depth shown on the 1924 plans.

Using the current bent numbering scheme from Oregon toward Washington, Piers 1 and 13-16, 18-20, and 21-28 are founded on spread footings. Abutment E, Bent D, and Bents

2-11 and 17 are founded on piles. Bent 12 is unique in that it was originally founded on a spread footing, but when the bridge was raised to accommodate the higher water elevation when the Bonneville Dam was installed, the Bent 12 footing was enlarged and piles were added.

In 2009, a foundation report for the I-84 Exit 64 (Button Bridge Road) Bridge was produced through a geotechnical investigation for the bridge replacement. The Exit 64 Bridge is located just south of the Hood River-White Salmon Bridge, but the foundation report suggests the south bridge abutment area consists of alluvial river deposits underlain by deep basalt (bed rock). Basically, the south abutment area may consist of loose sandy fill that may liquefy in an earthquake, resulting in loss of foundation strength.

5 Structural Seismic Vulnerabilities

A preliminary review of the Bridge identified several potential seismic vulnerabilities. For the purpose of this report the term vulnerability refers to a structural component, configuration, or condition that inadequate to provide the necessary load resistance, resulting in loss of function in the event of an earthquake. Identification is based on a study of the bridge configuration and site conditions, combined with experience on detailed analysis and design of similar structure types and bridge retrofits in the Pacific Northwest. A specific analysis of the Bridge for seismic loading was not completed at this early phase. Additional analysis is needed to better define the deficiencies and costs for retrofit. A drawing of the Bridge elevation found in Appendix B shows the locations of the seismic vulnerabilities described in the following sections. As described above, the various structure types that define the Bridge configuration have unique vulnerabilities and are separated for clarity.

5.1 Oregon Approach Spans

The two steel girder spans on the Oregon Approach have potential seismic vulnerabilities shown in Table 5-1 and further described in Appendix B.

Table 5-1. Oregon Approach Span Structure Seismic Vulnerabilities

Bridge Feature	Seismic Vulnerabilities & Anticipated Consequences	Location Details
Seat Width / Transverse Restraints	• Insufficient beam seat length and inadequate transverse restraints for lateral loading. • *Consequence: spans may fall off of the supports.*	Abutment E, Bent D & Bent 1
Pile Bents	• Concrete column and pile internal steel reinforcing is inadequate to confine the concrete core and will not be reliably ductile when subjected to cyclic loading. • Concrete piles to steel piles splices are poorly confined and prone to brittle shear failure. • *Consequence: piers may fail and collapse.*	Bent D
Knee Wall and Connection to Substructure	• The knee wall and its connection to the pier cap may lack sufficient strength to resist design seismic forces. • *Consequence: structure damage that may result in loss of strength and repair is anticipated.*	Bent 1
Pile Caps	• Pile cap foundations may lack adequate size and strength to resist seismic demands from pier walls • *Consequence: structure damage that may result in loss of strength and repair is anticipated.*	Bent E

5.2 Washington Approach Spans

The eight reinforced concrete deck girder spans on the Washington Approach have potential seismic vulnerabilities shown in Table 5-2 and further described in Appendix B.

Table 5-2. Washington Approach Span Structure Seismic Vulnerabilities

Bridge Feature	Seismic Vulnerabilities & Anticipated Consequences	Location Details
Seat Width / Transverse Restraints	• Insufficient beam seat length and inadequate transverse restraint against lateral seismic forces. • *Consequence: spans may fall off of the supports.*	Bents 20-28
Connection of Superstructure to Substructure	• At the fixed end of each girder, the existing girder to crossbeam dowel connection lacks sufficient strength to resist lateral seismic forces. • *Consequence: spans may fall off of the supports. Severe damage is anticipated.*	Bents 20-28
End Diaphragms	• End diaphragms may lack adequate strength to resist column demand loads • *Consequence: structure damage that may result in loss of strength and repair is anticipated.*	Bent 20, 28
Crossbeams	• Existing crossbeams may lack adequate strength to resist the forces transferred from columns during seismic events. • *Consequence: structure damage that may result in loss of strength and repair or replacement is anticipated.*	Bents 21-27
Column Extensions and Connections	• Column extensions at Bent 20 to support the reinforced concrete deck girder span (Span 20) are inadequately confined for reliable ductility when the bridge is subjected to cyclic loading and are more prone to brittle shear failure. • The dowel connection at the base of the column extension to the top of Bent 20 may lack sufficient strength to resist design seismic forces. • *Consequence: structure damage that may result in loss of strength and repair or replacement is anticipated.*	Bent 20
Spread Footings	• Existing spread footing foundations are too small and may lack adequate size and strength to resist seismic demand loads. • *Consequence: piers may fail and collapse.*	Bents 20-28
Columns	• Existing columns internal steel reinforcing is inadequate to confine the concrete core and will not be reliably ductile when the bridge is subjected to cyclic loading. • *Consequence: columns may fail causing collapse of spans.*	Bents 21-27

5.3 Steel Truss Spans Seismic Vulnerabilities

The many Steel Truss spans on the bridge have potential seismic vulnerabilities shown in Table 5-3 and further described in the Appendix B figures.

Table 5-3. Steel Truss Spans Structure Seismic Vulnerabilities

Bridge Feature	Seismic Vulnerabilities & Anticipated Consequences	Location Details
Seat Width / Transverse Restraints	• Insufficient beam seat length and inadequate transverse restraint against lateral seismic forces. • *Consequence: spans may fall off of the supports.*	Bent 1-20
Truss Members and Connections	• Existing steel gusset plates and truss members may lack sufficient strength to resist design seismic forces. • *Consequence: structure damage may result in closure of spans to repair steel.*	Spans 1-10, 12-19
Pile Caps	• Pile caps may lack adequate size and strength to resist seismic demand loads. • *Consequence: structure damage that may result in loss of strength. Repair is anticipated.*	Bents 2-11, 17
Pier Walls	• Existing pier walls may lack sufficient flexural and shear strength to resist design seismic forces. • *Consequence: structure damage that may result in loss of strength. Repair or replacement is anticipated.*	Bents 1-20
Bearings	• Steel rocker bearings are unstable during a seismic event and may tip over. Fixed steel bearings may be unable to transfer seismic forces to the substructure. • *Consequence: Trusses may fall off the piers.*	Bents 1-20
Spread Footings	• Existing spread footing foundations are too small and may lack adequate size and strength to resist seismic demand loads. • *Consequence: piers may fail and collapse.*	Bents 1, 12-16, 18-20

5.4 Lift Span Seismic Vulnerabilities

The Lift Span has a number of unique potential seismic vulnerabilities shown in Table 5-4 and further described in the Appendix B figures. This discussion excludes the deficiencies already noted in Section 5.3 regarding the concrete piers and steel truss spans, but these deficiencies are present in Span 11 and the flanking Spans 10 and 12.

