Sound Shake '08

Transportation

Port to Port Transportation Corridor Earthquake Vulnerability

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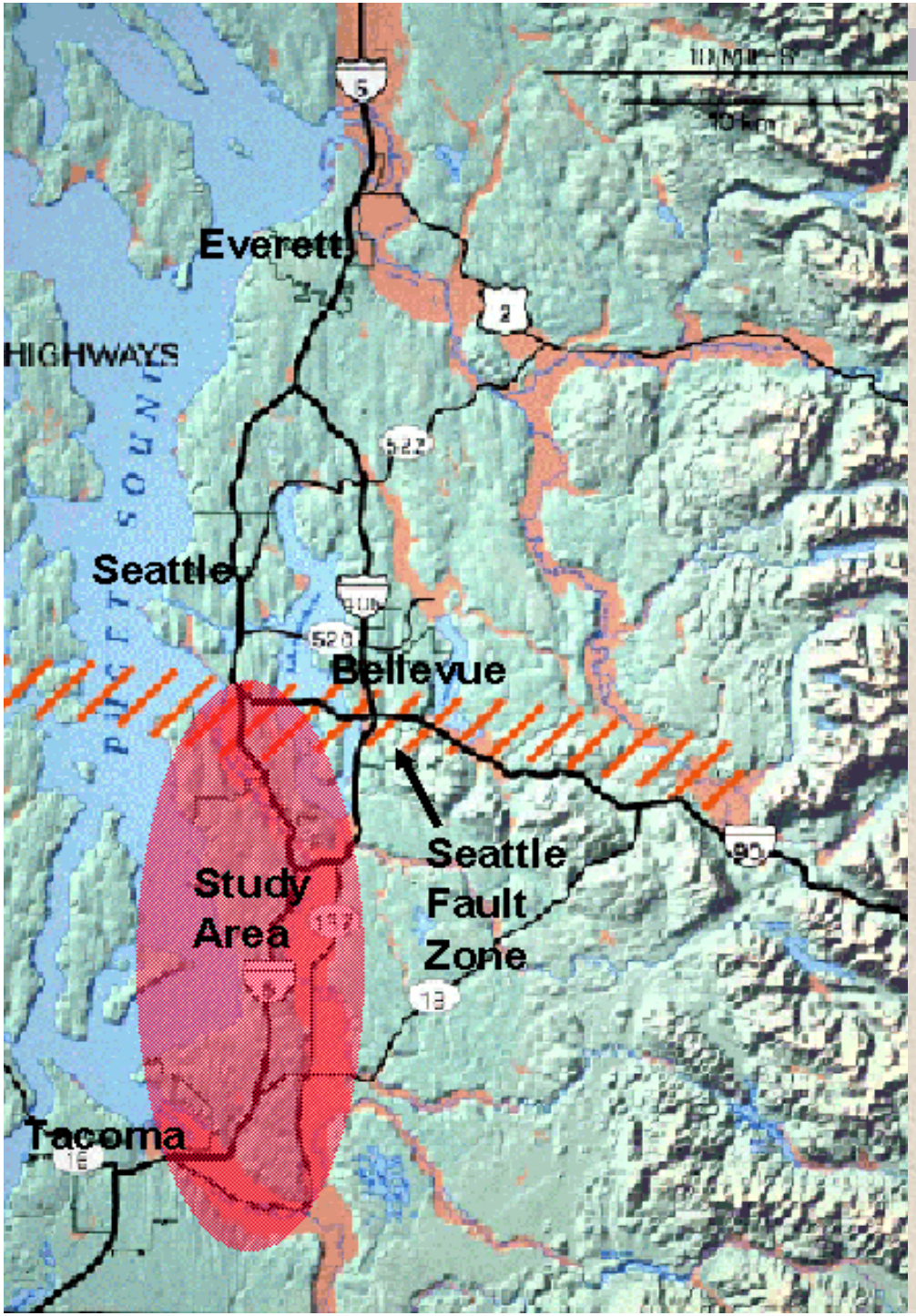
Project Objectives

- Engage business and government participation
- Evaluate post-earthquake transportation system survivability
- Develop an emergency response and recovery plan
- Estimate the economic impact of transportation system outage
- Promote mitigation of high-risk bridges on critical lifeline corridors



Project Location/ Pilot Project

- The selected transportation corridor connects Tacoma/ Pierce County and Seattle/ King County. I-5 north of downtown Seattle, and I-405 were specifically excluded so as to balance the effort between the two counties.
- The study is designed to be a pilot project so as to focus on the selected corridor that provides a critical transportation link between the ports of Seattle and Tacoma.
- The study was designed to avoid major structures such as the Alaska Way Viaduct,to maintain focus on “system” reliability issues.

