



# Seismic Vulnerabilities of Multnomah County's Willamette River Bridges

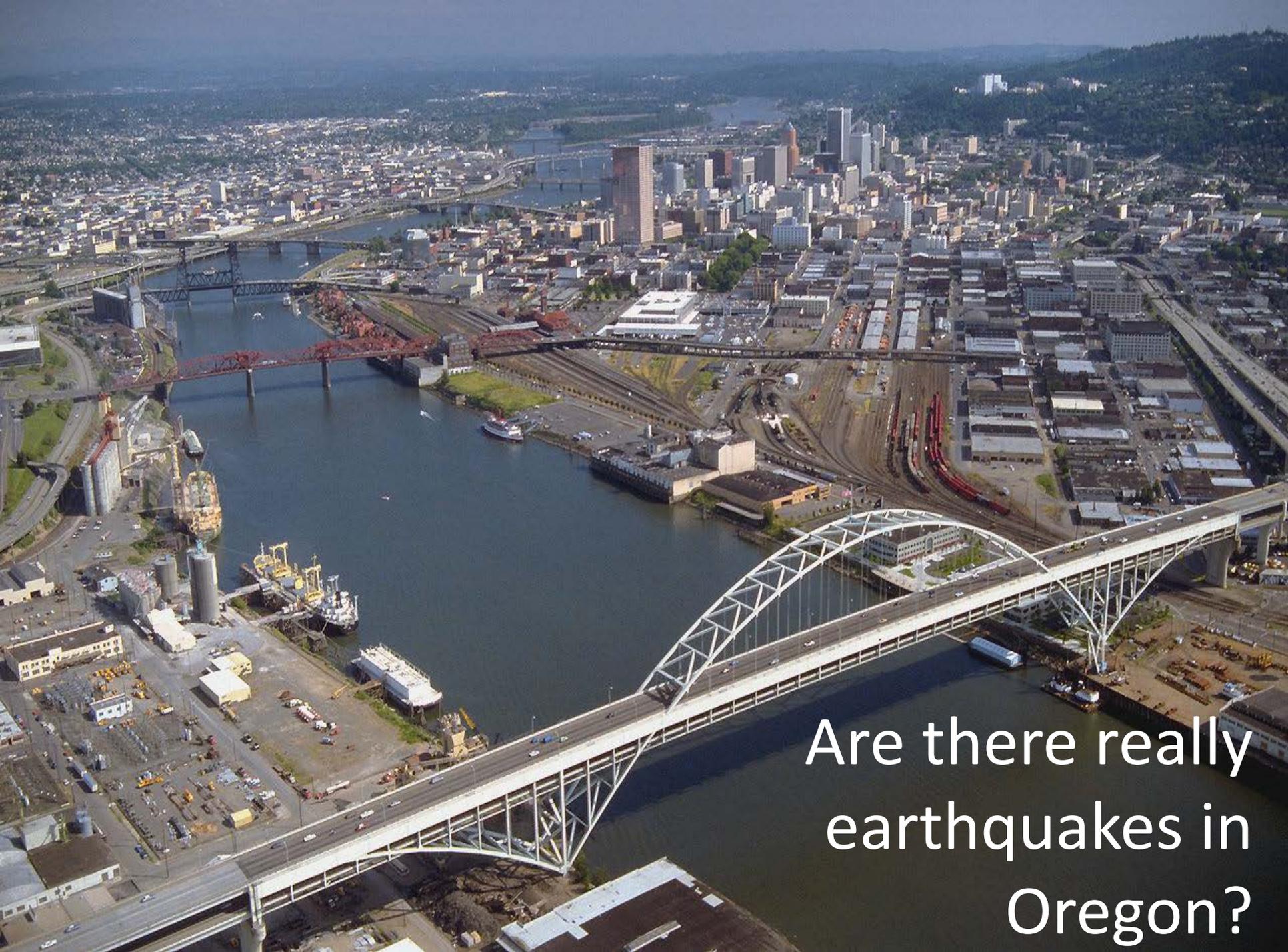
November 6, 2014

**Ian Cannon, P.E.** - Multnomah County Bridge Division

**Steve Drahota, P.E.** - HDR Engineering, Inc.

# Response to the Budget Note

- 1) Are there really earthquakes in Oregon?
- 2) Are the Willamette River bridges vulnerable?
- 3) What are examples of similar vulnerabilities?
- 4) What can be done to prepare for “The Big One”?
- 5) What have other Agencies done in response to their seismic vulnerabilities?

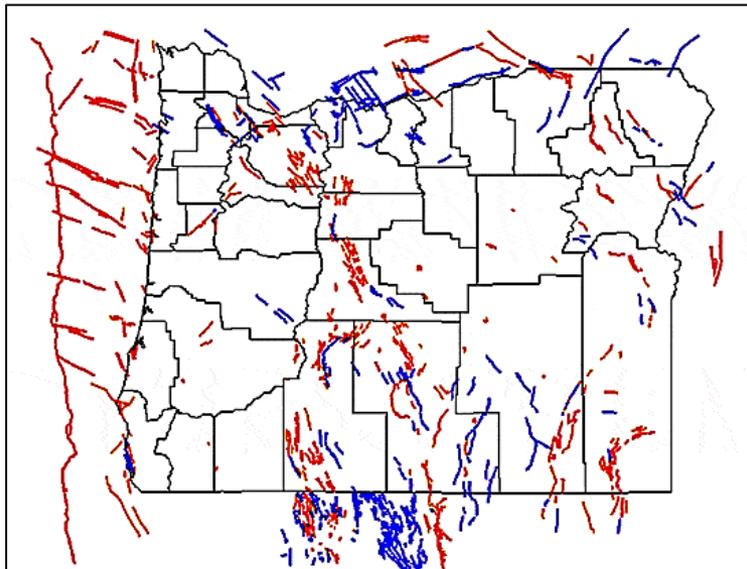


Are there really  
earthquakes in  
Oregon?

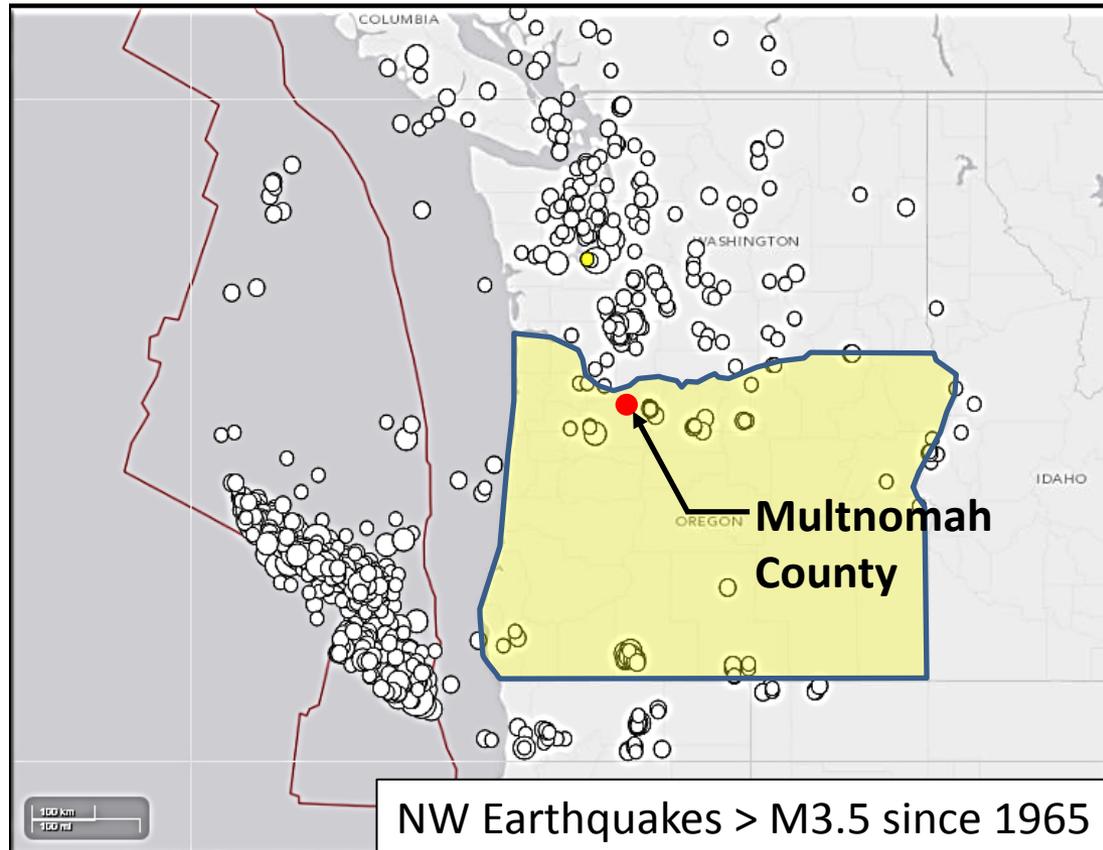
# NW Earthquake Activity

Source	Magnitude	Frequency	Latest Occurrence
Crustal	M < 5.5	Every 15–20 years	Annually
	M ≥ 5.5	???	1993: Scotts Mills & Klamath-Falls
CSZ*	M ≥ 8.0	Every 350–500 years	January, 1700
Intraplate	M = 4–7	Every 30–50 years	Feb., 2009 M4.1, Grants Pass, OR

**Note: M9.0 = 1000 x 2014 Napa EQ**

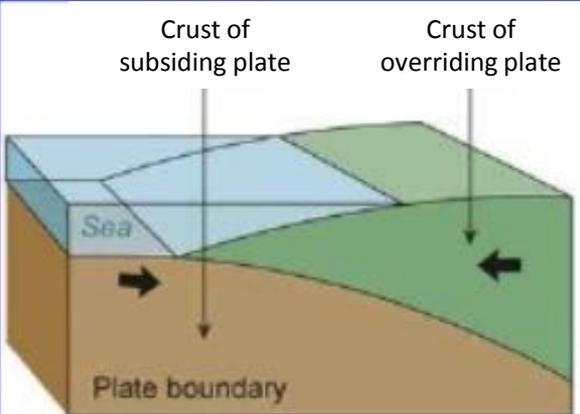
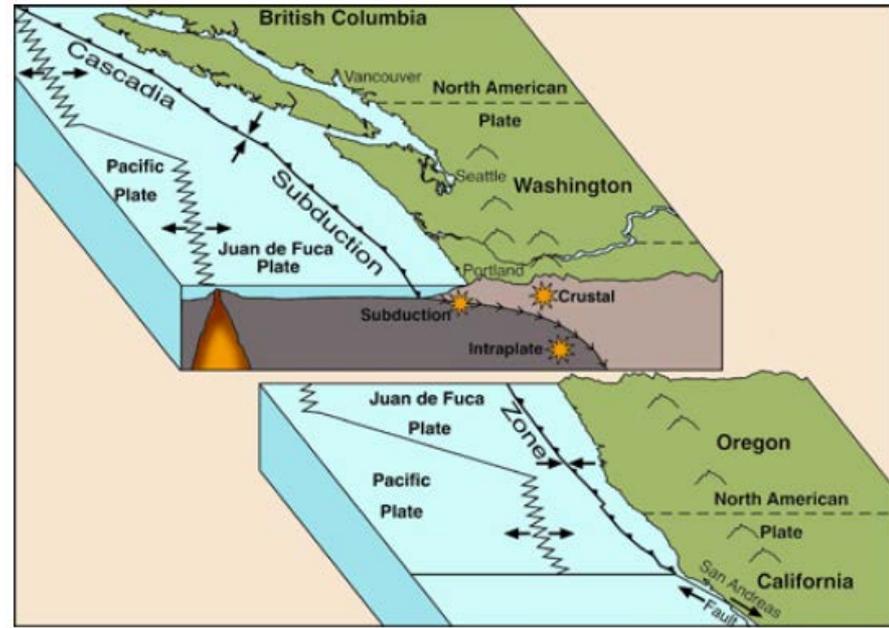


**Known Oregon EQ Faults**

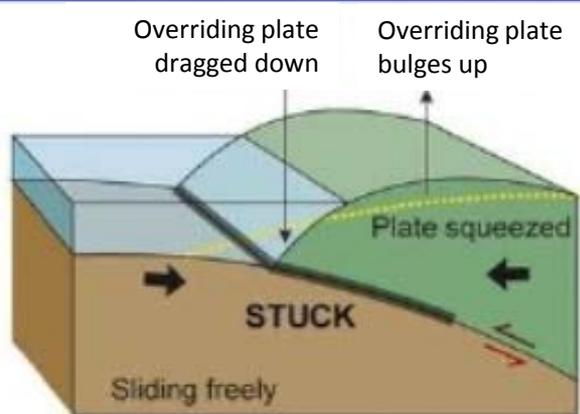


**NW Earthquakes > M3.5 since 1965**

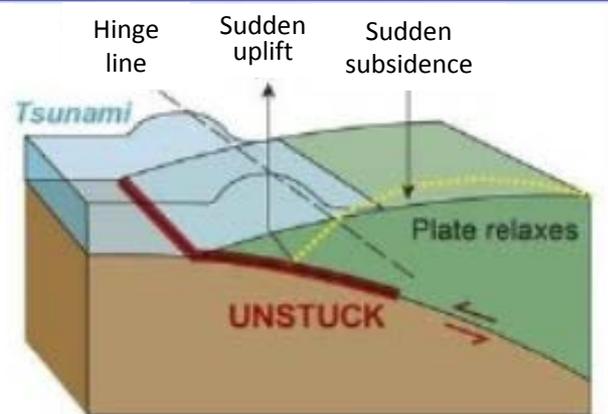
# Oregon's Cascadia Subduction Zone (CSZ) EQ: AKA, "The Big One"



**1** OVERALL: A tectonic plate descends, or "subducts" beneath an adjoining plate. But it does so in a stick-slip fashion.