Table 5-4. Lift Span Seismic Vulnerabilities

Bridge Feature	Seismic Vulnerabilities & Anticipated Consequences	Location Details
Concrete Counterweights	• Massive counterweights suspended near the tops of towers are expected to sway and impact the towers, causing damage. In addition, the massive swaying weight can imbalance the tower and overstress the structure. • *Consequence: full collapse of the towers and flanking spans is possible. Major damage expected.*	Lift Span Towers
Gusset Plates and Connections	• Existing steel gusset plates and truss members may lack sufficient strength to resist design seismic forces which are amplified due to the counterweight. • *Consequence: structure damage may result in closure of spans to repair steel. Extended closure expected.*	Span 11, Towers, Auxiliary Trusses
Steel Truss Members	• Existing steel truss members may lack sufficient strength to resist design seismic forces. • *Consequence: structure damage may result in closure of spans to repair steel. Extended closure expected.*	Span 11, Towers, Auxiliary Trusses
Mechanical & Electrical Equipment	• Various pieces may not be sufficiently secured to the bridge. • *Consequence: structure damage that may result in loss of strength. Repair or replacement is anticipated.*	Top of Towers & Operator's House
Bearings	• Steel rocker bearings are unstable during a seismic event and may tip over. Fixed steel bearings may be unable to transfer seismic forces to the substructure. • *Consequence: Trusses may fall off the piers. Extended closure expected.*	Piers 11, 12
Foundations	• Existing foundations are too small and very likely lack adequate size and strength to resist seismic demand loads which are significantly amplified by the tall towers and counterweights. • *Consequence: piers may fail and collapse. Extended closure expected.*	Piers 11, 12

6 Seismic Retrofit Approach

Using current high-level approaches to preliminary seismic risk assessment, the Bridge's potential areas of vulnerability were identified. Appropriate preliminary retrofit alternatives are outlined with associated concept level estimated costs. A full implementation of these retrofits can be made, or the retrofits can be implemented using a step-wise approach.

6.1 Full Retrofit Approach

There are three general approaches to mitigate the seismic vulnerabilities of the Bridge: Status Quo, Phase 1, and Phase 2. These are described further as:

1. **Status Quo** – This alternative involves the Bridge remaining as it is, along with continued routine inspections and monitoring. In the event of an earthquake, the structure will likely experience significant damage to the lift span and truss spans, and be inaccessible for at least months, if not years. If a large CSZ earthquake occurs, many regional resources will be strained further increasing the time required to restore the bridge. The Bridge is expected to need extensive repairs, including full span and pier replacements to restore the connection across the river. The lift span is particularly vulnerable and the U.S. Coast Guard is unlikely to allow limited vertical clearance after an earthquake, as large barges and vessels will be needed for regional recovery.
2. **Phase 1 Seismic Retrofit:** – This approach to seismic retrofit meets the "life safety" (aka Upper Level Event) design criteria used by Oregon Department of Transportation (ODOT) and the Federal Highway Administration (FHWA). It is associated with less frequent, stronger ground shaking forces and focuses on preventing loss of life. After an earthquake, the structure may not be useable but will be stable enough to allow people to evacuate the bridge to safety. The Bridge may then need extensive repairs or may need to be mostly replaced. A Phase 1 Seismic Retrofit secures the span trusses and beams to their supporting foundations to prevent them from falling off during an earthquake. Damage will still occur and need to be repaired. ODOT and FHWA define the Upper Level design event as the 1000-year earthquake that has a seven percent probability of exceedance during a 75 year period.
3. **Phase 2 Seismic Retrofit** – This approach to seismic retrofit typically includes all retrofit measures needed to meet the Phase 1 seismic retrofit, as well as a higher level of resiliency as it seeks to meet the post-earthquake "serviceability" (aka Lower Level Event) design criteria used typically by ODOT and FHWA. Designing for this alternative is associated with more frequent, lower magnitude ground shaking forces and requires the structure to remain useable post-earthquake, possibly with minor repair. In addition to the Phase 1 work, it increases the strength or ductility of the substructure and foundations (piers, footings, and piles) to resist or accommodate anticipated seismic loads. This can involve enlargement of the substructure and foundations by adding concrete and steel, seismic isolation bearings, and possibly soil improvements to combat potential soil liquefaction (loss of supporting strength during an earthquake). Phase 2 Seismic Retrofit is expected to cost more than Phase 1, but result in more resilient infrastructure and shorter time the Bridge will be

out of service. FHWA defines the Lower Level design event as the 500-year earthquake that has a 15 percent probability of exceedance during a 75 year period. In contrast, ODOT defines the Lower Level design event as the full rupture CSZ event.

The cost of full implementation of the retrofits is presented in Table 6-1. Note, the performance level ("life safety" or "serviceability") described above for the Bridge post-earthquake is for the structural components. The mechanical components of the lift span are sensitive to displacements caused by seismic motions even if retrofitted. It should be assumed that lift operations will be limited following any seismic event until a detail inspection of the mechanical and electric components is conducted and any necessary repairs are performed.

Table 6-1. Overview of Bridge Seismic Retrofit Alternatives & Concept Costs

Approach	Time to Complete Retrofit	Cost to Construct Retrofit
Status Quo	0 mos.	$ 0 M
Phase 1 Seismic Retrofit	24 mos.	$16 M
Phase 2 Seismic Retrofit	48 mos.	$124 M

After an earthquake, the Bridge is expected to require a varying amount of repair and will have associated closures to repair and replace damaged components before being reopened. Table 6-2 below provides concept-level estimates of the anticipated impacts to restore the Bridge to its current operating level. Full replacement of the Bridge using modern design standards would require additional funds.

Table 6-2. Overview of Bridge Post-Earthquake Impacts

Approach	Shortest Post-EQ Closure	Anticipated Post-EQ Closure	Order of Magnitude Cost to Remedy Damage
Status Quo	12 mos.	48 mos.	$180 M
Phase 1 Seismic Retrofit	3 mos.	6 mos.	$30 M
Phase 2 Seismic Retrofit	< 1 wk.	< 1 mo.	$3 M

6.2 Step-Wise Seismic Retrofit Approach

If funds are not available to fully implement a Phase 1 or Phase 2 seismic retrofit, a step-wise approach aims to implement the retrofits in manageable, affordable segments over time. A possible approach is to focus on each segment of the Bridge. Similarly, the Phase 1 and Phase 2 retrofits can be divided to prioritize solutions for a better final product. For example, substructure elements can be strengthened or isolation bearing can be installed to allow the superstructure to float on top of the substructure, thus limiting the required substructure strengthening and associated costs.

The step-wise approach presented below assumes:

1. The elements of the bridge which are most costly to repair are retrofit first. Retrofit cost is often much lower than the cost to repair or replace after damage occurs, so

the greatest return on investment comes from retrofitting the high-repair-cost elements before other elements which may be cheaper to repair later on.

2. A Phase 1 approach is done prior to Phase 2. In recent post-earthquake assessments, it was observed that most structures were generally intact but the superstructure had fallen off the substructure. This common failure mechanism is relatively simple to fix compared to Phase 2 needs, with generally easier, above-ground construction. Conducting a Phase 1 type retrofit has the potential for a greater resiliency against smaller level earthquakes when compared to the existing condition, and requires a much smaller initial expenditure to complete.
3. The Phase 2 retrofits are implemented and not indefinitely deferred. The most complete retrofit approach considers the whole structure and not just the superstructure.