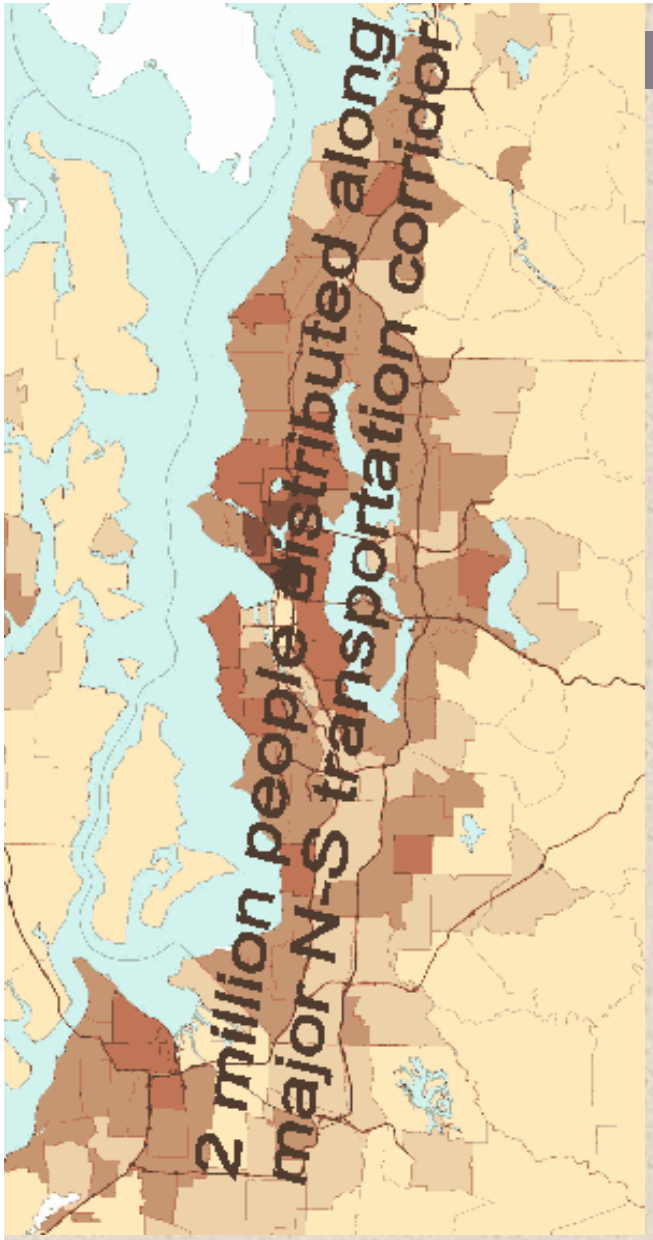
Participating Organizations

Public

- FEMA
- King County
- Pierce County
- Port of Seattle
- Port of Tacoma
- Sound Transit
- University of Washington
- USDOT
- USGS
- Washington Military Dept.
- WSDCTED
- WSDNR
- WSDOT

Private

- American Red Cross
- Bank of America
- BECU
- Boeing
- BNSF Railroad
- EQE International
- Frank Russell Company
- Gordon Trucking
- KOMOABC4
- Microsoft
- Olympic Pipe Line
- Tacoma-Pierce County Chamber of Commerce
- Western States Seismic Policy Council



N-S corridor is “funneled” between Puget Sound and the Cascade Mountains limiting E-W growth, and making detours difficult.

Puget Sound and the Cascade Mountains

Highways are jammed during rush hour, with no extra capacity for detours.