**2** TIME BETWEEN EARTHQUAKES: The plates slide freely at great depths, where hot and ductile. But at shallow depths, where cool and brittle, they stick together. Slowly squeezed, the top plate thickens.

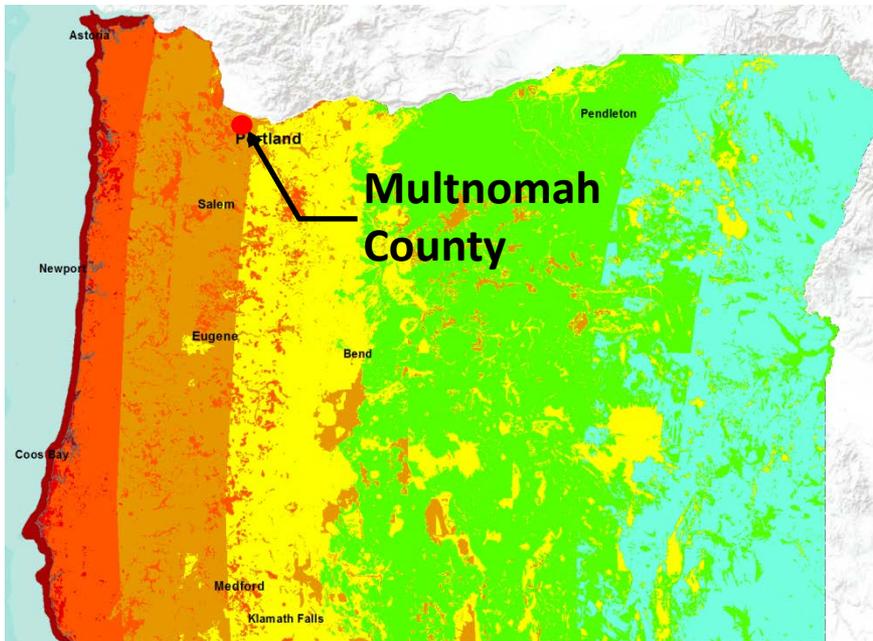


**3** DURING AN EARTHQUAKE: The leading edge of the top plate breaks free, springing seaward and upward. Behind, the plate stretches; its surface falls. The vertical displacements set off a tsunami.

After Atwater et al. (2005)

# M8+ Cascadia Subduction Zone EQ Predictions

- **37% Chance in next 50 Years**
- **2 to 4 minutes of *intensive* shaking**
- **1,250 to 10,000 immediate fatalities**
  - **Up to 5,000 more fatalities** due to lack of emergency response
- **\$350 Billion** in economic loss over 8-10 years
- **10s of thousands** of displaced households and destroyed buildings
- **Hundreds** of bridge failures

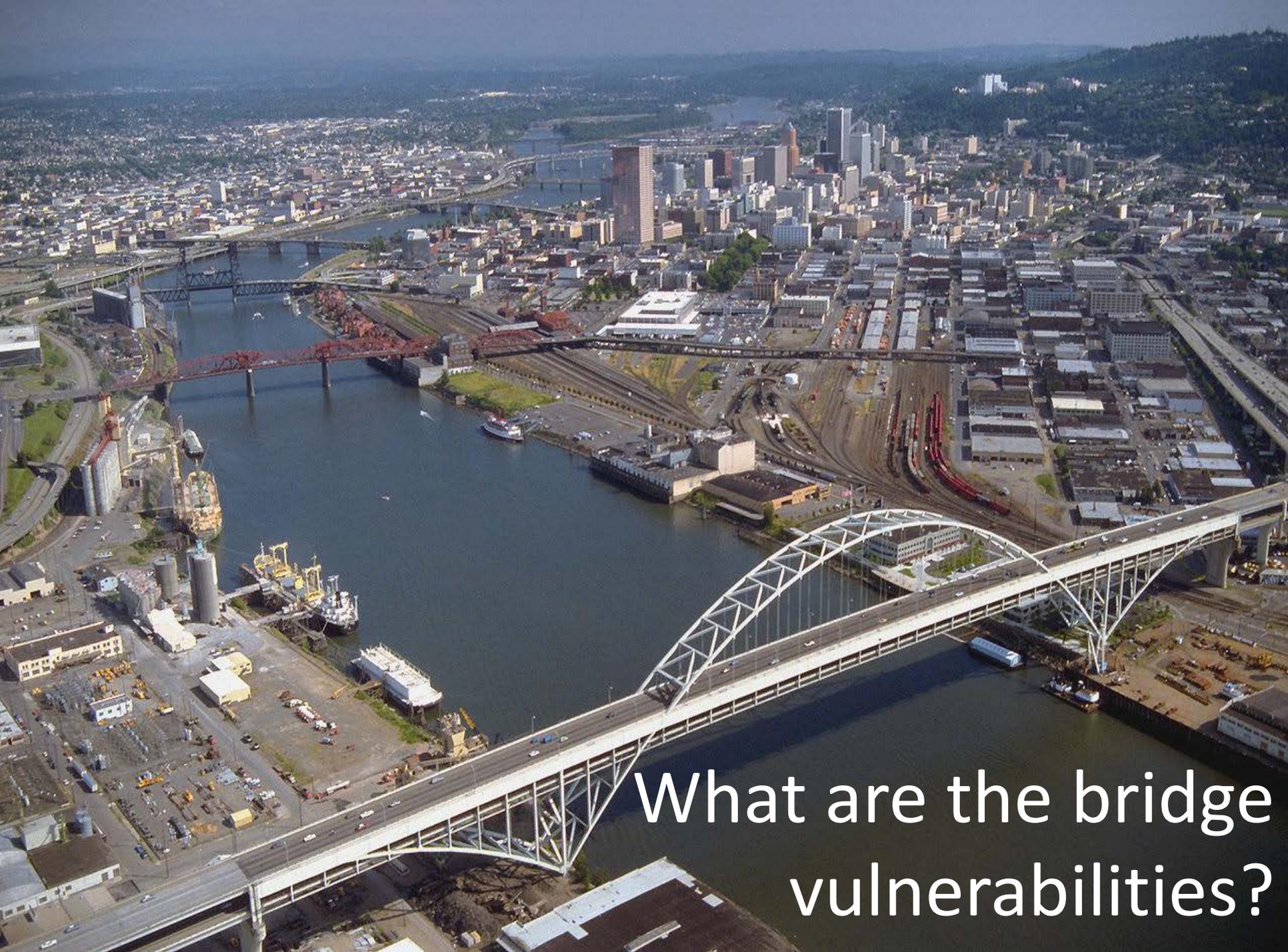


“ODOT has expended minimal resources on seismic retrofitting. As a result, much of Oregon’s highway system will not be usable immediately after a major seismic event.” – *ORP*

## Sources:

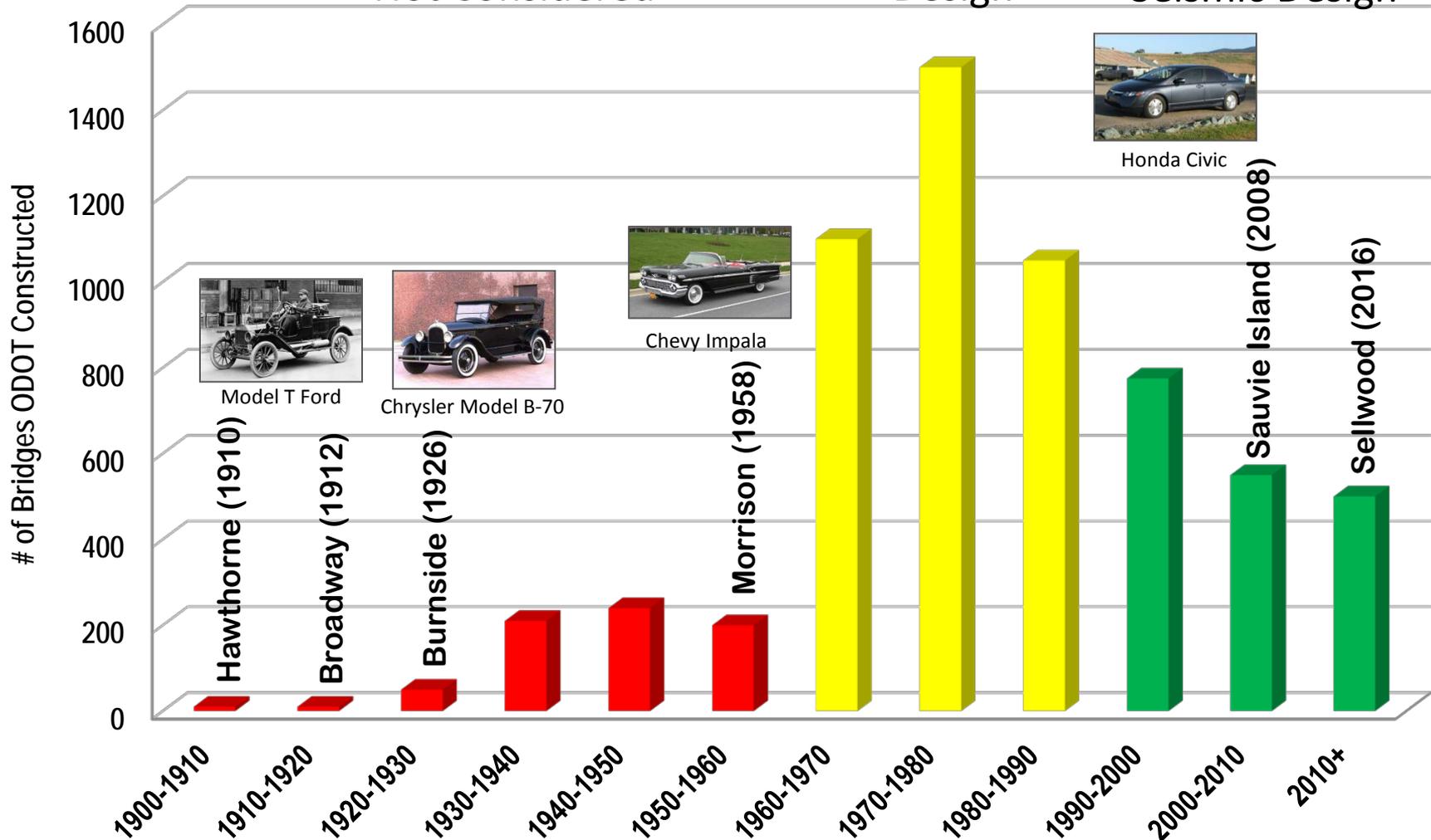
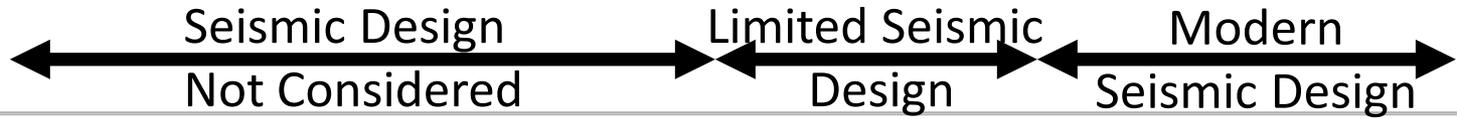
“*Oregon Highway Seismic Options Report*” (Mar, 2013)  
Oregon Department of Transportation