The Table 6-3 below provides an overview of the costs of a step-wise implementation of retrofit. Additional details are provided in Appendix B. Note that the estimated costs in the table below do not include liquefaction mitigation. Per the discussion in "2.2 Sources of Seismic Hazard," liquefaction is anticipated but the degree cannot be determined without additional geotechnical exploration. Depending on the severity of liquefaction, constructing Phase 2 retrofits may not be cost effective without performing expensive liquefaction mitigation first.

Table 6-3. Step-Wise Approach to Improving Seismic Resiliency

Phase	Step	Cost		Benefit Gained
		Each Step	Cumulative	
1	1	$1,752,000	$1,752,000	Reduce probability of Lift Span's collapse
	2	$11,431,000	$13,183,000	Reduce probability of Steel Truss Spans' collapse
	3	$2,030,000	$15,213,000	Reduce probability of WA Approach Spans' collapse
	4	$990,000	$16,203,000	Reduce probability of OR Approach Spans collapse
2	1	$7,285,000	$7,285,000	Greatly increased resiliency of Lift Span
	2	$107,086,000	$114,371,000	Greatly increased resiliency of Steel Truss Spans
	3	$8,344,000	$122,715,000	Greatly increased resiliency of WA Approach Spans
	4	$925,000	$123,640,000	Greatly increased resiliency of OR Approach Spans

Note: The assumptions listed above are reflected in this table – 1) the lift span is assumed to be retrofit first since it would likely be the most costly to repair or replace after an earthquake, 2) Phase 1 is listed first, and 3) Phase 2 is also listed. Each of these steps may be further divided.

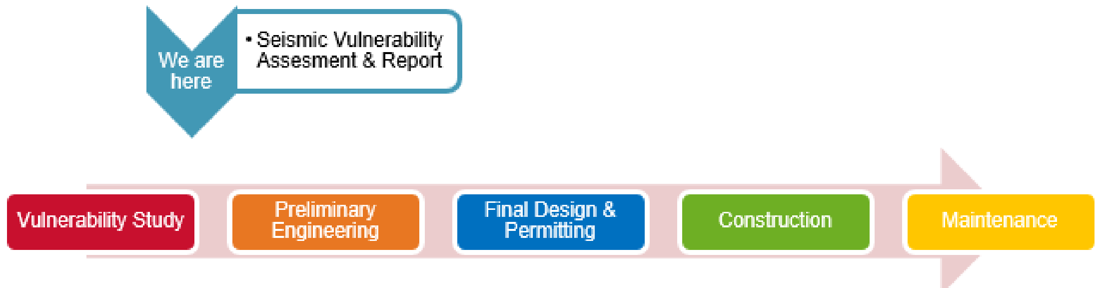
7 Concept Cost Estimates

Construction cost estimates were prepared for each alternative based on estimated quantities and unit pricing for the proposed retrofit measures. Non-bridge-related costs were estimated based on anticipated access, traffic control, and roadway impacts. A 10 percent mobilization factor, 40 percent contingency factor, 12 percent preliminary engineering factor, and 12 percent construction engineering and inspection factor were applied to the construction subtotal. The detailed cost estimate summary is provided in Appendix A.

8 Seismic Resiliency Process

The process toward improving the Bridge's seismic resiliency involves a series of intentional steps of engineering analysis, design, permitting, external coordination, and construction to advance toward implementation of a solution that would meet the goals and objectives of the Port.

Figure 8-1. Process Toward Improved Bridge Seismic Resiliency



1. **Seismic Vulnerability Assessment**: The concept study and report (which is covered by this report) is the first step in the process toward improving the Bridge's seismic resiliency by the constructing physical retrofit. This study provides high-level information to make risk-based and informed decisions and utilizes existing drawings and applying engineering experience and judgment to identify potential vulnerabilities and resolution. Detailed seismic analysis of the existing bridge is not conducted at this time. This step solely provides decision-making information.
2. **Preliminary Engineering:** The next step is to finalize the design criteria and conduct analytical calculation of the bridge in order to pin down the specific locations and magnitude of vulnerabilities and identify actual retrofit design solutions to mitigate the seismic vulnerabilities. In the Preliminary Engineering phase, a structural analysis of the Bridge is conducted to characterize and quantify the response to an earthquake using specialized software programs. The results of this analysis provide the data needed to develop cost estimates and schedule implications if taken through construction. At the beginning of this phase, the Port can select a preferred alternative and level of retrofit or choose to advance multiple alternatives to have better data to support decision-making. Depending on the selected alternative for seismic retrofit, which the Port may want to better understand or advance in this step, a more detailed analysis may be required in this phase. For example, a simple Phase 1 Seismic Retrofit Alternative will require less data collection and engineering analysis. A Phase 2 Seismic Retrofit Alternative, in contrast, will require a more detailed analysis, and supporting data such as subsurface soil borings in the river. The Port should finalize the selection of the preferred alternative by the end of the Preliminary Engineering phase. The Port should select a level of seismic retrofit that best resolves the goals and objectives of the Port within the available means.

3. **Final Design & Permitting:** In this step of the seismic retrofit process, the preferred alternative is advanced through a series of analysis and design tasks to culminate in construction bid plans, specification, and detailed construction cost estimates. This step requires external stakeholder engagement and partnering with regulatory and impacted agencies, such as the U.S. Coast Guard, cities, counties, and state governments on both sides of the river. Environmental and public impacts may need to be identified, quantified, and mitigated in order to avoid extensive impacts. Depending on the selected level of seismic resiliency and level of impacts that could result from construction (e.g., noise, traffic) the design may be more or less complicated.
4. **Construction:** Once the design is complete and final plans and specifications are ready for bid, a contractor can be selected and full construction implemented. This is typically the most costly steps as it involves mobilizing the contractor and associated risks.
5. **Maintenance:** After construction is completed and documented, it is important to continue to monitor, maintain, operate, and repair the Bridge to ensure the designs installed for retrofit are in good working order. For example, bearings and seismic restrainers, if used, will need on-going inspection and maintenance. The lift span of the Bridge will require on-going maintenance to ensure proper performance.

9 Key Issues for Seismic Retrofit

The Bridge and site include the following features relevant to eventual seismic retrofit:

- **Traffic**: The detour route via the Bridge of the Gods in Cascade Locks, Oregon is approximately 40 miles, though there is seasonal flux due to the harvest season. Construction closures will negatively impact traffic flow and should consider seasonal peak volumes. To retrofit the lift span, temporary lane closures and limited vertical clearance may be required.
- **Utilities**: The Bridge carries gas and communications lines. If retrofit design cannot accommodate the existing conduits, relocation coordination will be required.
- **Safety**: The Bridge inspection reports, anecdotal reports, and field observations indicate the bridge rail is substandard. There are numerous dings and scrapes on the bridge rail and lift span truss elements due to the substandard roadway width and travel speeds exceeding posted limits. Construction traffic control will need to account for these hazards.
- **Environmental**: Various species of concern, including salmon, inhabit the Columbia River. Forested wetlands may be present on the Washington shore. Migratory Bird Treaty Act compliance provisions must be met, and construction work below the ordinary high water may require permitting with the U.S. Army Corps of Engineers (USACE) and the Department of State Lands (DSL). To meet construction schedules, design should account for the various species and necessary permitting lead times.