- I-5 carries approximately 200,000 vehicles/day south of Seattle, and about 150,000 vehicles/day north of Tacoma.
- SR-167 carries about 100,000 vehicles per day where it intersects I-405, with lower volumes to the south.
- SR-99 carries about 25,000 vehicles per day.
- Each of the 3 routes is at capacity during rush hour, and there is little opportunity for detours available should I-5 or SR-167 be out of service.

Use of HAZUS

- HAZUS is used in the project as a tool to assist in the loss estimation process.
- HAZUS, developed by FEMA, runs on a GIS platform. Both MapInfo and ArcView versions are available.
- HAZUS is a convenient tool to load data and quickly evaluate a range of scenarios

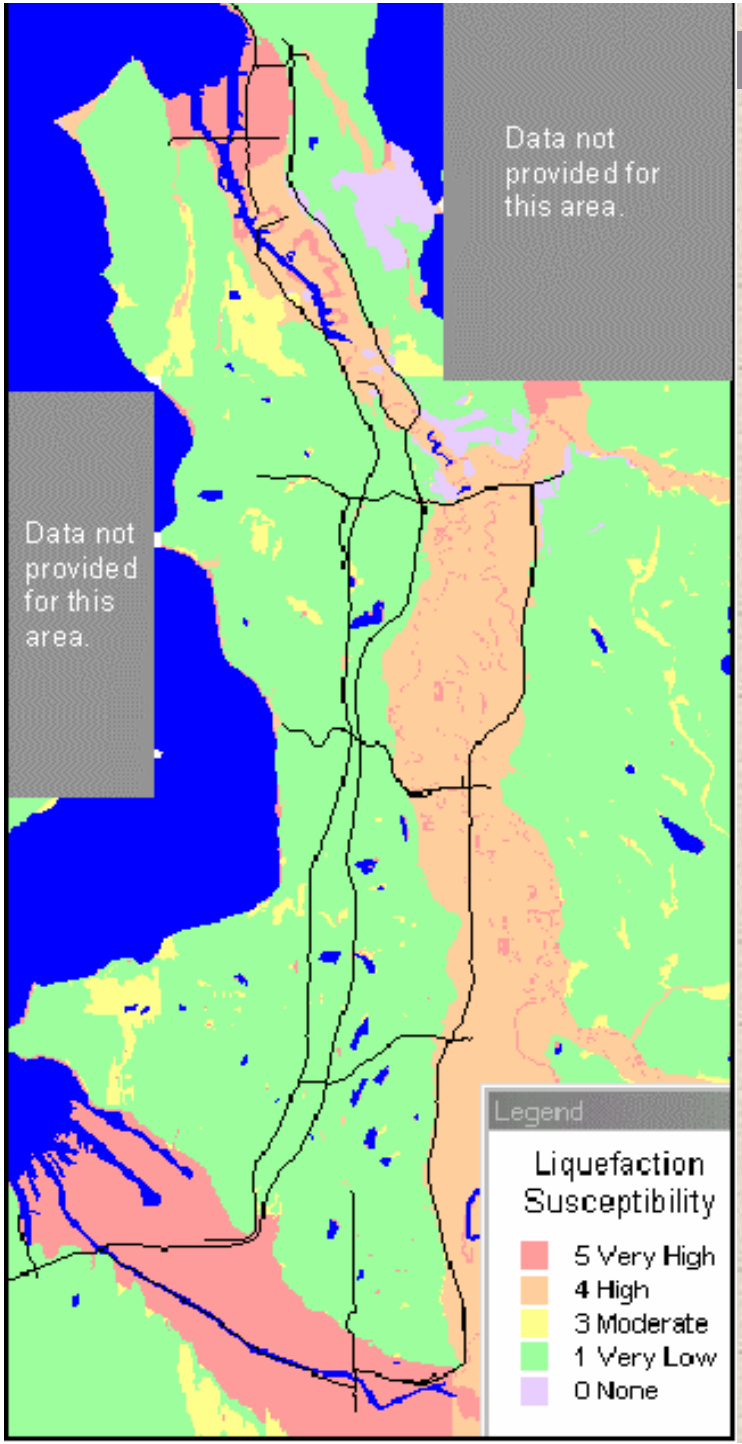
Earthquake Hazard Scenarios

Earthquake Scenarios
(select a button to view a map)