“*Oregon Resiliency Plan*” (Feb, 2013)  
Report to the 77th Legislative Assembly from Oregon  
Seismic Safety Policy Advisory Commission (OSSPAC)

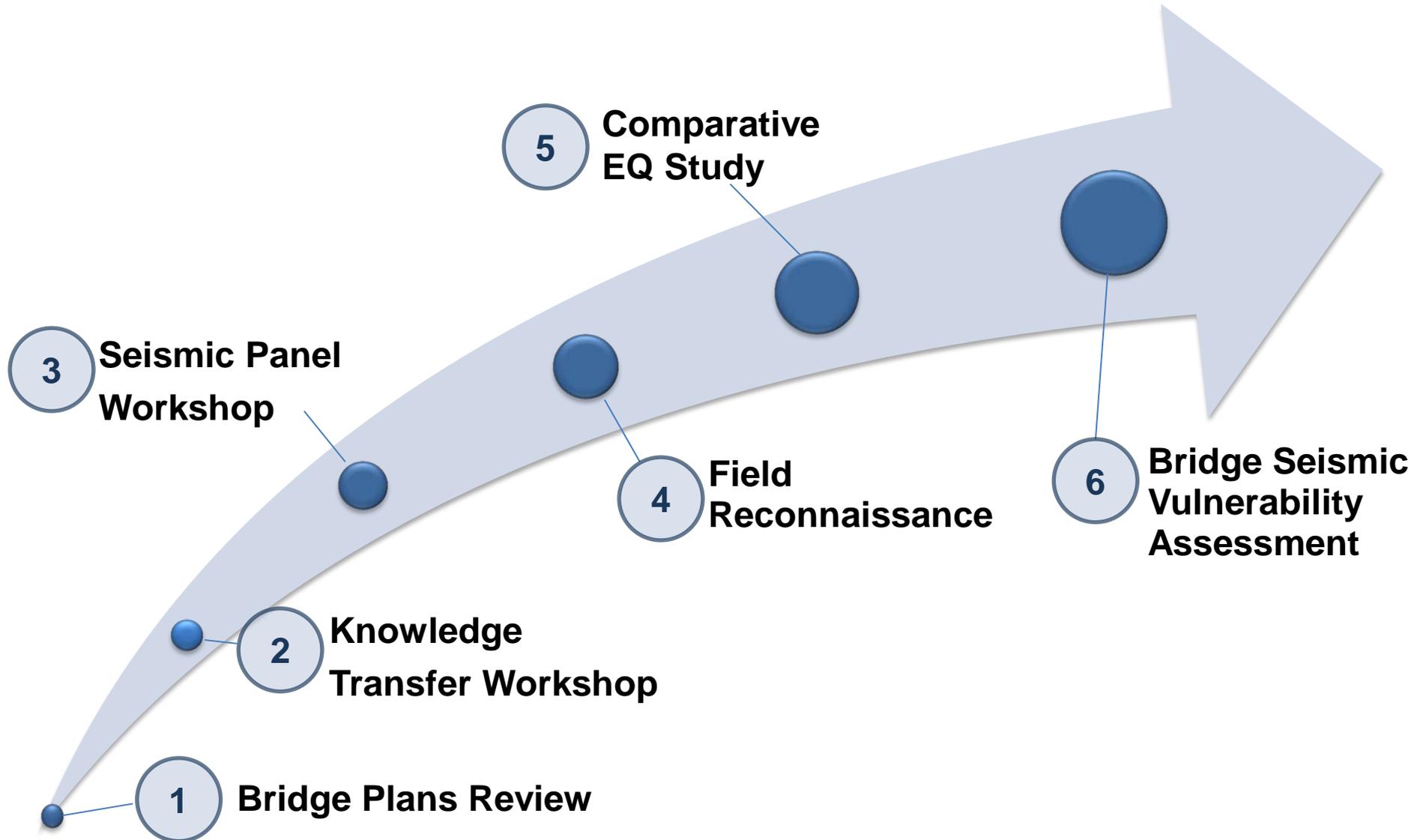


What are the bridge vulnerabilities?

# Oregon Seismic Design History



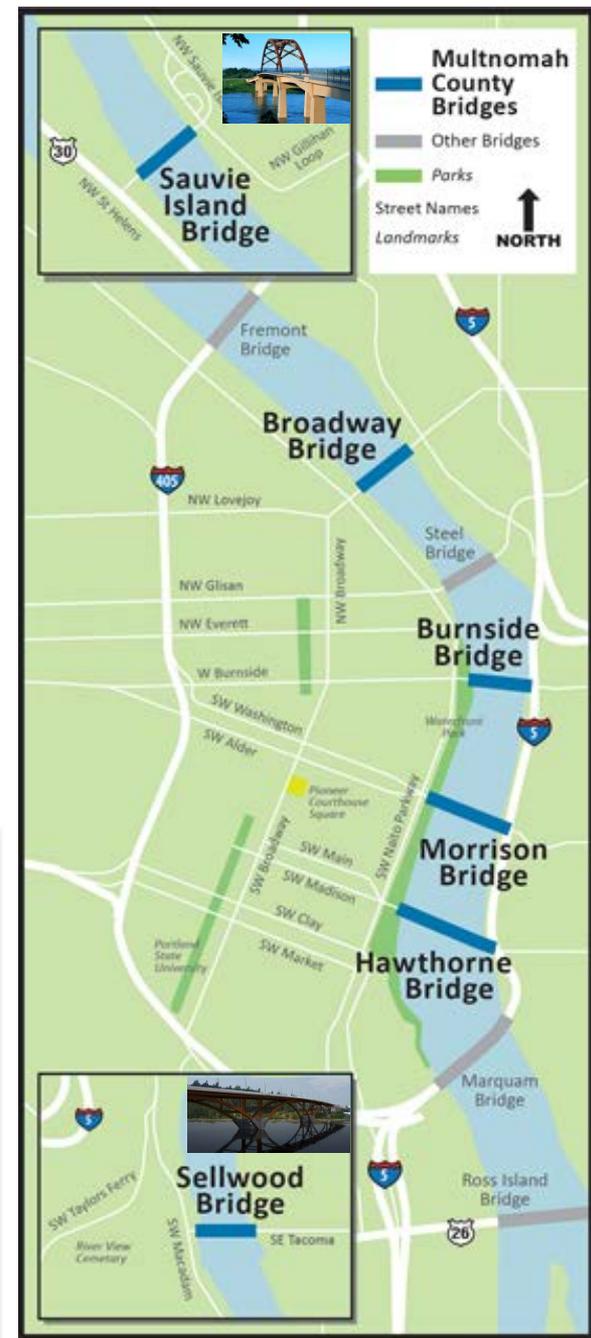
# 2014 Seismic Assessment Process



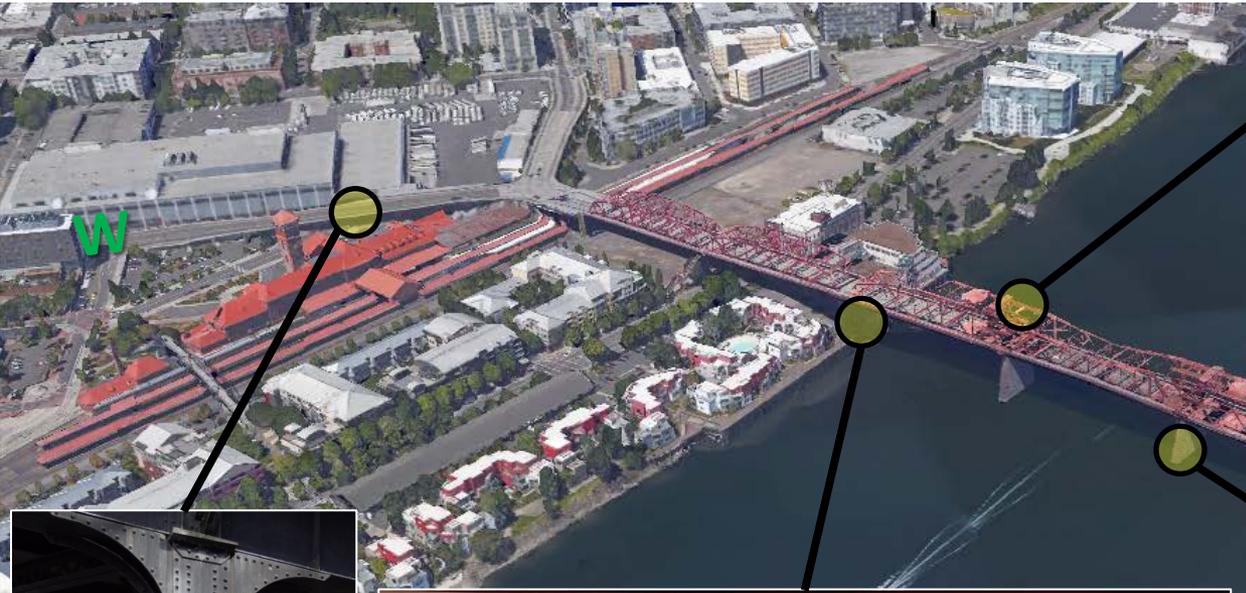
# Multnomah County's Willamette River Bridges

- ☑ Sauvie Island Bridge (Seismically OK)
- x Broadway Bridge
- x Burnside Bridge
- x Morrison Bridge
- x Hawthorne Bridge
- ☑ Sellwood Bridge (Seismically OK)

Note: Multnomah County is also responsible for 20 other smaller bridges.



# Broadway Bridge Extents & Unique Details



# Broadway Bridge – Double-Leaf Rall-type Bascule Bridge

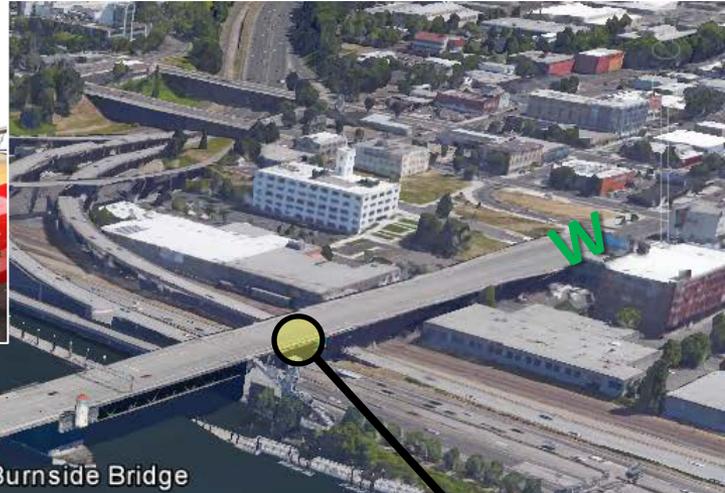


## Primary Seismic Vulnerabilities:

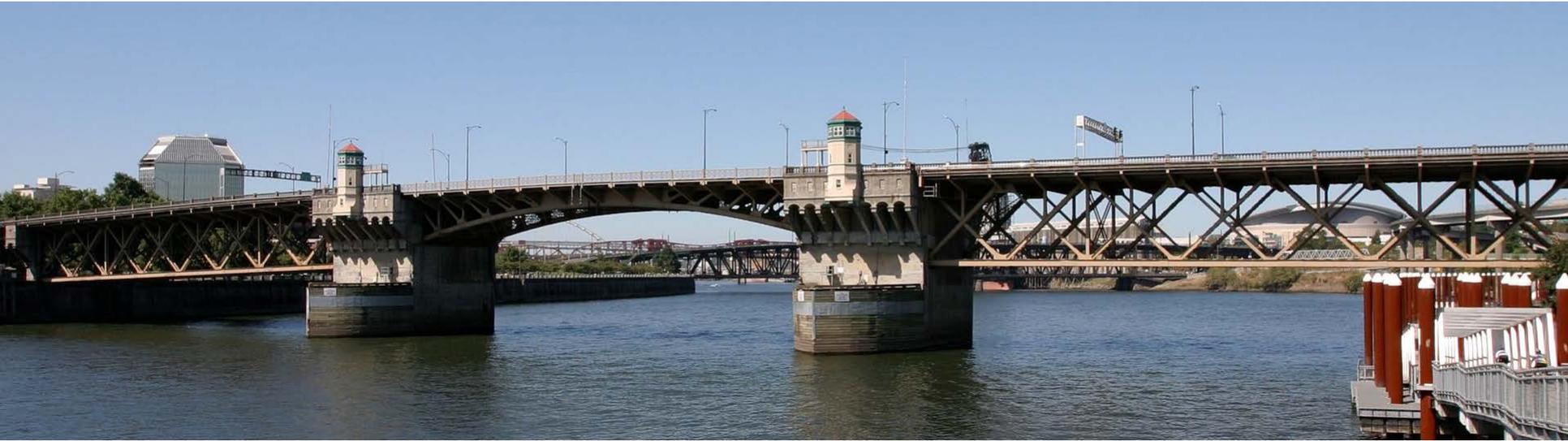
- Bridge falling from its supports
- Piers and columns
- Below-water foundations
- Rall wheel and track
- Mechanical and electrical systems
- Liquefaction settlement
- Bearing connections
- Truss members



