



DRAFT—Sellwood Bridge Existing Structural Deficiencies

The purpose of this memorandum is to summarize the structural deficiencies of Sellwood Bridge and provide assumptions for cost estimates to compare rehabilitation and replacement options. The structural deficiencies, in combination with geometric, safety, and operational deficiencies, will form the basis for the project's purpose and need statement.

Bridge Background

The Sellwood Bridge, Portland's first fixed-span bridge over the Willamette River, opened to traffic in December 1925, and currently serves more than 31,000 vehicles per day. The bridge includes a 24-foot roadway for two traffic lanes and a 4-foot, 3-inch-wide sidewalk on the north side. The length of the entire structure is 1,972 feet.

The 28-span bridge structure consists of three sections:

- **East Approach**—586 feet long; 16 spans, including reinforced concrete deck girder spans and 1 steel girder span
- **Main River Span**—1,092 feet long; 4-span continuous steel Warren truss with end spans of 246 feet and interior spans of 300 feet
- **West Approach**—294 feet long ;8 spans, including 1 steel girder span, 6 reinforced concrete deck girder spans, and 1 prestressed concrete girder span (added in 1961)

In 1960, the west approach structure and the west end of the truss spans were damaged due to an approach embankment settlement and movement of 33 inches toward the river. Repairs implemented in 1961 included construction of new columns and foundations, installation of supplemental supporting members, modification of the steel girder span and truss bearings, and addition of prestressed girder Span 28.

2005 Condition Inspection and Evaluation

The most recent structural condition inspection and evaluation, conducted in 2005, concluded that the condition of the overall structure of the bridge ranges from fair to serious. This is based on the National Bridge Inventory System rating system:

- **"Fair" condition:** all primary structural elements are sound, but may have minor section loss, cracking, spalling, or scour
- **"Poor" condition:** advanced section loss, cracking, spalling, or scour.
- **"Serious" condition:** loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible.

TABLE 1
2005 Sellwood Bridge Condition Inspection Results

| Structural Component | Condition |
|----------------------------------------------|-----------|
| Deck | Fair |
| Roadway Approach | Fair |
| Bents | Poor |
| Concrete Girder Approach Spans | Serious |
| Paint System for Steep Portions of Structure | Serious |

Load-Carrying Capacity

The 2005 study also identified the safe load-carrying capacity by comparing the combined weight of the structure (dead load) and the load of traffic (live load) with the calculated load-carrying capacity. Because analysis was complex and involved multiple concrete approach spans of varying length and degraded conditions (cracked concrete), several different analytical tools were used to analyze the condition of the structure. These sophisticated software tools helped increase the reliability of the capacity calculation. The reinforced concrete deck girder approach spans were evaluated with both two-dimensional software (commonly used by ODOT) and highly sophisticated finite-element analysis software. The steel approach spans and truss spans were evaluated with three-dimensional modeling software.

For More Details

For detailed discussion of the structural deficiencies, load ratings, and seismic evaluation of the Sellwood Bridge, see the 2005 Sellwood Bridge Evaluation and Repair Study and the 1995 Seismic Evaluation Report. The 2005 structural evaluation conformed with the *American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications, Second Edition (1998)*; and the *AASHTO 1989 Guide Specification for Strength Evaluation of Existing Steel and Concrete Bridges*.

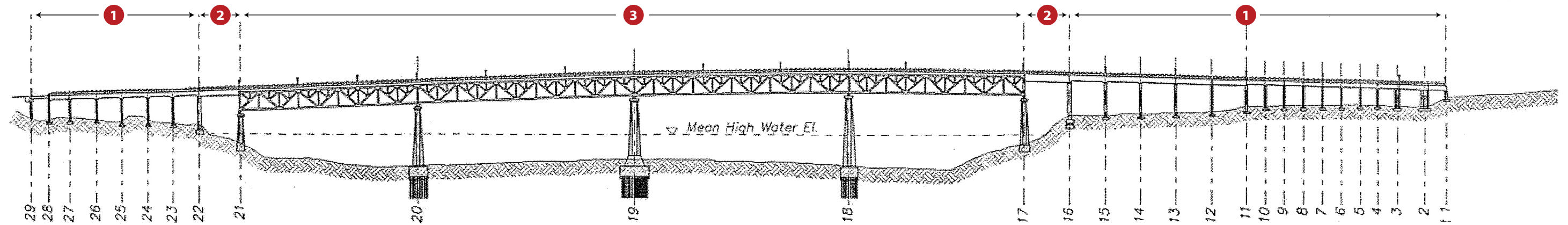
Structural Deficiencies (See Figure 1)

Seismic Vulnerability

A seismic vulnerability evaluation of the structure, completed in 1995, indicates that a significant seismic event—magnitude greater than 0.2g—would likely cause **major damage** and even collapse in **all three sections** of the bridge. Column and pile-supported footings are too small to resist overturning from longitudinal and transverse seismic loads. (Risks specific to each of the bridge sections are discussed below.)