- Map overview
- Seattle Fault M6.5
- Seattle Fault M7.0
- Benioff (Deep) M6.5
- Benioff (Deep) M7.1
- Tacoma Fault M6.7
- Cascadia Subduction M9.0

Soil Maps

- Soil Type
- Liquefaction Susceptibility



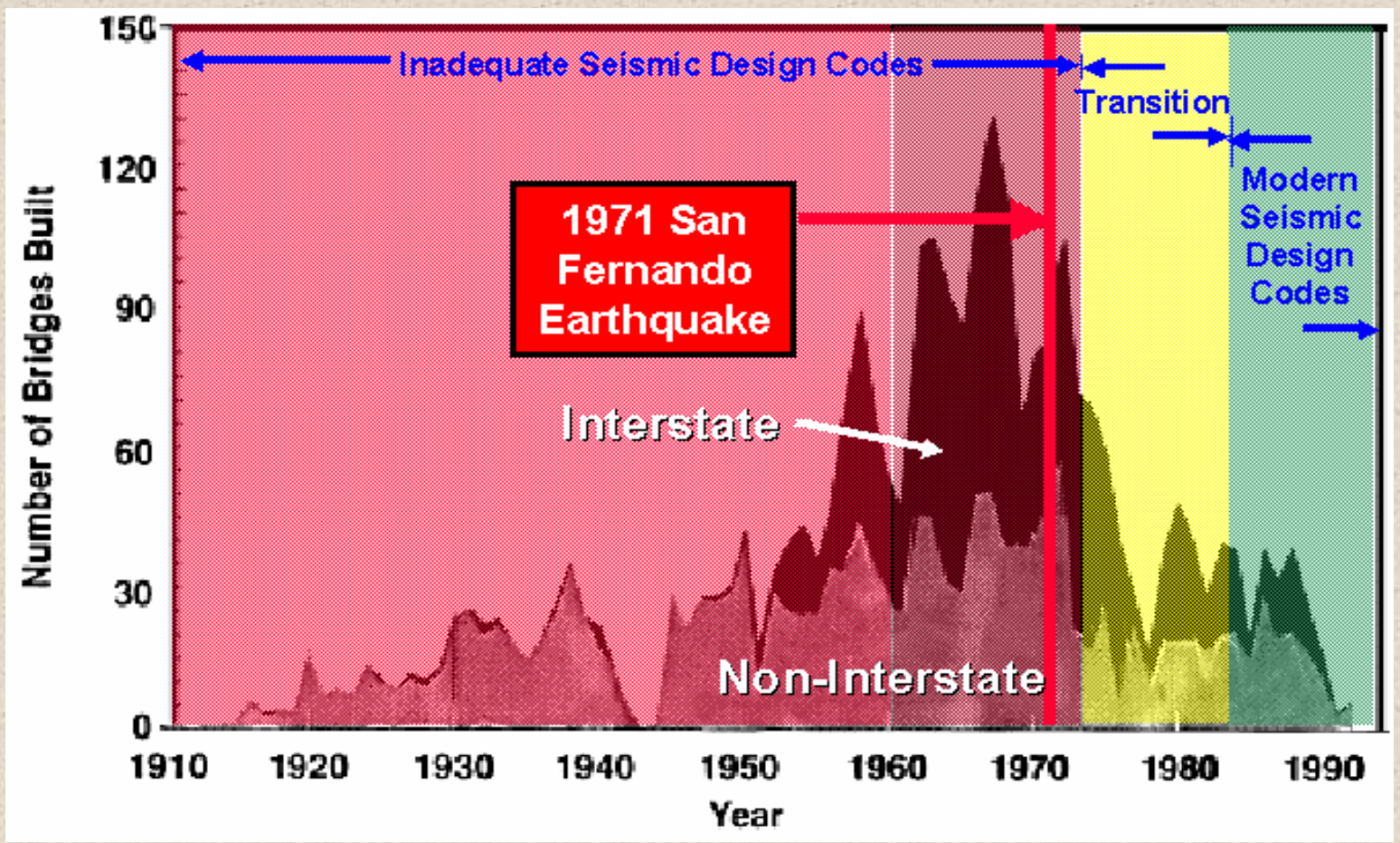
Liquefaction

- **There is a high liquefaction susceptibility in many valleys in the Puget Sound region because of high water tables in river valleys with young geologic deposits.**
- **HAZUS incorporates a magnitude scaling factor and a displacement correction factor to better adjust for the duration of shaking in larger (or smaller) earthquakes.**
- **HAZUS used the Liquefaction Severity Index, LSI, to estimate lateral spreading.**
- **Liquefaction susceptibility mapping, developed by the Washington State Department of Natural Resources, was used to estimate liquefaction.**

Bridge Reliability

- Damage relationships (fragility curves) relate earthquake hazard parameters and bridge reliability.
- Earthquake hazard parameters considered include:
  - Shaking /Site amplification
  - Liquefaction/Lateral spread
- Fragility curves consider:
  - Structural design codes and detailing (I-5 constructed in late 1950's - 1960's)