# Burnside Bridge Extents & Unique Details



# Burnside Bridge – Double-Leaf Strauss-type Bascule Bridge



## Primary Seismic Vulnerabilities:

- Bridge falling from its supports
- Piers and columns
- Below-water and on-land foundations
- Counterweight connections and trunnion supports
- Mechanical and electrical components
- Soil liquefaction settlement
- Truss members
- Bearing elements

# Morrison Bridge Extents & Unique Details



# Morrison Bridge – Double-Leaf Chicago-type Bascule Bridge

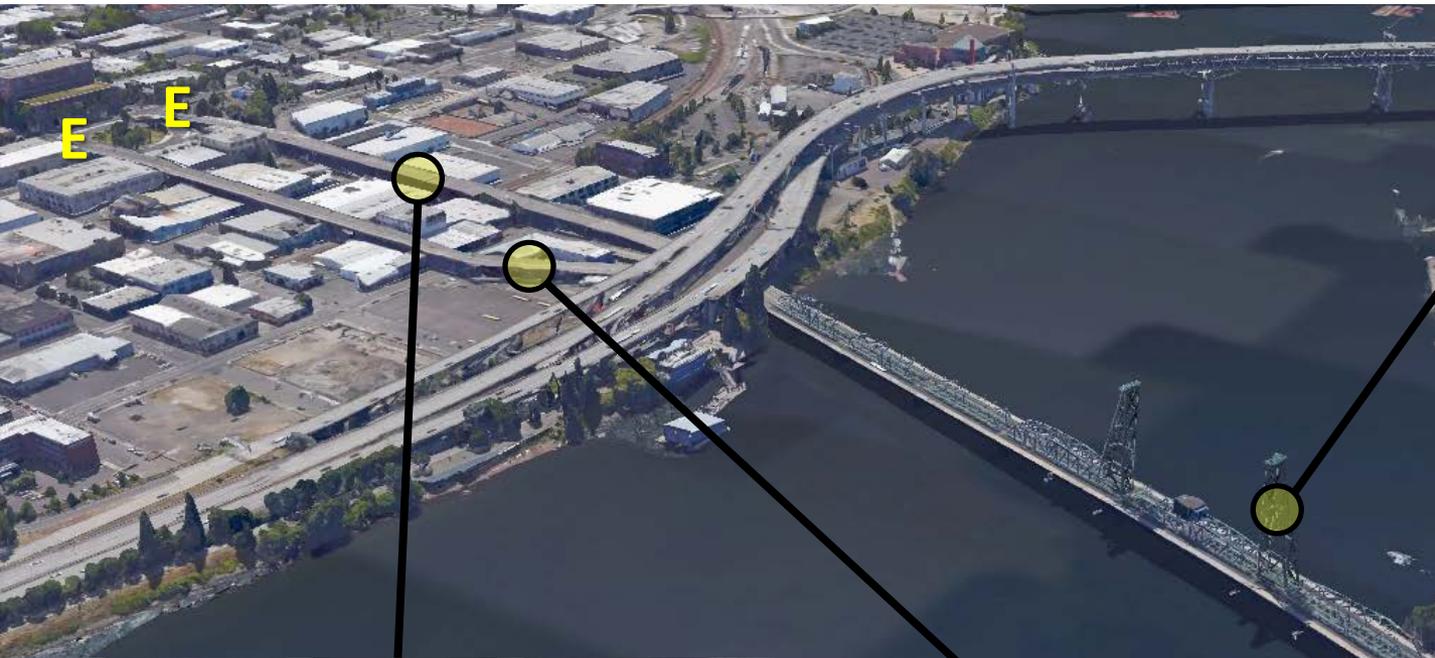


## Primary Seismic Vulnerabilities:

- Bridge falling from its supports
- Piers and columns
- Below-water and on-land foundations
- Counterweight connections and trunnion supports
- Mechanical and electrical components
- Truss members
- Bearings elements



# Hawthorne Br. Extents & Unique Details



# Hawthorne Bridge – Vertical Lift Bridge



## Primary Seismic Vulnerabilities:

- Bridge falling from its supports
- Piers and columns
- Below-water and on-land foundations
- Mechanical and electrical components
- Lift tower steel members
- Supporting cap beams
- Soil liquefaction settlement
- Truss members
- Bearing elements



Where were similar vulnerabilities?

# Major Comparable Earthquakes

## Subduction Zone Earthquakes

- 2011 Tohoku (Japan) EQ – M9.0; \$235B in economic loss
  - 15,889 deaths
  - Massive Force generation (2.99g)
- **2010 Chile EQ – M8.8; \$15-30B in economic loss**
  - **525 deaths**
  - **Thirteen aftershocks > M6.0 (131 total)**
- 2004 Indian Ocean EQ – M9.0; \$Unknown
  - 280,000 deaths
  - 100' high tsunami
- 2001 Nisqually CSZ EQ (WA) – M6.8; \$1B Damage
  - 1 death
- 1964 Alaska EQ - M9.2; \$0.5B damage
  - 138 deaths (15 from EQ; Tsunami: 5 in OR, 13 in CA, & 105 elsewhere)
  - Large tsunamis and up to 38' vertical shifts
- **1700 Oregon CSZ EQ – M9; \$Unknown**



The NW's CSZ Event is expected to be similar to the 2010 Chile EQ.



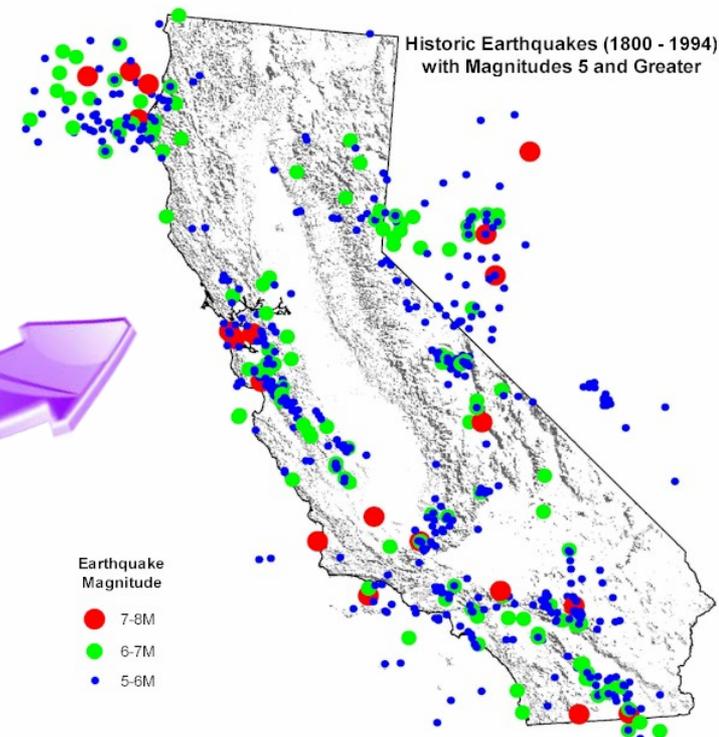
# Major Comparable Earthquakes

## Subduction Zone Earthquakes

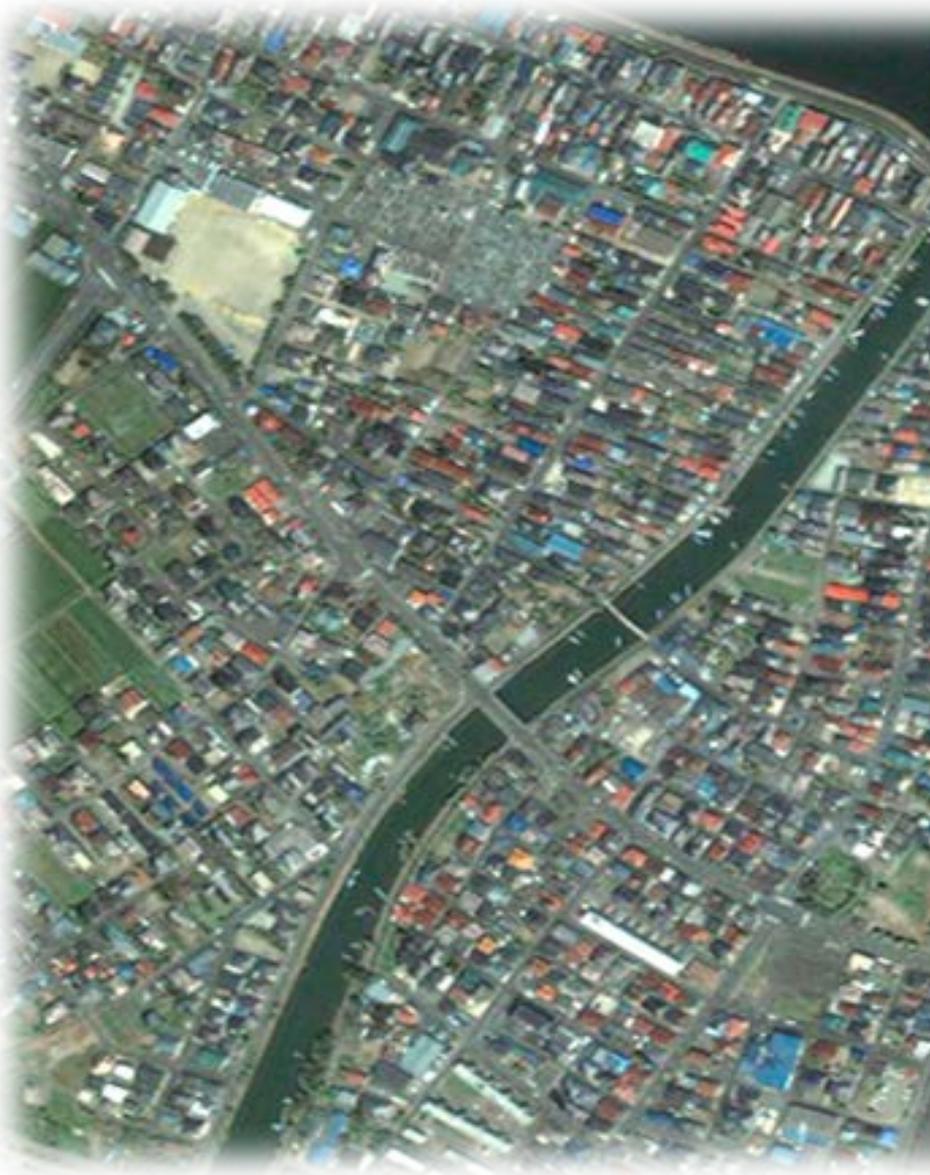
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## Other West Coast Earthquakes

- 2014 Napa EQ (CA) – M6.0; \$0.7B
  - 200 injuries
- 1994 Northridge EQ (CA) – M6.7; \$20B
  - 57 deaths
  - Many bridge collapses (even post-1970 designs)
  - Very large force generation (1.8g horiz and 1.2g vertical)
- 1989 Loma Prieta EQ (CA) – M6.9; \$5.8B damage
  - Many bridge collapses (even post-1970 designs)
  - 63 deaths