Load Limit

The posted load limit on the bridge is currently 10 tons; this limit has been imposed in an effort to prevent cracks from widening due to excessive deflection.



| 294 feet long (Spans 21-29) | 1,092 feet long (Spans 17-20) | 586 feet long (Spans 1-16) |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| WEST APPROACH SPANS | MAIN RIVER SPANS | EAST APPROACH SPANS |
| <ul style="list-style-type: none"> • Cracks in concrete girders, deck and columns • Significant corrosion of steel girders • Girders are inadequate for 20-ton (H20) vehicles, TriMet buses • Potential damage to structure and possible collapse under major earthquake | <ul style="list-style-type: none"> • Cracks in concrete deck • Significant corrosion in steel stringers and floorbeams • Collision damage to bridge piers • Corrosion in steel truss • Potential damage to structure and possible collapse under major earthquake • Floorbeams are inadequate for 40-ton, 20-ton (H20) vehicles, TriMet buses | <ul style="list-style-type: none"> • Cracks in concrete, girders, decks and columns • Significant corrosion of steel girders • Potential damage to structure and possible collapse under major earthquake • Girders are inadequate for 20-ton (H20) vehicles, TriMet buses |
| 10-Ton Load Limit | | |



LEGEND

- ① Reinforced Deck Girder Spans
- ② Steel Girder Spans
- ③ Steel Warren Truss Spans

FIGURE 1
Sellwood Bridge Structural Deficiencies

East Approach (Spans 1 through 16)

Condition

- Cracks, Spalls, Delaminations:
 - Cracking **widths vary from 0.008 to 0.040 inch** throughout the structure
 - Numerous cracks throughout the spans of the reinforced concrete deck girder approach
 - Vertical and horizontal cracks in the sides and bottoms of girders
 - Transverse cracks in the underside of deck
 - Transverse cracking over several of the supporting bents where the girder spans are continuous over the supports
 - Numerous popouts, spalls, and delaminations at the bottoms of girders, exposing reinforcement.
 - Numerous spalls and delaminations on the concrete columns
- **Cracking** and significant **deterioration of the paint** system in steel approach span deck
- Some **corrosion** in the steel girders and floor beams

Load-Carrying Capacity

The most recent determination of the safe load-carrying capacity of the east approach spans indicates that the concrete approach span girders and steel span girders and floor beams **do not have sufficient structural capacity to support a legal 40-ton vehicle (Type 3-3 or 3S-2), 20-ton (H20) vehicle, and 19-ton TriMet buses.**

Seismic Vulnerability

The columns in the east approach spans have insufficient flexibility – or flexural capacity – to resist seismic forces, and insufficient confinement reinforcing to provide adequate ductility (the capacity to resist lateral loads).

Main River Spans (Spans 17 through 20)

Condition

- Cracks, Spalls:
 - Concrete deck has transverse cracks and spalls, exposing corroded reinforcing steel on the underside.
 - Barge collision with southeast corner of Pier 19 resulted in a spall, exposing and breaking the vertical reinforcing steel at that corner.
- Steel members in trusses, floorbeams, and stringers have **peeling paint**, with **corrosion** in the lower half of the trusses and at locations where the deck is leaking.

- **Condition of the paint** on the south truss is significantly worse due to effects of sunlight and weather.
- Truss **floorbeams** are **failing**, compromising the integrity of the bridge deck. The floorbeams are **corroding** at the interface with the concrete-encased south fascia stringer. Corrosions in the floorbeams are up to 3/8-inch deep along the lower 6 inches of the floorbeam webs.
- **Concrete** surface near the waterline of the river piers has **moderate deterioration**, exposing the aggregate.

Load-Carrying Capacity

The most recent determination of the safe load-carrying capacity of the main river spans indicates that the main river span **steel stringers and floorbeams do not have sufficient structural capacity to support a legal 40-ton vehicle (Type 3-3 or 3S-2), 20-ton (H20) vehicle, and 19-ton TriMet buses.**

All **truss members** currently **have a safe load-carrying capacity greater than a legal 40-ton vehicle, 20-ton (H20) vehicle, and 19-ton TriMet buses.** If the deck structure were to be widened enough to accommodate the desired configuration (travel lane, bike path, and sidewalk in each direction), the deck truss members (upper chords, lower chords, diagonals, sub-diagonals, verticals and sub-verticals) would not have enough capacity to support a legal 40-ton vehicle and HS-20 design live load. In addition, the remaining fatigue life of these truss members may not provide sufficient fatigue capacity to accommodate these live loads. (Fatigue life is a measure of the ability of a member to sustain repeated cycles of loading from vehicles.)