  - Empirical/historical performance of similar structures
  - Structural/push-over analysis
- Bridge analytical approach

Most of Washington State's Highway Bridges were constructed before adequate codes were in place.



About 1/3 of the bridges studied are in the most vulnerable bridge class.

Bridges are categorized by design type and expected performance.

The most vulnerable bridges (lowest structural capacity, ~ 44% x g) are classes HWB 5, 12, and 17.

~ 1/3 of the bridges in the study area are Bridge Class HWB17.

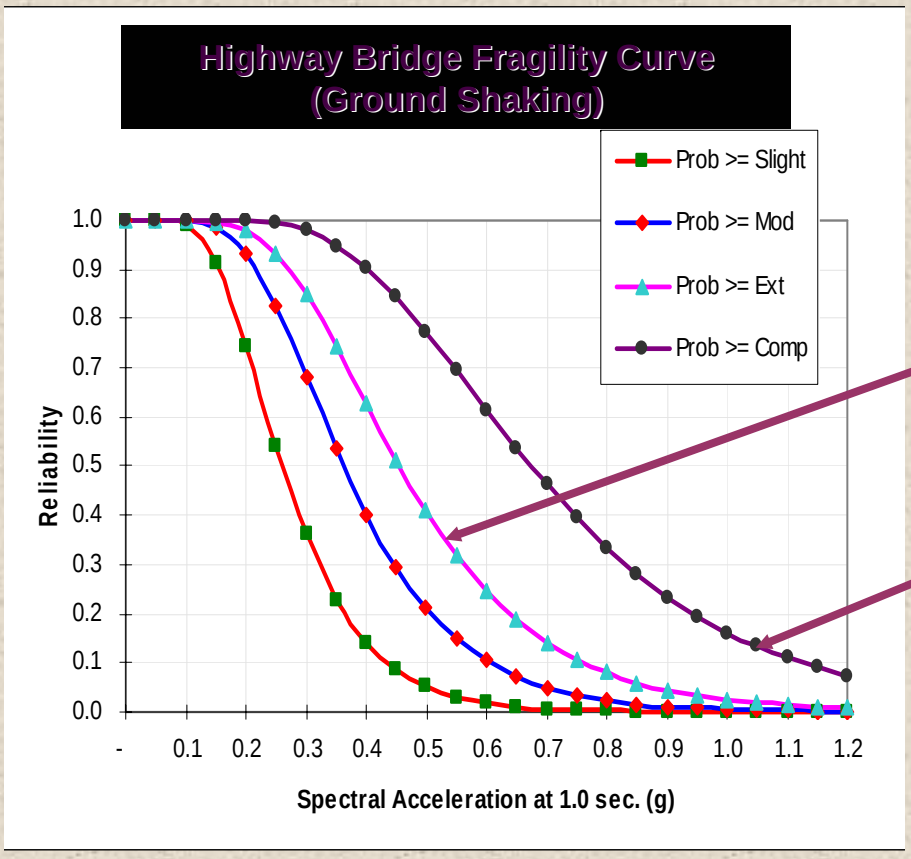
Bridge Class	Total		Capacity 1sec SA(g)	Bridge Type
HWB10	87	38%	1.05	Continuous Concrete
HWB17	74	32%	0.44	Multi-Col. Bent, Simple Support – P/T Concrete
HWB22	28	12%	1.05	Continuous – Prestressed Concrete
HWB3	8	4%	1.1	Single Span
HWB23	8	4%	1.05	Continuous – Prestressed Concrete
HWB12	4	2%	0.44	Multi-Col. Bent, Simple Support – Steel
HWB11	3	1%	1.05	Continuous Concrete
HWB15	3	1%	0.76	Continuous Steel
HWB4	2	1%	1.1	Single Span
HWB5	1	0.40%	0.44	Multi-Col. Bent, Simple Support – Concrete
HWB19	1	0.40%	1.05	Multi-Col. Bent, Simple Support – P/T Concrete