# 2011 Tohoku (Japan) EQ and Tsunami

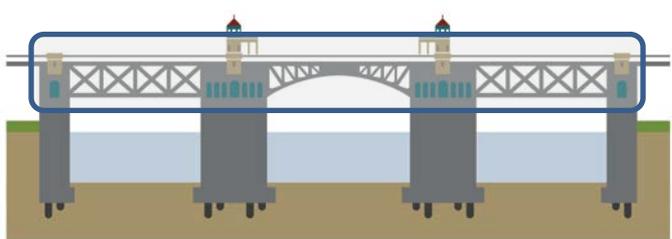


Before



After

# 2011 Tohoku Earthquake Bridge Sliding off its Supports

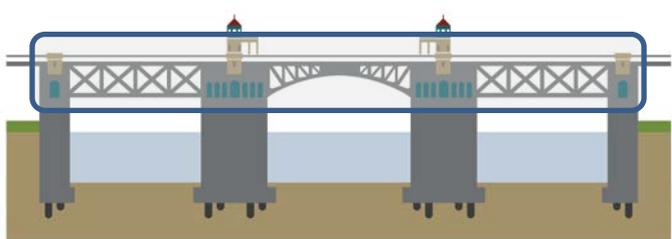


## Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



# 2010 Chili Earthquake Bridge Sliding off its Supports



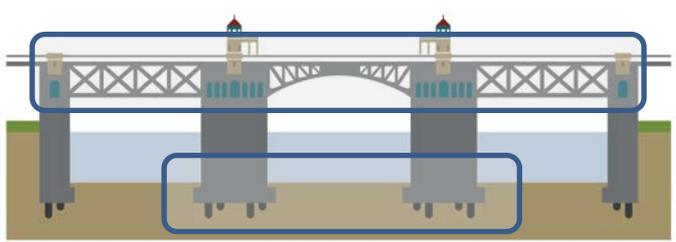
## Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



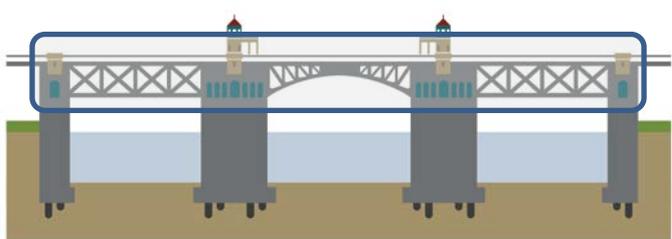
PTCBS  
22-02  
13100

# 2010 Chili Earthquake Bridge Sliding off its Supports / Soil Liquefaction Settlement



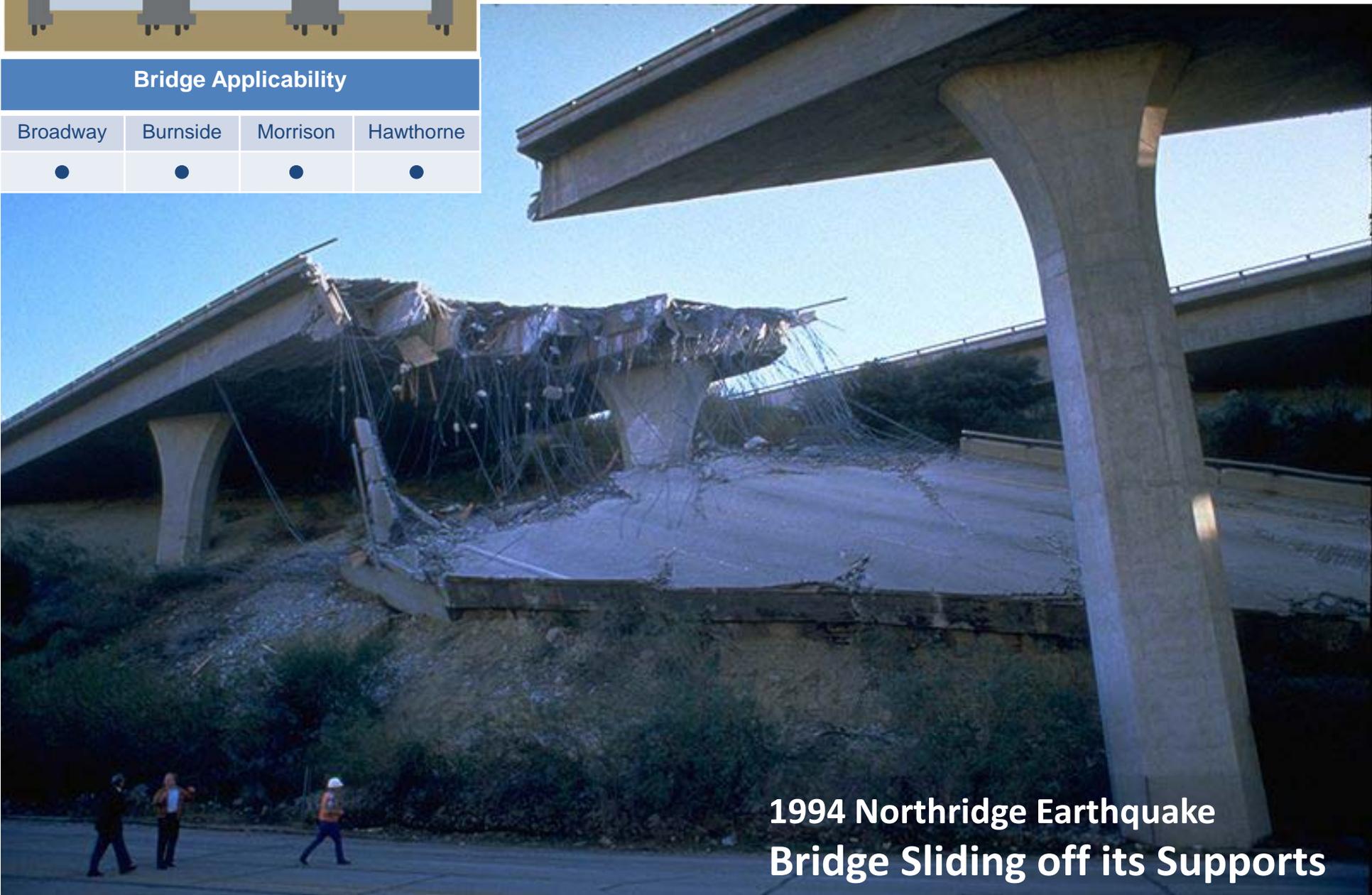
Bridge Applicability			
Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



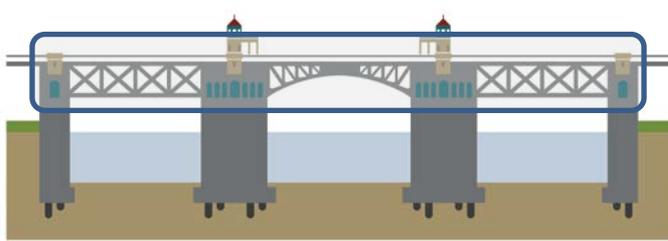


### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



**1994 Northridge Earthquake  
Bridge Sliding off its Supports**

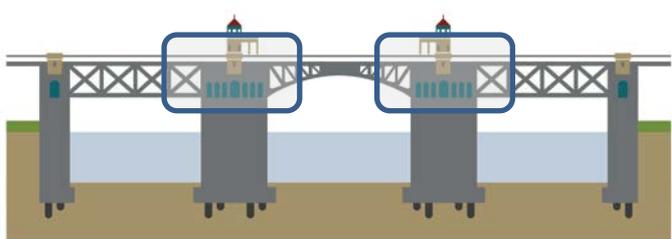


### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



**1989 Loma Prieta Earthquake  
Bridge Sliding off its Supports**



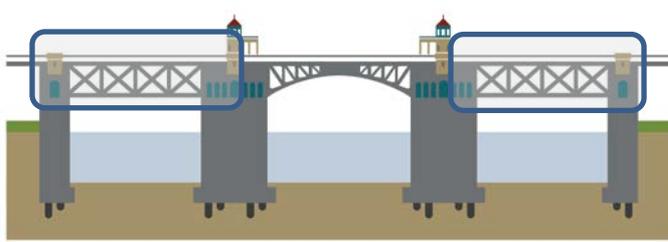
### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



**1964 Alaska Earthquake  
Bridge Sliding off its Supports**

# 2010 Chili Earthquake Bridge Girder Damage

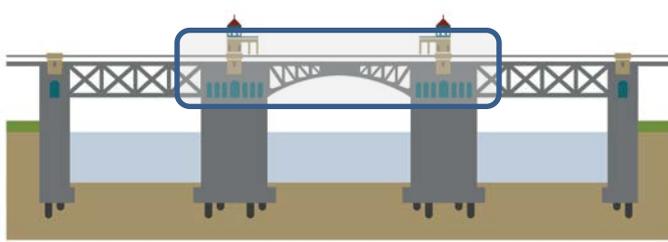


## Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



# 2001 Nisqually (WA) Earthquake Retrofit costs drove the replacement of Seattle's South Park Bascule Bridge



## Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
	●	●	

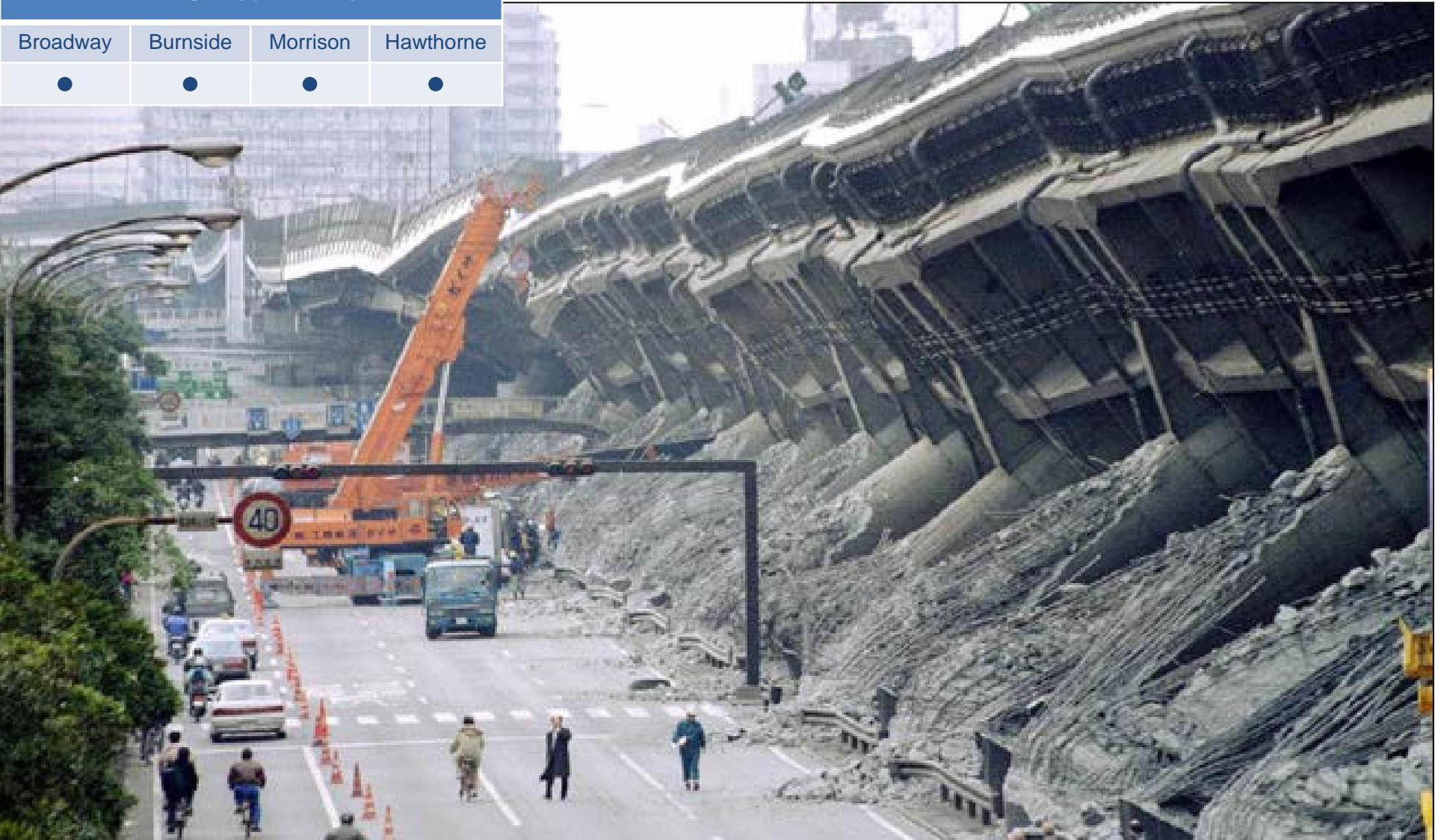


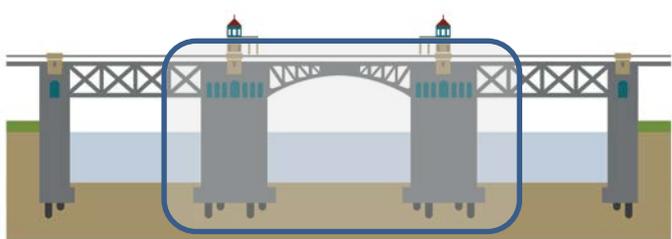
# 1995 Kobe Japan Earthquake Column Failure



## Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●





### Bridge Applicability

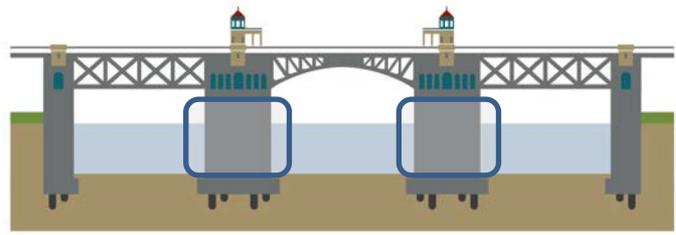
Broadway	Burnside	Morrison	Hawthorne
●	●		●



**2010 Chili Earthquake  
Under-Reinforced Pier Failure**



**2011 Tohoku Earthquake  
Soil Liquefaction Settlement / Column Damage**

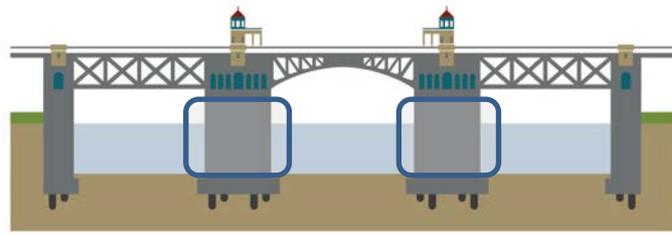


### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●

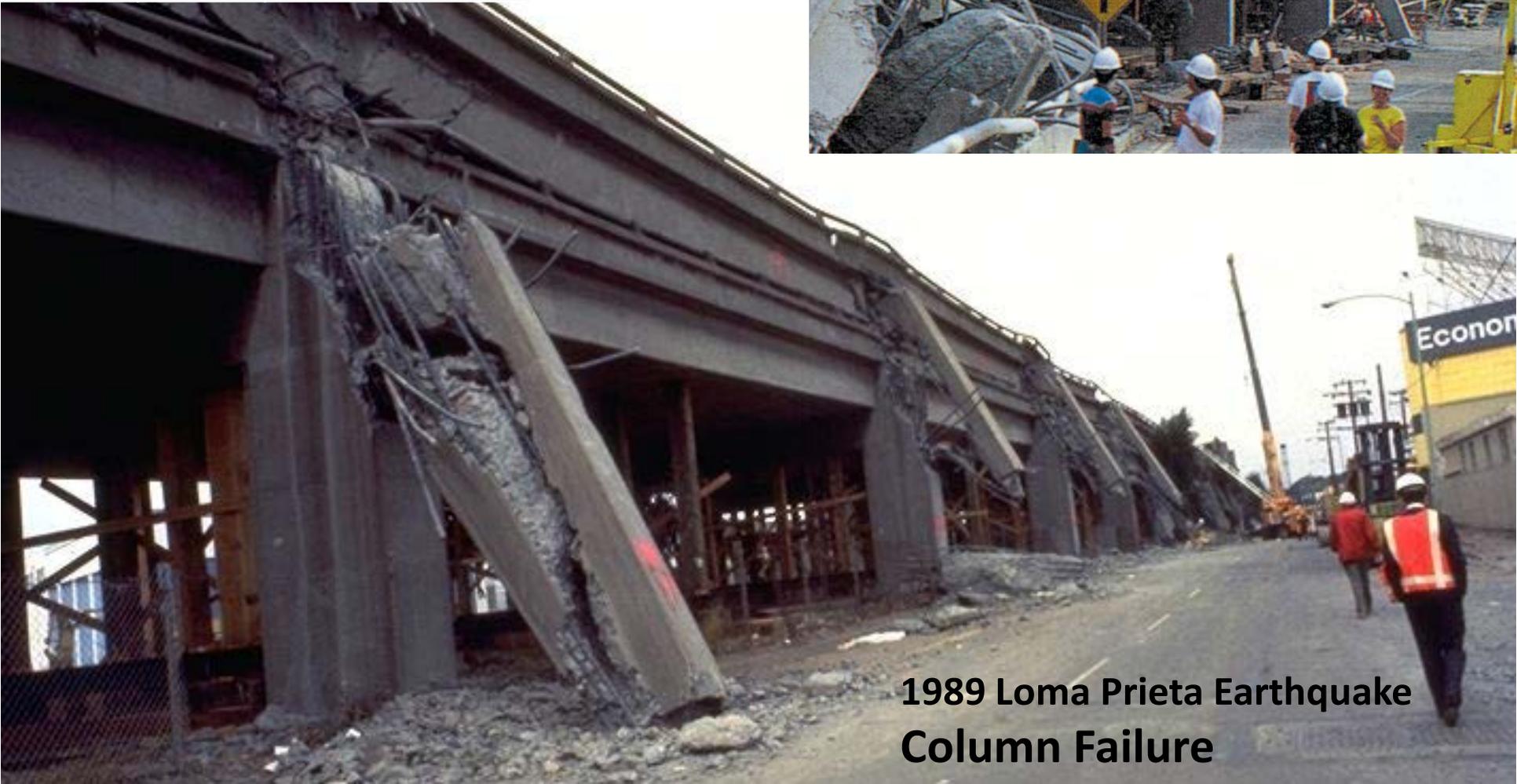


**1994 Northridge Earthquake  
Column Failure**

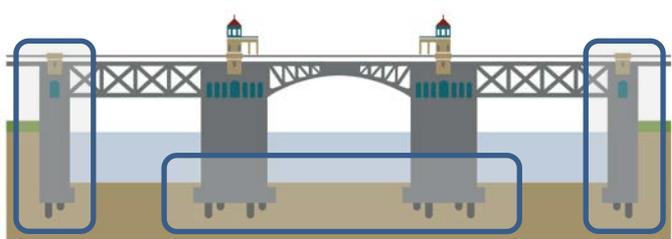


### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



**1989 Loma Prieta Earthquake  
Column Failure**

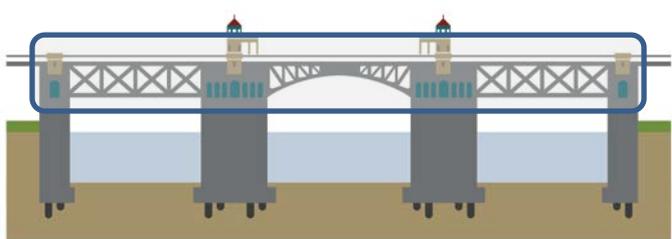


### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



**2010 & 2011 New Zealand Earthquakes  
 Canterbury / Christchurch  
 Soil Liquefaction Settlement**



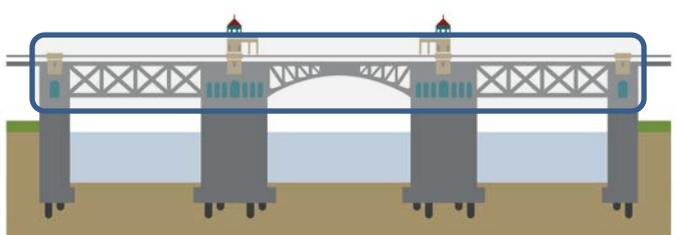
### Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



**2010 New Zealand Earthquakes  
Pedestrian Bridge Damage**

# 2011 Tohoku Earthquake Truss Member and Connection Failures

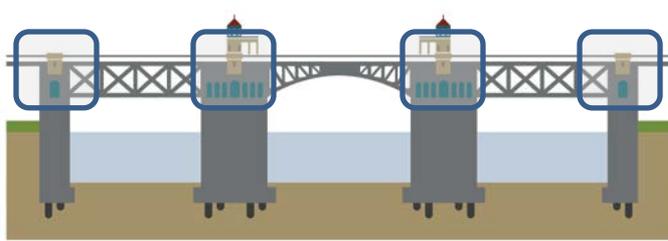


## Bridge Applicability

Broadway	Burnside	Morrison	Hawthorne
●	●	●	●



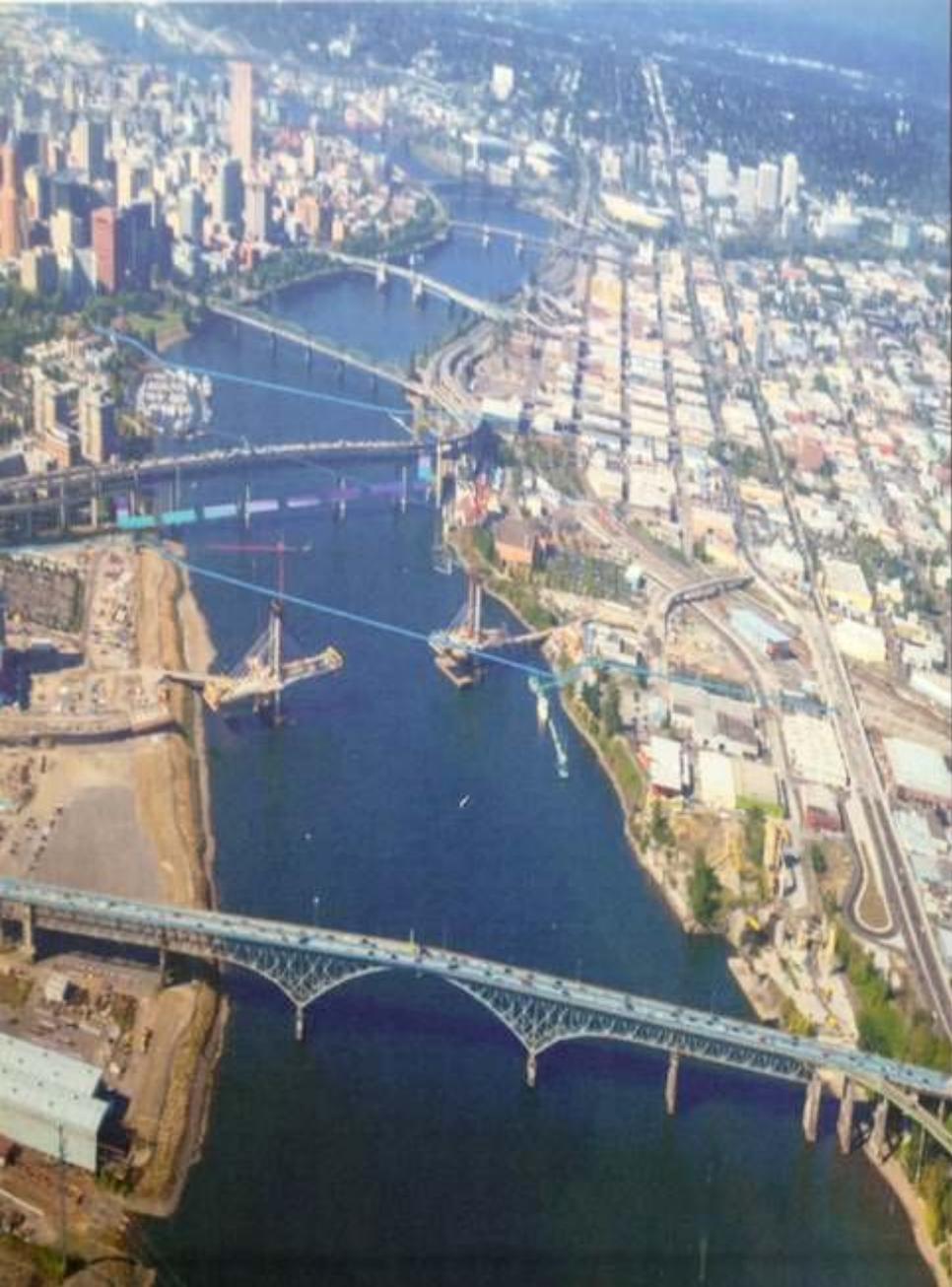
# 1993 Scotts Mills, OR Earthquake: Yamhill River - Rocker Bearing Failure