Seismic Vulnerability

The truss lateral-bracing members have insufficient capacity to resist seismic lateral loads in compression and truss-bearing anchor bolts have insufficient structural capacity to resist seismic lateral loads. River piers have insufficient flexibility – or flexural capacity – and shear capacity (capacity to resist lateral loads) – to resist seismic loads.

West Approach (Spans 21 through 29)

Condition

- Cracks, Spalls, Delaminations:
 - Cracking widths **vary from 0.008 to 0.066 inch** throughout the structure.
 - In general, numerous spalls and delaminations and a greater amount and severity of cracking than in the east approach.
 - Numerous cracks throughout reinforced concrete deck girder approach spans; includes vertical and horizontal cracks in the sides and bottoms of girders and transverse cracks in the underside of the deck.
 - Transverse cracking over several of the supporting bents where the girder spans are continuous.

- Vertical cracks at the bottoms of girders near the Bents 27 and 28 as a result of the differential settlement and horizontal movement of the west approach.
- Cracking in steel approach span deck.
- Embankment movement has caused west approach spans to crack and move. Epoxy injection repairs were made to Bents 22 and 23, but cracks have formed through epoxy repairs at Bent 22.
- Spalls, patches, and honeycombed concrete (full of holes) occur at several locations in the approach span bents.
- Significant **deterioration of the paint system** on the steel plate girders and floor beams and some **corrosion** of the steel.
- Bent 29 is structurally sound and not deficient

Load-Carrying Capacity

The most recent determination of the safe load-carrying capacity of the west approach spans indicates that the west approach concrete span girders and steel span plate girders and floor beams **do not have sufficient structural capacity to support a legal 40-ton vehicle (type 3-3 or 3S-2), 20-ton (H20) vehicle, and 19-ton TriMet buses.**

Seismic Vulnerability

The columns in the west approach span have insufficient flexibility – or flexural capacity – to resist seismic forces and columns have insufficient confinement reinforcing to provide adequate ductility (capacity to resist lateral loads).

Bridge Deck

- Minor rutting at the asphalt wearing surface.
- Expansion joint material at Bents 4, 6, 8, 11, 12, 14, 16 has fallen out of the joint at several locations.
- Vertical cracks and spalls are exposing the reinforcing steel in the precast balusters of the railing.
- Overhang of the sidewalk has significant spalls and delaminations, exposing the reinforcing steel underneath.

Summary of Findings

Without rehabilitation to correct the deficiencies of the existing bridge, the current 10-ton-load limit may need to be reduced even further. If deterioration is allowed to continue, the bridge may eventually need to be closed to traffic. The current proposal to maintain the 10-ton posting for the next 10 to 15 years will cost an estimated \$0.6 million. It will cost an additional \$4 million to \$6 million to stabilize the west approach enough to maintain the 10-ton-load capacity.

Assumptions for Comparison of Bridge Rehabilitation with Replacement Options

To assist with understanding the tradeoffs between bridge rehabilitation and replacement options for correcting deficiencies, the Bridge Working Group is preparing a memorandum, to be published in September. The memorandum will compare cost and other factors associated with these options. The general assumptions for this comparison follow.

General Assumptions

Life-Cycle Cost Analysis

- The present worth analysis to compare rehabilitation and replacement costs will be performed using a 5.25 percent expected rate of return, provided by the county.
- Life-cycle cost will include maintenance and repair costs.
- Life-cycle cost will include painting, rehabilitation, and major inspection of steel truss.
- The painting cost will be based on the escalated per-square-foot cost of recently painted steel surface areas on the Hawthorne Bridge and Broadway Bridge.
- All existing painted surfaces will be removed to bare steel for painting.
- The new coat of paint is expected to last 20 to 30 years.
- The design cost will be included in the cost comparison between rehabilitation and replacement options. It is expected that the percentage of construction cost for rehabilitation will be more than the percentage of the construction cost for replacement of the bridge.

Service Life of the Structure

- The life-cycle cost analysis for the structure will be based on a 75-year service life. (Service life is defined as the length of time the structure is expected to be in operation.)
- The design life is 75 years. (AASHTO LRFD Bridge Design Specifications define design life as the period of time that the statistical derivation of transient loads is based [i.e., the length of time that the loads and load and resistance factors for design are not expected to be exceeded]).
- Design load and resistance factors would need to be modified to create a design life of greater than 75 years.
- The metal fatigue of the existing steel truss members will be considered when determining the remaining life of the main spans.
- Should the remaining fatigue life be less than 75 years, an additional rehabilitation cost for the steel truss will be applied.