Typical HBW17 Bridge

Simple Support Post-Tensioned Concrete Girders

Bents supported on Multiple Columns

HWB17 Fragility Curve



1. No damage
2. Slight damage (minor cracking/spalling)
3. Moderate damage (column shear cracks)
4. Extensive damage (columns structurally unsafe, major settlement at approaches)
5. Complete damage (column collapse, imminent roadway deck collapse)

Damage states 4 and 5 result in loss of functionality, and are of primary interest.

Bridge fragility curves within each category are modified based on its skew angle, the span length, the number of spans, and its width.

Benioff M6.5

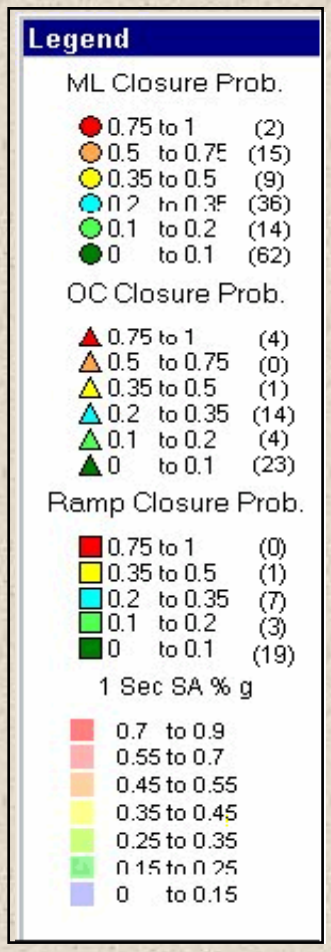
Benioff M7.1

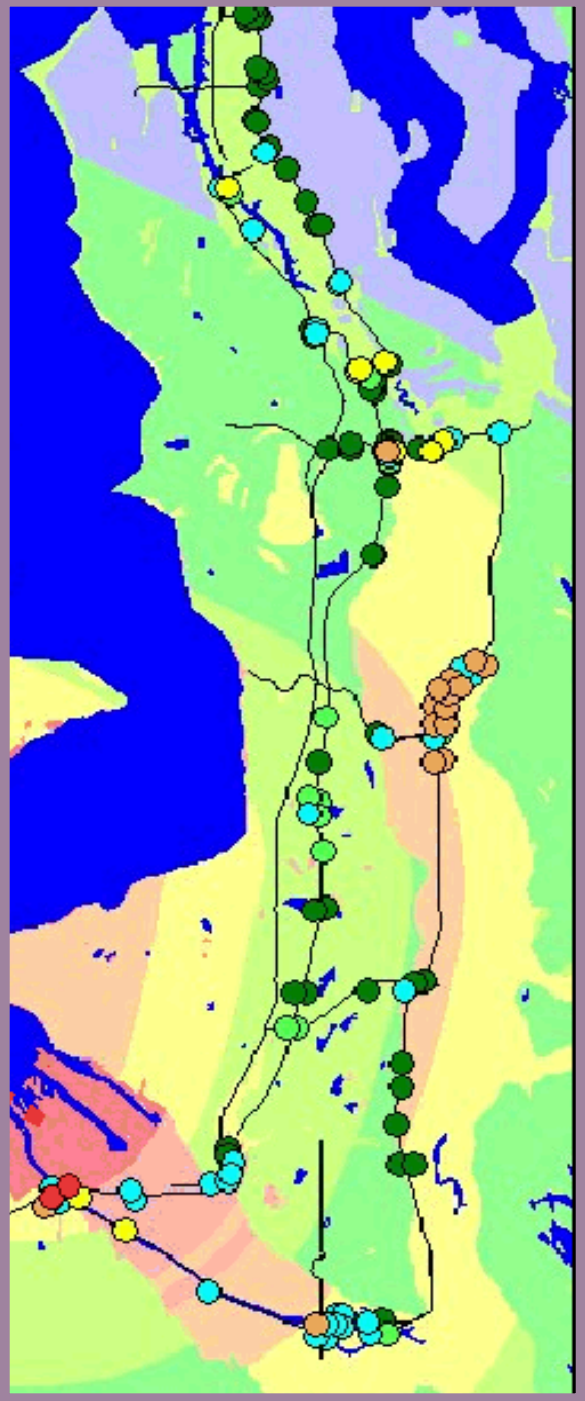
Tacoma M6.7

Cascadia M9.0

Seattle M6.5

Seattle M7.0





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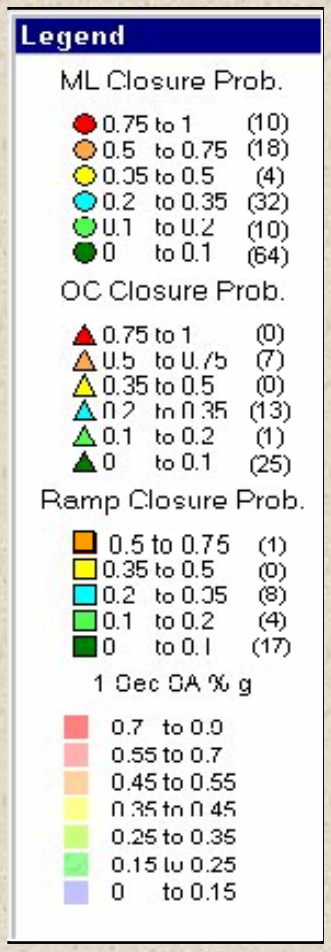
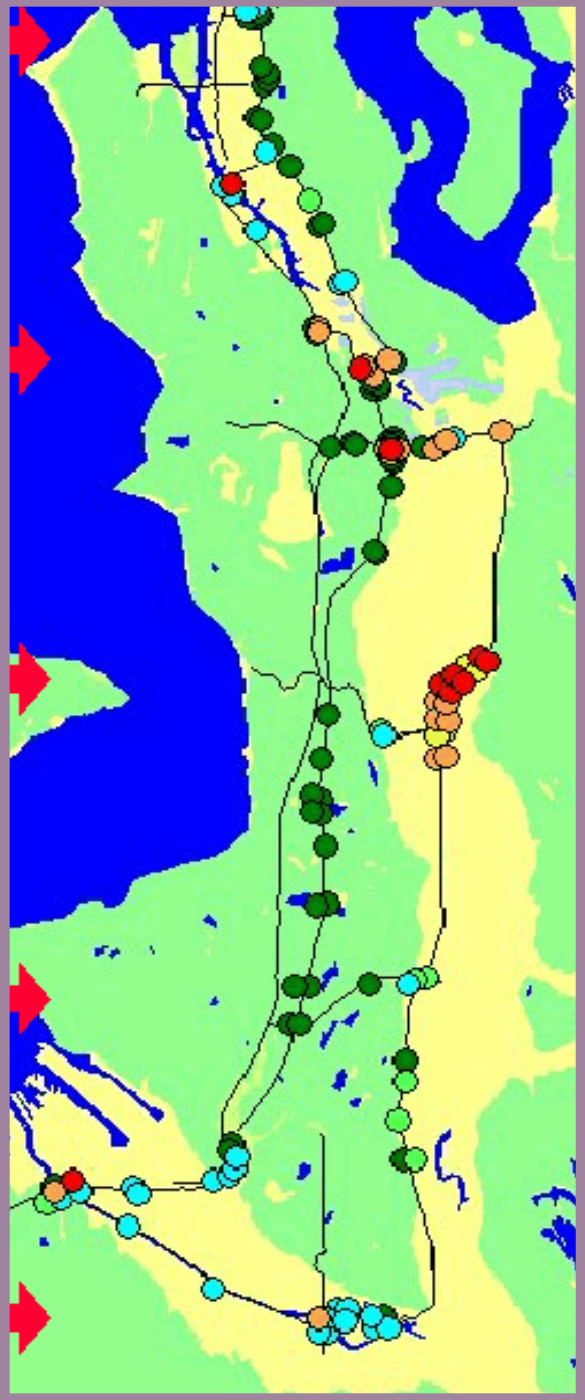