## Bridge Applicability

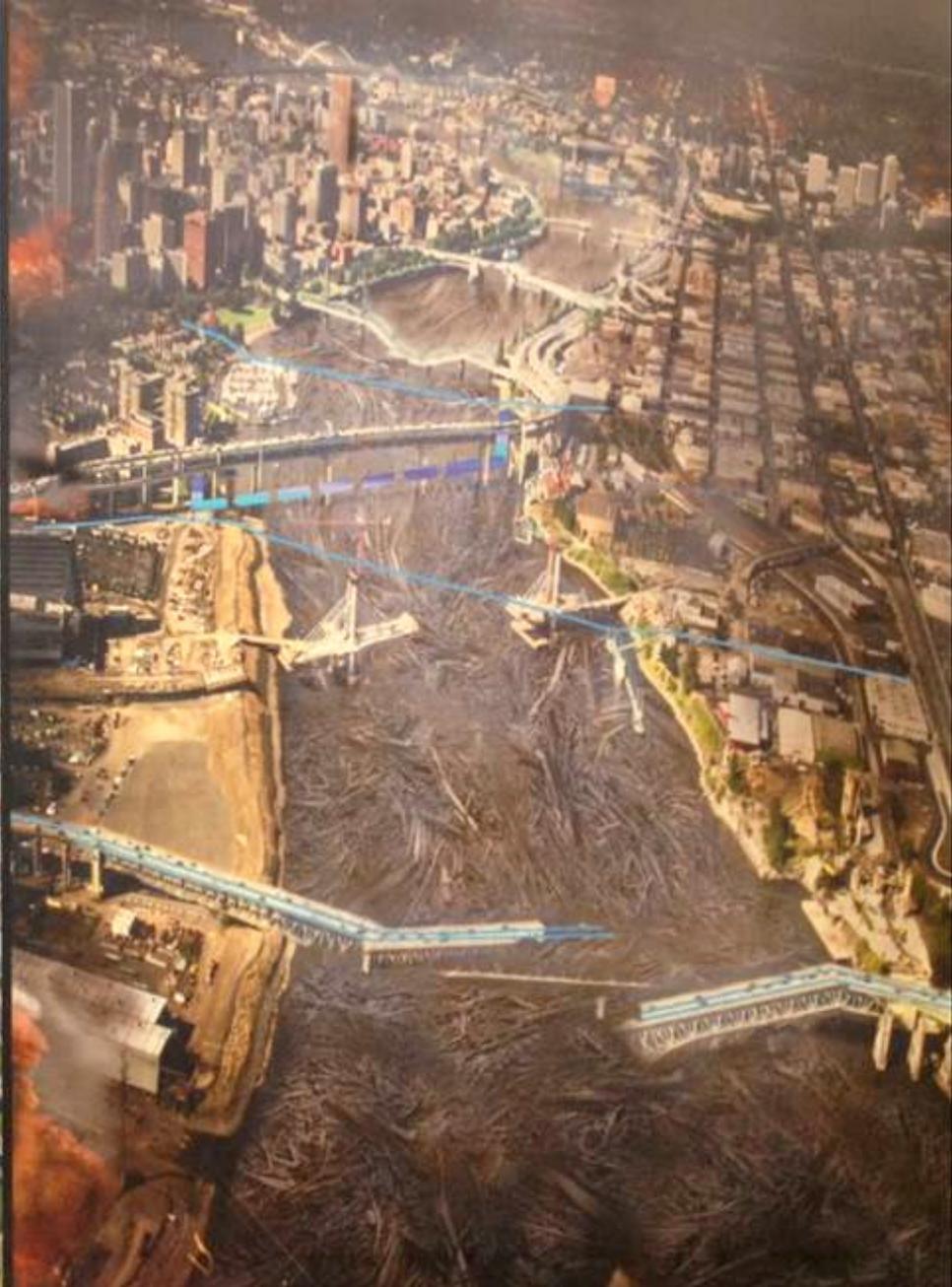
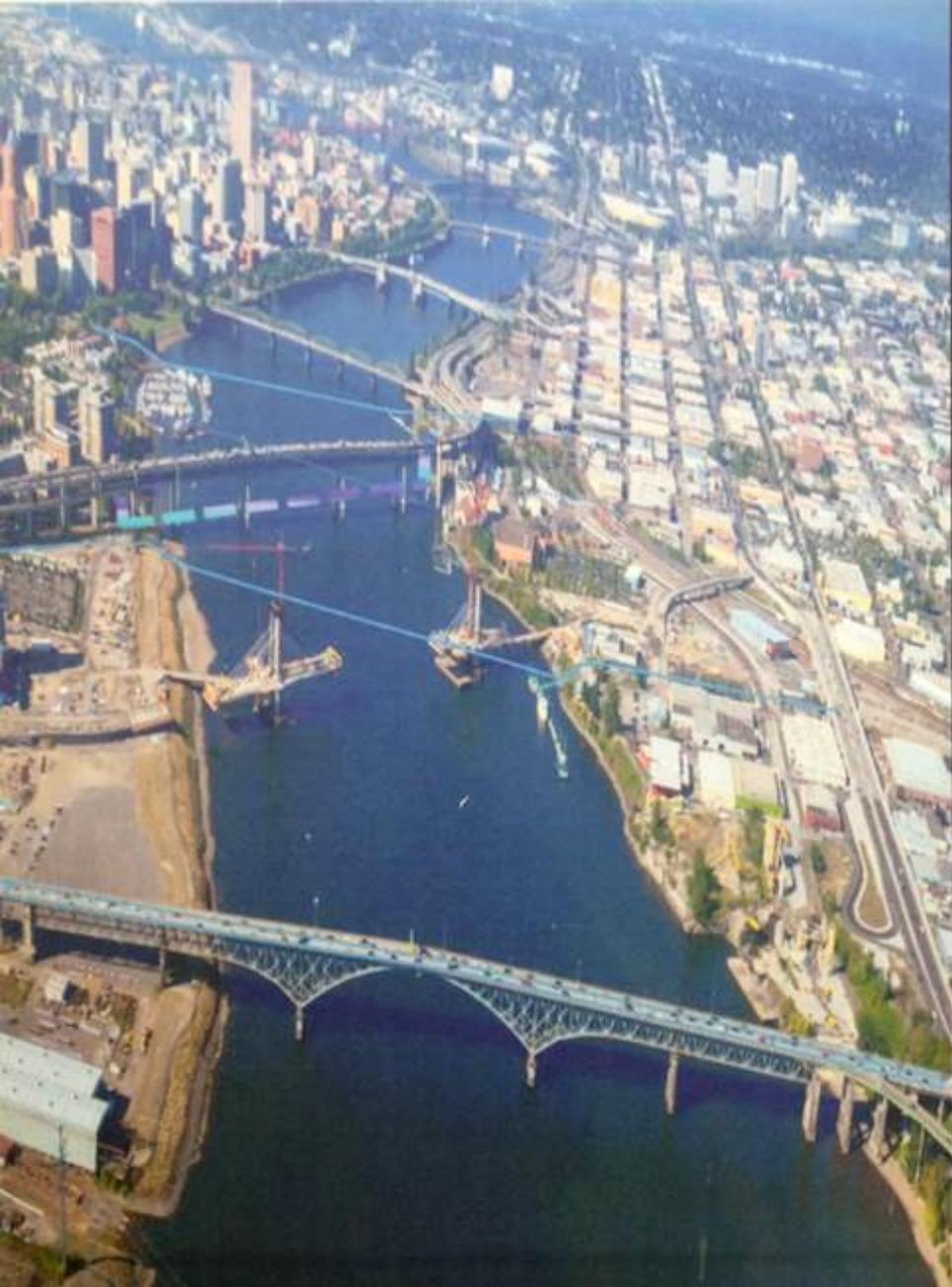
Broadway	Burnside	Morrison	Hawthorne
●	●	●	●





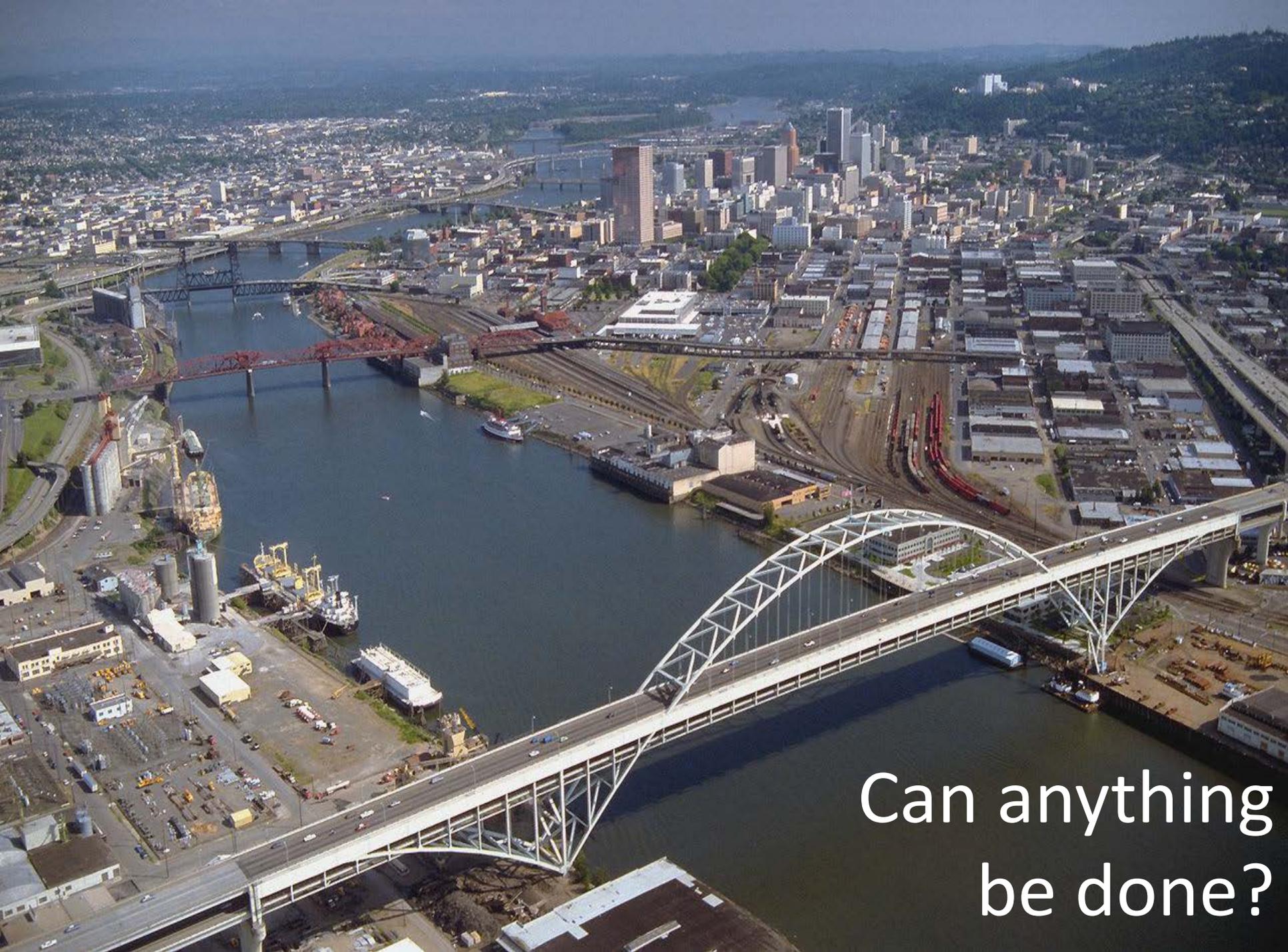
**Artist Rendering of Portland in 2013 (Pre-CSZ Event)**