- **Right-of-Way/Access:** There is no existing access road to the Columbia River, however, there are boat launches on both shores downstream of the bridge. Access to the in-water piers may include barges or work bridges. There is a pedestrian path under Span 2 on the Oregon shore; a single railroad track passes under Span 26 on the Washington shore. Heavy vegetation and trees are under the Washington Approach. Construction access may require vegetation grubbing, railroad coordination, barge docking, and equipment delivery routes. Retrofit of the lift span may require limited or no operation of the lift span and will required coordination with the U.S. Coast Guard.

10 References

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Appendix A. Cost Estimate Summary

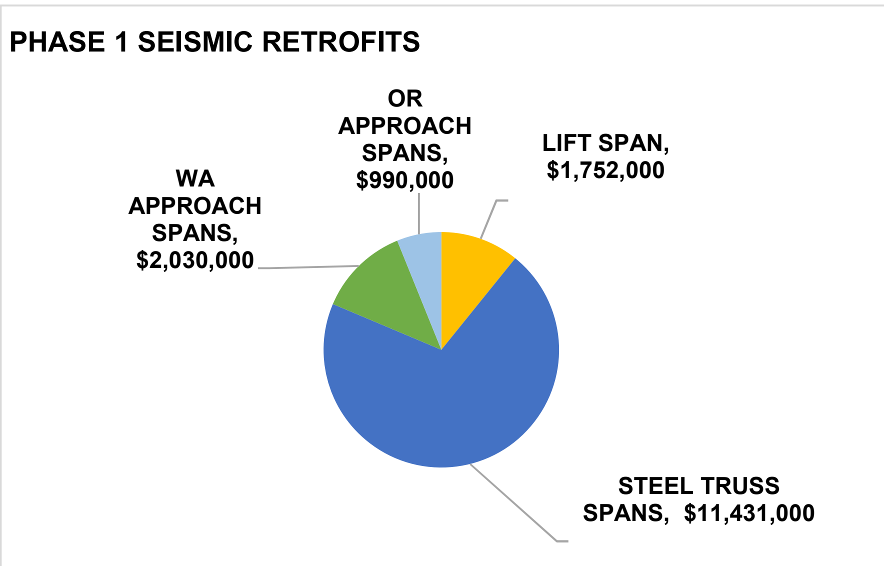
PORT OF HOOD RIVER BRIDGE - SEISMIC VULNERABILITY STUDY

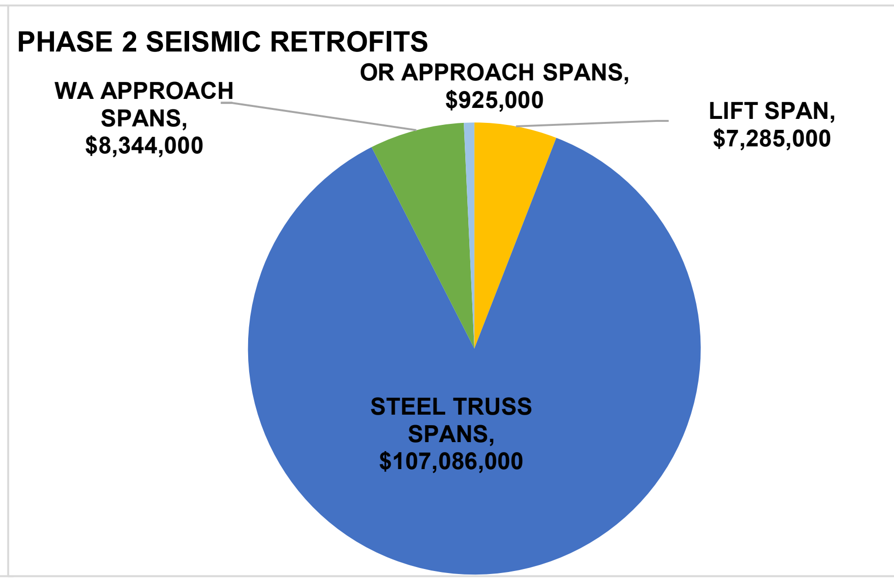
Concept Cost Estimates for Seismic Retrofits

1/17/2017

All Phases | All Steps

PHASE	STEP	RETROFIT AREA - LOCATION	STEP TOTAL	CUMM. TOT.
1	1	LIFT SPAN	$ 1,752,000	$ 1,752,000
	2	STEEL TRUSS SPANS	$ 11,431,000	$ 13,183,000
	3	WA APPROACH SPANS	$ 2,030,000	$ 15,213,000
	4	OR APPROACH SPANS	$ 990,000	$ 16,203,000
2	1	LIFT SPAN	$ 7,285,000	$ 7,285,000
	2	STEEL TRUSS SPANS	$ 107,086,000	$ 114,371,000
	3	WA APPROACH SPANS	$ 8,344,000	$ 122,715,000
	4	OR APPROACH SPANS	$ 925,000	$ 123,640,000





Concept Cost Estimates for Seismic Retrofits

Phase 1 | Step 1

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
LIFT SPAN	Span 11, Bents 11-12	LS	1	$ 745,000	$ 745,000
	7 Strengthen truss members & connections	LS	1	$ 480,000	$ 480,000
	Structural steel	LB	24000	$ 20	$ 480,000
	8 Strengthen truss members & connections	LS	1	$ 240,000	$ 240,000
	Structural steel	LB	12000	$ 20	$ 240,000
	9 Secure mechanical equipment	LS	1	$ 25,000	$ 25,000
		LS	1	$ 25,000	$ 25,000
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 745,000**

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	0.5%	$ 3,700
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 44,700
Contractor Mobilization	8.0%	12.0%	10.0%	$ 74,500
Erosion Control	0.5%	2.0%	0.5%	$ 3,700
Construction Contingency	5.0%	45.0%	40.0%	$ 298,000
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 149,200
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 573,800***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 1,319,000***

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$5,000	$ 5,000
Owner Administrative Costs	5.0%	15.0%	8.0%	$ 105,500
Design Consulting Engineering	8.0%	15.0%	12.0%	$ 158,300
Construction Admin, Engineering, & Inspection	8.0%	15.0%	12.0%	$ 158,300
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 5,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 433,000***
TOTAL PROJECT COST ESTIMATE				***$ 1,752,000***

Concept Cost Estimates for Seismic Retrofits

1/17/2017

Phase 1 | Step 2

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
STEEL TRUSS SPANS	Bents 1-11 and 12-20	LS	1	$ 2,160,000	$ 2,160,000
	1 Enlarge seat/shear lugs	LS	1	$ 1,320,000	$ 1,320,000
	Concrete	CUYD	560	$ 1,500	$ 840,000
	Reinforcement	LB	150000	$ 1	$ 150,000
	Dowels	EACH	5000	$ 30	$ 150,000
	P/T	LB	18000	$ 10	$ 180,000
	6 Replace steel bearings	LS	1	$ 840,000	$ 840,000
	Bearings	EACH	84	$ 10,000	$ 840,000
	Spans 1-10 and 12-19	LS	1	$ 2,880,000	$ 2,880,000
	7 Strengthen truss members & connections	LS	1	$ 2,880,000	$ 2,880,000
	Structural steel	LB	144000	$ 20	$ 2,880,000
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 5,040,000**