Project Boundaries

- The rehabilitation option will include all of the structure from the east abutment to the west abutment of the existing bridge and the new interchange at the west approach.

- The replacement option will include all of the structure from the east abutment to the west abutment of the new bridge and new interchange at the west approach.
- The transitions from the existing east approaches will not be included as part of the cost estimate.
- The alignment of the replacement bridge will be located outside of the existing bridge alignment.

Bridge Width

- The bridge width under the rehabilitation option will be the maximum allowable within the constraints of truss strength. The design will not be able to accommodate the proposed new roadway section without major modification of the steel trusses. The current roadway section is 28 feet wide, including sidewalks. The proposed roadway cross-section is 52 feet wide, and includes two traffic lanes plus additional width for bike and pedestrian crossing (two 12-foot traffic lanes, 6-foot shoulders, 8-foot sidewalks, and bridge rail for a total 55-foot bridge cross-section).
- The proposed cross-section will meet minimum AASHTO standard for roadway width for traffic, bike, and pedestrian crossings.
- The replacement option will have a cross-section similar to the rehabilitation option.
- To demonstrate cost escalation for the bridge replacement option, an additional comparison of a four-lane section consisting of two traffic lanes, two lane widths for mass transit, and an additional width for bike and pedestrian crossings will be generated. The two additional lanes on the four-lane cross-section will be called “transit” or “express” lanes.

Vertical Clearance

- Both rehabilitation and replacement options will maintain the existing vertical clearance over the Willamette River.

Seismic Retrofit

- Cost estimates for Phase I and Phase II seismic retrofits will be included as part of the rehabilitation option.
- The Phase II seismic retrofit will include the seismic retrofit of the truss span bridge pier foundations in the river and strengthening of truss crossframes and lateral bracing.

Traffic Control During Construction

- The rehabilitation option will require closure of the bridge to traffic. It is expected that a detour bridge will be required to maintain traffic during construction. A cross-section of the detour bridge will be maintained at a narrow width to minimize construction cost.
- The alignment of the new bridge will be outside of the existing alignment.
- Closure of the bridge to traffic for the bridge replacement option is expected to be minimal, limited to the time required to construct tie-ins at bridge approaches.

Right of Way

- The cost of right of way for the bridge replacement option will be captured as a factor of right-of-way cost of the bridge rehabilitation option.
- It is anticipated that a multiplier will be used to demonstrate the differential in the cost of right of way for the two options.
- The current assumption is that the fee title right of way would not be required for the rehabilitation option. The maintenance easement will allow for rehabilitation of the existing bridge with additional easement for a wider section.

Bridge Terms: Quick Reference Guide

| Term | Definition |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Abutment | End vertical support of a bridge span; separates the roadway on the ground from the bridge |
| Bent | Foundation structure to support bridge girders and deck; term can be used interchangeably with "pier" |
| Cross-Bracing Members | Structural members providing lateral stability for main truss members |
| Dead Load | Weight of structural members comprising the bridge |
| Delaminations | Separation of concrete from steel reinforcement |
| Diagonals | Structural members connecting the upper chord members and lower chord members of a truss |
| Fascia | Flat vertical surface immediately below the deck; exterior girder |
| Girder | Main longitudinal load-carrying members of a bridge span |
| Floorbeam | Load-carrying member of bridge deck perpendicular to the roadway alignment; transfers the load of deck onto the girders and truss |
| Live Load | Weight of trucks and pedestrians as applied to design of bridge members |
| Longitudinal | Parallel to the direction of traffic on a bridge |
| Lower Chords | Lower horizontal members of steel truss |
| Pier | Foundation structure to support spans; intermediate vertical support for a bridge span" |
| Popout | Concrete separation from member due to corrosion or impact force |
| Seismic Loads | Horizontal forces generated by earthquake |
| Spall | Separation of small pieces of concrete from a larger mass of concrete due to corrosion |
| Span | Horizontal portion of a bridge that crosses over a roadway or river |
| Stringers | Structural members that support the bridge deck |
| Sub-Diagonals | Secondary steel members that connect the upper and lower chord members of a steel truss |
| Sub-Verticals | Secondary vertical members that connect the upper and lower chords of steel truss |
| Supports | Bridge footings and columns comprising the bridge foundation |
| Transverse | Perpendicular to the direction traffic runs on a bridge |
| Truss | A structure comprised of straight members connected at each end, or joints by pins and loaded by forces applied only at the joints (straight members are typically arranged in a system of triangles) |
| Upper Chords | Upper horizontal members of steel truss |
| Verticals | Vertical members connecting the upper and lower chords of steel truss |