Courtesy of City of PDX Water Bureau



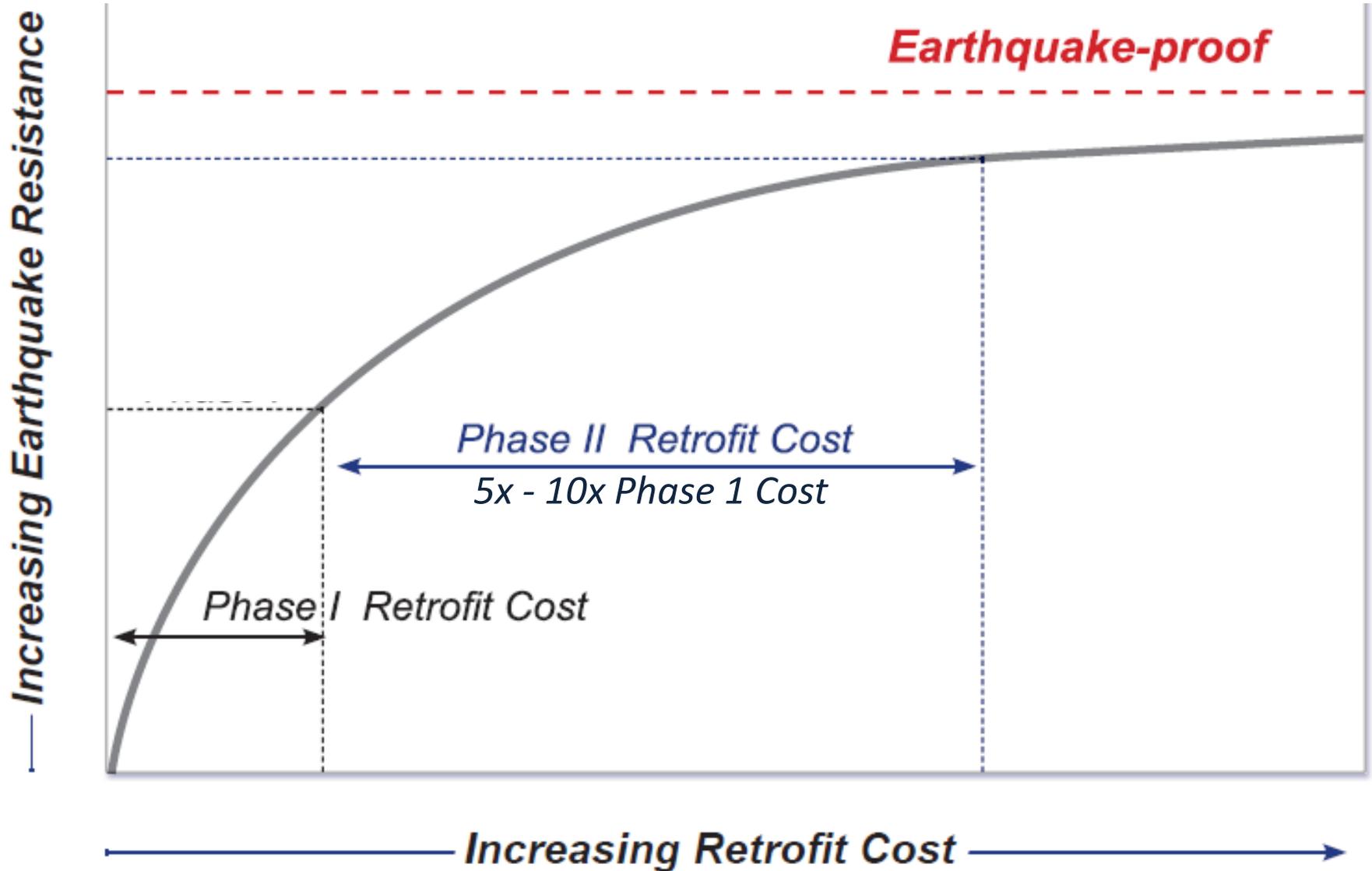
**Artist Rendering of Portland in 2013 (Pre- & Post-CSZ Event)**

Courtesy of City of PDX Water Bureau



Can anything  
be done?

# YES, with the proper investment.



# Low Seismic Resiliency Investment



Phase 1 Seismic Retrofit Elements

# High Seismic Resiliency Investment

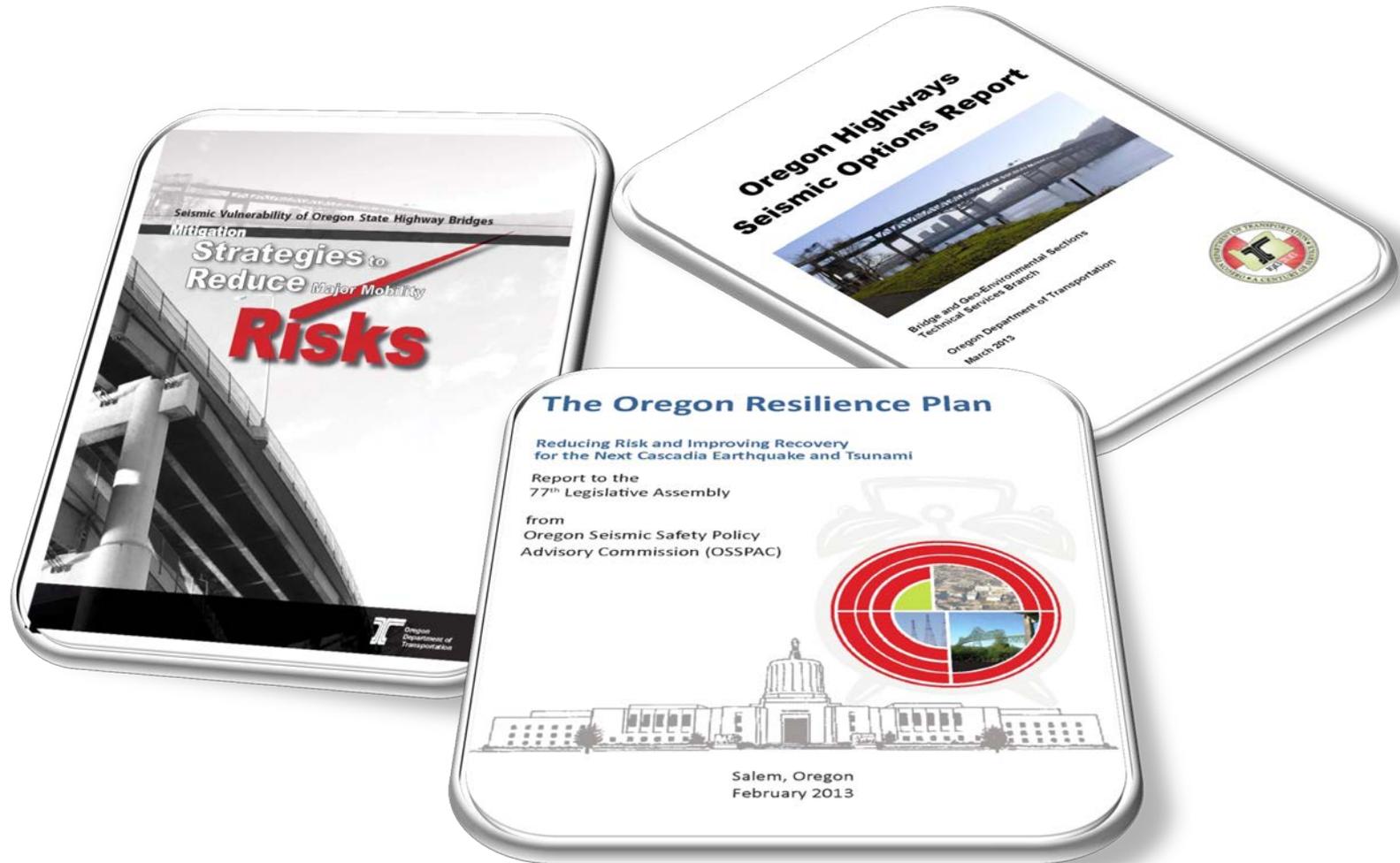


Phase 1 and 2 Seismic Retrofit Elements



How have  
other Agencies  
responded?

# Oregon's Bridge Seismic Reports



[http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/2009\\_Seismic\\_Vulnerability\\_final.pdf](http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/2009_Seismic_Vulnerability_final.pdf)

[http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/Oregon\\_Highways\\_Seismic\\_Options\\_Report\\_3\\_2013.pdf](http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/Oregon_Highways_Seismic_Options_Report_3_2013.pdf)

[http://www.oregon.gov/OMD/OEM/Pages/ossnac/ossnac.aspx#Oregon\\_Resilience\\_Plan](http://www.oregon.gov/OMD/OEM/Pages/ossnac/ossnac.aspx#Oregon_Resilience_Plan)

# Other Agency Seismic Programs



In 2006, City of Seattle voters passed a 9-year, \$365 million levy for transportation maintenance and improvements. The levy is complemented by a commercial parking tax.



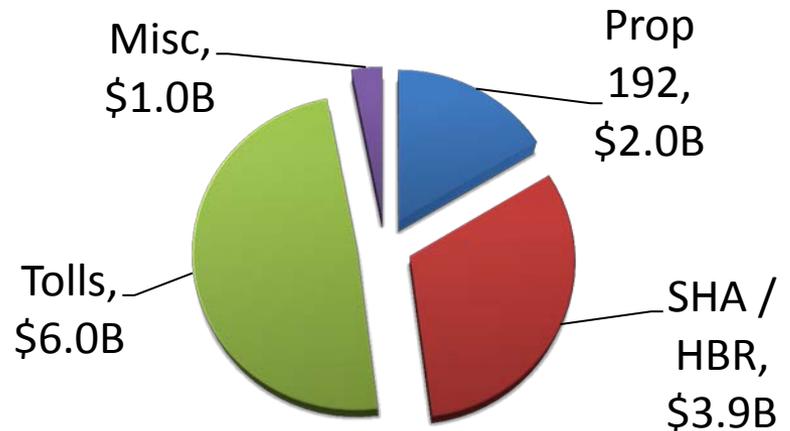
Clark County relies on HBR funds distributed through the WSDOT-led BRAC (Bridge Replacement Advisory Committee) selection process. Clark County received \$4M in HBR funds for seismic retrofits in 2012-13.



\$177M Bridge Seismic Retrofit Program started in 1977.

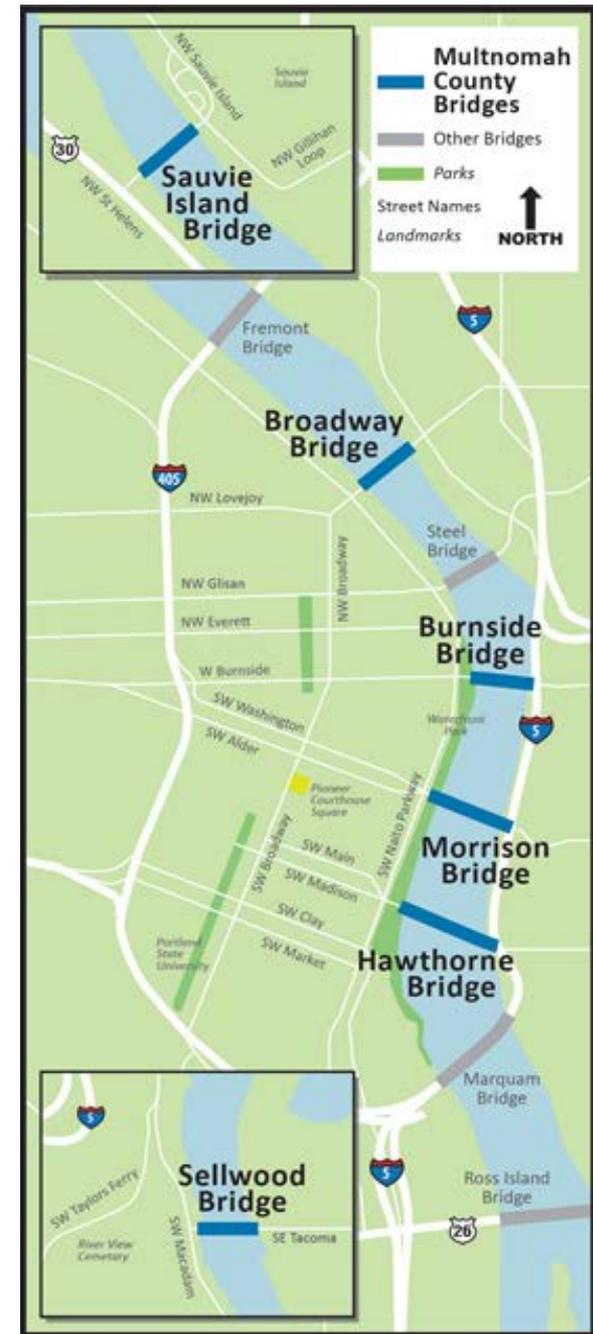


\$13B Bridge Seismic Retrofit Program since 1989.



# Next Steps:

- Recommend bridge seismic resiliency projects within the Mult Co. Bridge CIP for the:
  - Broadway Bridge
  - Burnside Bridge
  - Morrison Bridge
  - Hawthorne Bridge
- Distribute Draft Bridge CIP for BCC and Public comment
- Publish Final Bridge CIP





## Questions?

Ian Cannon, P.E. - Multnomah County Bridge Division

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