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	0.5%	$ 25,200
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 302,400
Contractor Mobilization	8.0%	12.0%	10.0%	$ 504,000
Erosion Control	0.5%	2.0%	0.5%	$ 25,200
Construction Contingency	5.0%	45.0%	40.0%	$ 2,016,000
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 1,008,900
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 3,881,700***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 8,922,000***

Concept Cost Estimates for Seismic Retrofits

Phase 1 **Step 2**

1/17/2017

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$5,000	$ 5,000
Owner Administrative Costs	5.0%	15.0%	6.0%	$ 535,300
Design Consulting Engineering	8.0%	15.0%	10.0%	$ 892,200
Construction Admin, Engineering, & Inspection	8.0%	15.0%	12.0%	$ 1,070,600
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 5,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 2,509,000***
TOTAL PROJECT COST ESTIMATE				***$ 11,431,000***

Concept Cost Estimates for Seismic Retrofits

Phase 1 | Step 3

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
WASHINGTON APPROACH SPANS	Bents 20 and 28	LS	1	$ 185,200	$ 185,200
	1 Enlarge seat/shear lugs	LS	1	$ 132,000	$ 132,000
	Concrete	CUYD	56	$ 1,500	$ 84,000
	Reinforcement	LB	15000	$ 1	$ 15,000
	Dowels	EACH	500	$ 30	$ 15,000
	P/T	LB	1800	$ 10	$ 18,000
	3 Allow dowel fuse	EACH	2	$ -	$ -
	4 Strengthen end diaphragm	LS	1	$ 53,200	$ 53,200
	Concrete	CUYD	26	$ 1,500	$ 39,000
	Reinforcement	LB	7000	$ 1	$ 7,000
	Dowels	EACH	240	$ 30	$ 7,200
	Bents 21-27	LS	1	$ 711,200	$ 711,200
	1 Enlarge seat/shear lugs	LS	1	$ 462,000	$ 462,000
	Concrete	CUYD	196	$ 1,500	$ 294,000
	Reinforcement	LB	52500	$ 1	$ 52,500
	Dowels	EACH	1750	$ 30	$ 52,500
	P/T	LB	6300	$ 10	$ 63,000
	3 Allow dowel fuse	LS	9	$ -	$ -
	5 Strengthen crossbeams	LS	1	$ 249,200	$ 249,200
	Concrete	CUYD	91	$ 1,500	$ 136,500
	Reinforcement	LB	24500	$ 1	$ 24,500
	Dowels	EACH	840	$ 30	$ 25,200
	P/T	LB	6300	$ 10	$ 63,000
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 896,400**

Concept Cost Estimates for Seismic Retrofits

Phase 1 **Step 3**

1/17/2017

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	1.0%	$ 9,000
Temp. Protection & Direction of Traffic	3.0%	8.0%	3.0%	$ 26,900
Contractor Mobilization	8.0%	12.0%	10.0%	$ 89,600
Erosion Control	0.5%	2.0%	0.5%	$ 4,500
Construction Contingency	5.0%	45.0%	40.0%	$ 358,600
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 176,600
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 665,200***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 1,562,000***

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$100,000	$ 25,000
Owner Administrative Costs	5.0%	15.0%	6.0%	$ 93,700
Design Consulting Engineering	8.0%	15.0%	10.0%	$ 156,200
Construction Admin, Engineering, & Inspection	8.0%	15.0%	12.0%	$ 187,400
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 5,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 468,000***
TOTAL PROJECT COST ESTIMATE				***$ 2,030,000***

Concept Cost Estimates for Seismic Retrofits

Phase 1 | Step 4

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
OREGON APPROACH SPANS	Bent E	LS	1	$ 66,000	$ 66,000
	1 Enlarge seat/shear lugs	LS	1	$ 66,000	$ 66,000
	Concrete	CUYD	28	$ 1,500	$ 42,000
	Reinforcement	LB	7500	$ 1	$ 7,500
	Dowels	EACH	250	$ 30	$ 7,500
	P/T	LB	900	$ 10	$ 9,000
	Spans SE and SD	LS	1	$ 300,000	$ 300,000
	2 Replace with one span	LS	1	$ 300,000	$ 300,000
	Deck area estimate	SF	2000	$ 150	$ 300,000
	Bent 1	LS	1	$ 66,000	$ 66,000
	1 Enlarge seat/shear lugs	LS	1	$ 66,000	$ 66,000
	Concrete	CUYD	28	$ 1,500	$ 42,000
	Reinforcement	LB	7500	$ 1	$ 7,500
	Dowels	EACH	250	$ 30	$ 7,500
	P/T	LB	900	$ 10	$ 9,000
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 432,000**

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	0.5%	$ 2,200
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 25,900
Contractor Mobilization	8.0%	12.0%	10.0%	$ 43,200
Erosion Control	0.5%	2.0%	0.5%	$ 2,200
Construction Contingency	5.0%	45.0%	40.0%	$ 172,800
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 86,500
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 332,800***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 765,000***

Concept Cost Estimates for Seismic Retrofits

Phase 1 | Step 4

1/17/2017

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$5,000	$ 5,000
Owner Administrative Costs	5.0%	15.0%	6.0%	$ 45,900
Design Consulting Engineering	8.0%	15.0%	10.0%	$ 76,500
Construction Admin, Engineering, & Inspection	8.0%	15.0%	12.0%	$ 91,800
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 5,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 225,000***
TOTAL PROJECT COST ESTIMATE				***$ 990,000***

PORT OF HOOD RIVER BRIDGE - SEISMIC VULNERABILITY STUDY

Concept Cost Estimates for Seismic Retrofits | Phase 2 | Step 1

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
LIFT SPAN	Bents 11-12	LS	1	$ 3,200,000	$ 3,200,000
	17 Isolation bearings & seismic restrainers	EA	16	$ 200,000	$ 3,200,000
					$ -
					$ -
					$ -
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 3,200,000**

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	1.0%	$ 32,000
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 192,000
Contractor Mobilization	8.0%	12.0%	10.0%	$ 320,000
Erosion Control	0.5%	2.0%	0.5%	$ 16,000
Construction Contingency	5.0%	45.0%	40.0%	$ 1,280,000
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 642,600
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 2,482,600***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 5,682,600***

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$5,000	$ 5,000
Owner Administrative Costs	5.0%	15.0%	6.0%	$ 341,000
Design Consulting Engineering	8.0%	15.0%	10.0%	$ 568,300
Construction Admin, Engineering, & Inspection	8.0%	15.0%	12.0%	$ 681,900
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 5,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 1,602,000***
TOTAL PROJECT COST ESTIMATE				***$ 7,285,000***

PORT OF HOOD RIVER BRIDGE - SEISMIC VULNERABILITY STUDY

Concept Cost Estimates for Seismic Retrofits

Phase 2 | Step 2

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
STEEL TRUSS SPANS	Bents 1, 12-16, 18-20	LS	1	$ 4,323,400	$ 4,323,400
	13 Strengthen spread footings	LS	1	$ 4,323,400	$ 4,323,400
	Concrete	CUYD	2140	$ 1,500	$ 3,210,000
	Reinforcement	LB	535000	$ 1	$ 535,000
	Dowels	EACH	15000	$ 30	$ 450,000
	Excavation	CUYD	4280	$ 30	$ 128,400
	Bents 1-20	LS	1	$ 9,696,000	$ 9,696,000
	16 Strengthen pier walls	LS	1	$ 9,696,000	$ 9,696,000
	Concrete	CUYD	4800	$ 1,500	$ 7,200,000
	Reinforcement	LB	1200000	$ 1	$ 1,200,000
	Dowels	EACH	43200	$ 30	$ 1,296,000
	Bent 20	LS	1	$ 50,000	$ 50,000
	12 Strengthen column extension & connection	LS	1	$ 50,000	$ 50,000
		LS	1	$ 50,000	$ 50,000
	Bents 2-11,17	LS	1	$ 37,386,950	$ 37,386,950
	15 Strength pile caps	LS	1	$ 37,386,950	$ 37,386,950
	Concrete	CUYD	11690	$ 1,500	$ 17,535,000
	Reinforcement	LB	2922000	$ 1	$ 2,922,000
	Dowels	EACH	17315	$ 30	$ 519,450
	Excavation	CUYD	17530	$ 30	$ 525,900
	Drilled shaft concrete	CUYD	8200	$ 400	$ 3,280,000
	Drilled shaft reinf	LB	983000	$ 1	$ 983,000
	CSL tubes	LF	35200	$ 8	$ 281,600
	CSL tests	EACH	880	$ 1,000	$ 880,000
	Drilled shaft excavation	CUYD	8200	$ 900	$ 7,380,000
	Permanent casing	LF	4400	$ 700	$ 3,080,000
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 51,456,350**

Concept Cost Estimates for Seismic Retrofits

1/17/2017

Phase 2 | Step 2

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	1.0%	$ 514,600
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 3,087,400
Contractor Mobilization	8.0%	12.0%	10.0%	$ 5,145,600
Erosion Control	0.5%	2.0%	0.5%	$ 257,300
Construction Contingency	5.0%	45.0%	35.0%	$ 18,009,700
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 10,004,800
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 37,019,400***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 88,475,750***

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$10,000	$ 10,000
Owner Administrative Costs	5.0%	15.0%	5.0%	$ 4,423,800
Design Consulting Engineering	8.0%	15.0%	8.0%	$ 7,078,100
Construction Admin, Engineering, & Inspection	8.0%	15.0%	8.0%	$ 7,078,100
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$20,000	$ 20,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 18,610,000***
TOTAL PROJECT COST ESTIMATE				***$ 107,086,000***

PORT OF HOOD RIVER BRIDGE - SEISMIC VULNERABILITY STUDY

Concept Cost Estimates for Seismic Retrofits

Phase 2 | Step 3

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
WASHINGTON APPROACH SPANS	Bent 28	LS	1	$ 250,000	$ 250,000
	10 Leave end bents, improve approach soil	LS	1	$ 250,000	$ 250,000
		LS	1	$ 250,000	$ 250,000
	Bents 21-28	LS	1	$ 3,502,450	$ 3,502,450
	13 Strengthen spread footings	LS	1	$ 759,850	$ 759,850
	Concrete	CUYD	400	$ 1,500	$ 600,000
	Reinforcement	LB	98000	$ 1	$ 98,000
	Dowels	EACH	1800	$ 30	$ 54,000
	Excavation	CUYD	785	$ 10	$ 7,850
	14 Strengthen columns	LS	1	$ 2,742,600	$ 2,742,600
	Concrete	CUYD	1470	$ 1,500	$ 2,205,000
	Reinforcement	LB	367500	$ 1	$ 367,500
	Dowels	EACH	5670	$ 30	$ 170,100
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 3,752,450**

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	0.5%	$ 18,800
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 225,100
Contractor Mobilization	8.0%	12.0%	10.0%	$ 375,200
Erosion Control	0.5%	2.0%	0.5%	$ 18,800
Construction Contingency	5.0%	45.0%	40.0%	$ 1,501,000
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 751,200
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 2,890,100***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 6,642,550***

Concept Cost Estimates for Seismic Retrofits

1/17/2017

Phase 2 | Step 3

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$20,000	$ 20,000
Owner Administrative Costs	5.0%	15.0%	5.0%	$ 332,100
Design Consulting Engineering	8.0%	15.0%	10.0%	$ 664,300
Construction Admin, Engineering, & Inspection	8.0%	15.0%	10.0%	$ 664,300
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 20,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 1,701,000***
TOTAL PROJECT COST ESTIMATE				***$ 8,344,000***

PORT OF HOOD RIVER BRIDGE - SEISMIC VULNERABILITY STUDY

Concept Cost Estimates for Seismic Retrofits

Phase 2 | Step 4

1/17/2017

RETROFIT TYPE & LOCATION		UNIT	QTY.	UNIT COST	SUBTOTAL
OREGON APPROACH SPANS	Bent E	LS	1	$ 250,000	$ 250,000
	10 Leave end bents, improve approach soil	LS	1	$ 250,000	$ 250,000
		LS	1	$ 250,000	$ 250,000
	Bent 1	LS	1	$ 50,000	$ 50,000
	11 Strengthen knee wall & connection	LS	1	$ 50,000	$ 50,000
		LS	1	$ 50,000	$ 50,000
SUBTOTAL (RAW CONSTRUCTION COSTS)					**$ 300,000**

ADDITIONAL CONSTRUCTION ITEMS	LOW	HIGH	ESTIMATE	SUBTOTAL
Construction Surveying	0.5%	5.0%	50.0%	$ 150,000
Temp. Protection & Direction of Traffic	3.0%	8.0%	6.0%	$ 18,000
Contractor Mobilization	8.0%	12.0%	10.0%	$ 30,000
Erosion Control	0.5%	2.0%	0.5%	$ 1,500
Construction Contingency	5.0%	45.0%	40.0%	$ 120,000
Construction Cost Escalation (%/year)	0.5%	3.5%	3.0%	-
Year of Cost & Total Escalation	2018	2022	2020	$ 79,000
SUBTOTAL (ADDITIONAL CONSTRUCTION ITEMS)				***$ 398,500***
TOTAL ESTIMATED CONSTRUCTION COST				***$ 698,500***

ADDITIONAL PROJECT COSTS	LOW	HIGH	ESTIMATE	SUBTOTAL
Right-of-Way & Easements	$ 5,000	$ 200,000	$5,000	$ 25,000
Owner Administrative Costs	5.0%	15.0%	6.0%	$ 41,900
Design Consulting Engineering	8.0%	15.0%	10.0%	$ 69,900
Construction Admin, Engineering, & Inspection	8.0%	15.0%	12.0%	$ 83,800
Reimburseable Utility Relocations	$ 5,000	$ 50,000	$5,000	$ 5,000
SUBTOTAL (ADDITIONAL PROJECT ITEMS)				***$ 226,000***
TOTAL PROJECT COST ESTIMATE				***$ 925,000***

Appendix B. Preliminary Vulnerabilities & Retrofit Concepts

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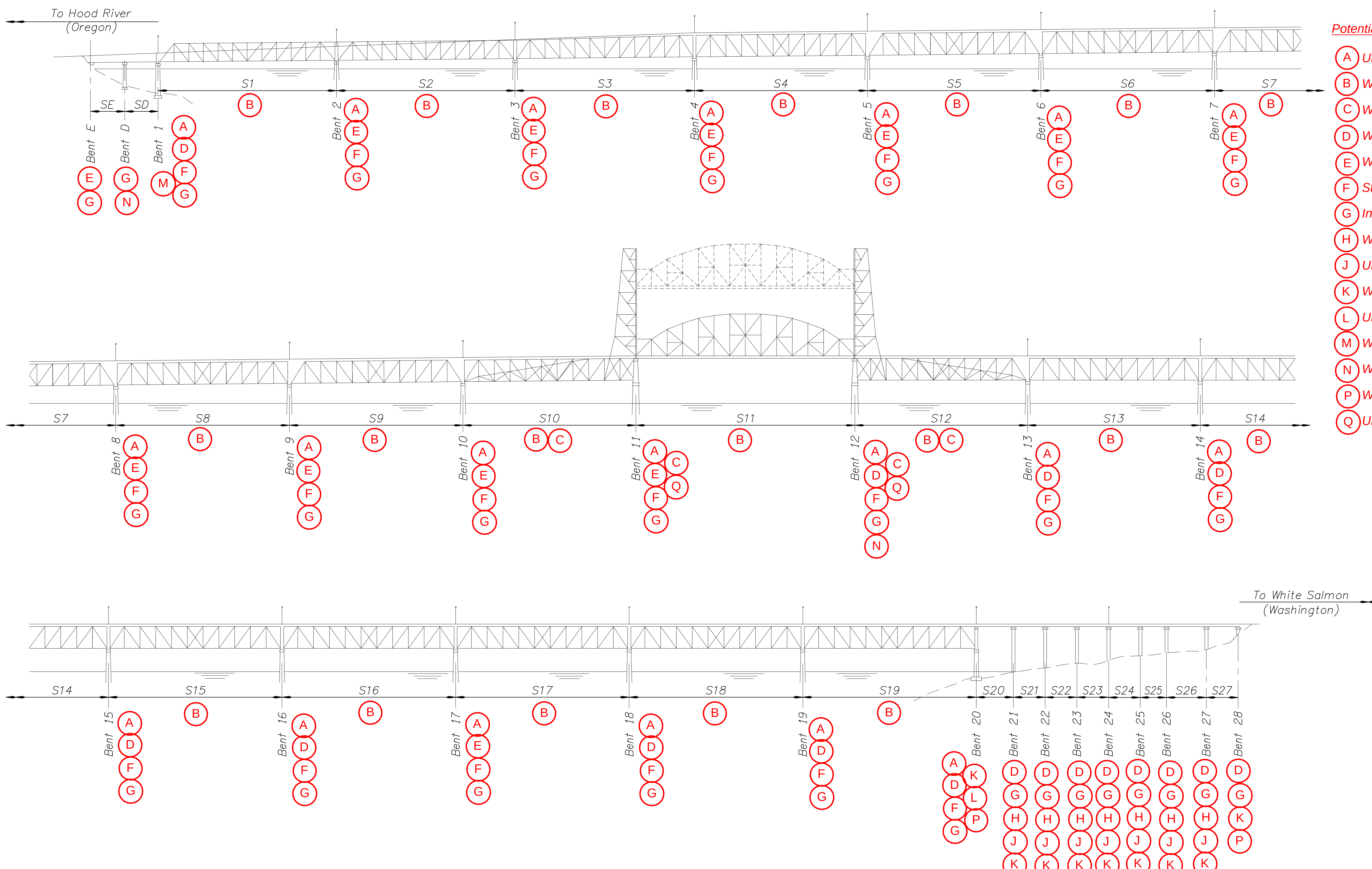

Potential Vulnerabilities Legend

- A Unstable bearings
- B Weak truss members & connections
- C Weak tower members & connections
- D Weak spread footings
- E Weak pile caps
- F Stiff or weak pier walls
- G Insufficient seat width/transverse restraint
- H Weak crossbeams
- J Unconfined columns
- K Weak dowel super-/substructure connection
- L Unconfined column extension & connection
- M Weak knee wall & connection
- N Weak pile bent
- P Weak end diaphragm
- Q Unsecured mechanical equipment

DATE	REVISION	BY

ACCOMPANIED BY DWGS.

DRAFTER:
DESIGNER:
CHECKER:
REVIEWER:

EXPIRES:
EXPIRES:

PORT OF HOOD RIVER COMMISSION

HDR

STRUCTURE NO. 00645

DATE July 2016

CALC. BOOK

HOOD RIVER INTERSTATE BRIDGE

HOOD RIVER - WHITE SALMON HIGHWAY
HOOD RIVER, OR & KLICKITAT, WA COUNTIES

POHR TO2
POTENTIAL VULNERABILITIES

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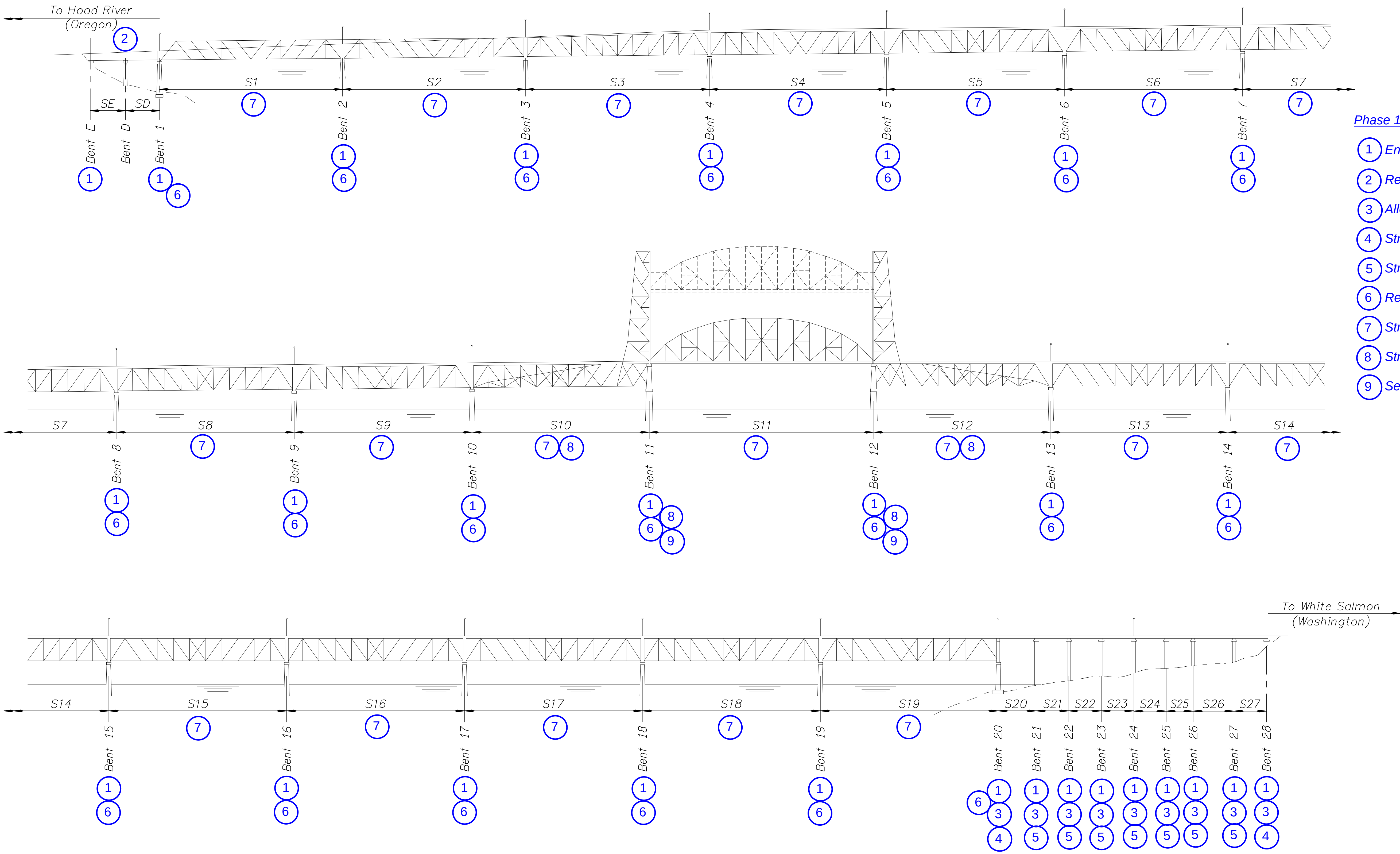

Phase 1 Seismic Retrofit Legend

1. Enlarge seat/add shear lugs
2. Replace with one span
3. Allow dowel fuse
4. Strengthen end diaphragm
5. Strengthen crossbeams
6. Replace steel bearings
7. Strengthen truss members & connections
8. Strength tower members & connections
9. Secure mechanical equipment

△	DATE	REVISION	BY

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HOOD RIVER INTERSTATE BRIDGE

HOOD RIVER - WHITE SALMON HIGHWAY
HOOD RIVER, OR & KLICKITAT, WA COUNTIES

POHR TO2
PHASE 1 SEISMIC RETROFIT

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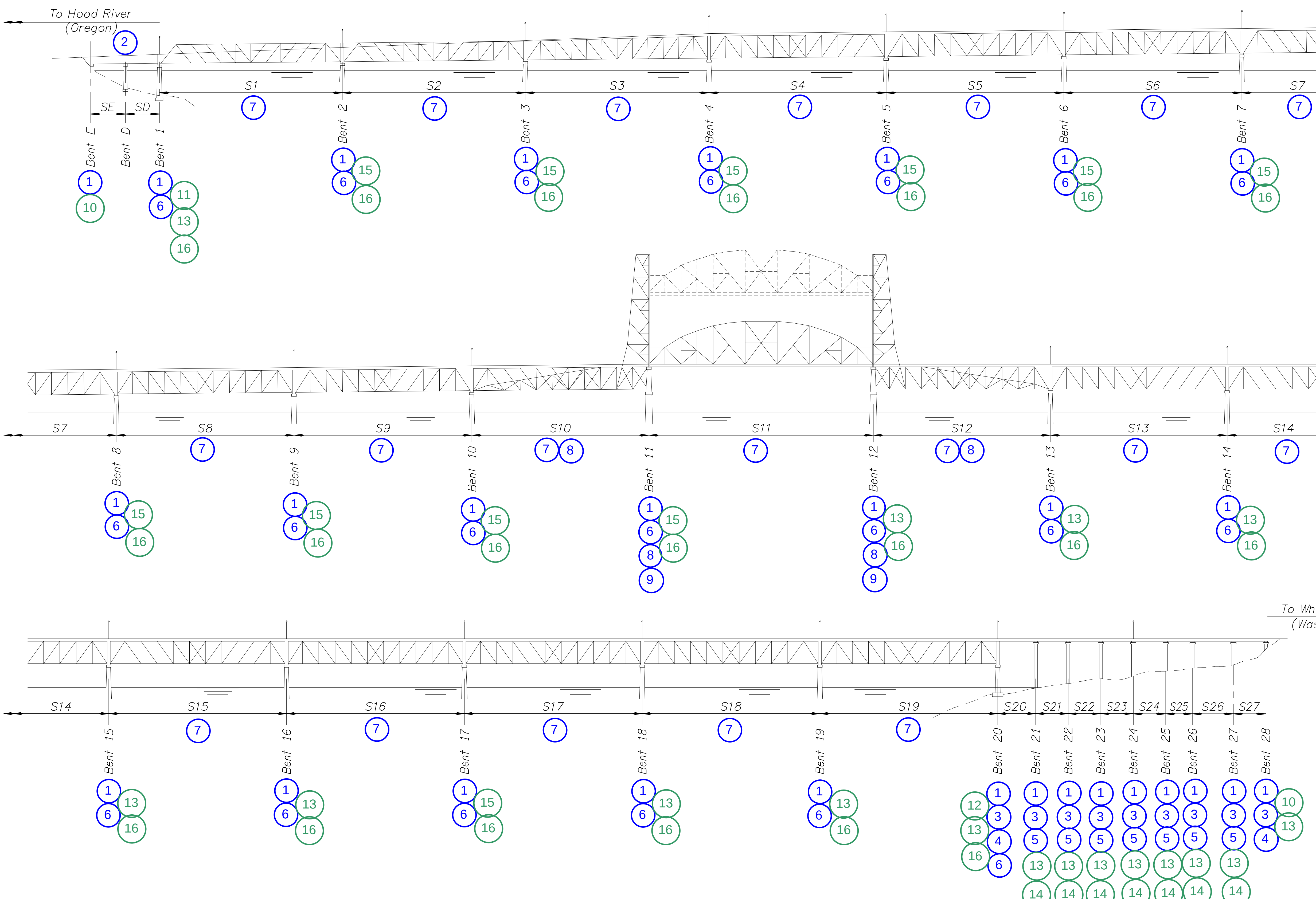

Phase 2 Seismic Retrofit Legend

- 1 - 9 Phase 1 Seismic Retrofit elements
- 10 Leave end bents, improve approach soil
- 11 Strengthen knee wall & connection
- 12 Strengthen column extension & connection
- 13 Strengthen spread footings
- 14 Strengthen columns
- 15 Strengthen pile caps
- 16 Strengthen pier walls

△	DATE	REVISION	BY

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HOOD RIVER INTERSTATE BRIDGE

HOOD RIVER - WHITE SALMON HIGHWAY
HOOD RIVER, OR & KLICKITAT, WA COUNTIES

POHR TO2
PHASE 2 SEISMIC RETROFIT

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