Move the mouse up and down over the green buttons.

Benioff M6.5

Benioff M7.1

Tacoma M6.7

Cascadia M9.0

Seattle M6.5

Seattle M7.0

Legend

ML Closure Prob.

0.75 to 1	(22)
0.5 to 0.75	(18)
0.35 to 0.5	(10)
0.2 to 0.35	(35)
0.1 to 0.2	(12)
0 to 0.1	(41)

OC Closure Prob.

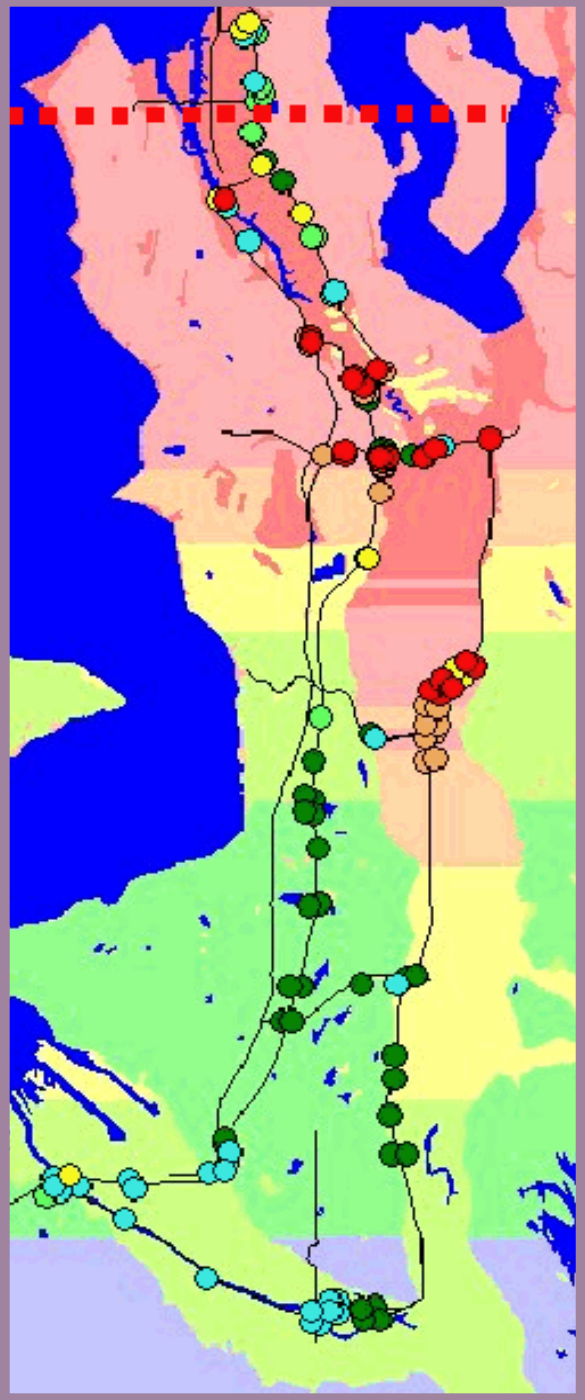
0.75 to 1	(3)
0.5 to 0.7	(5)
0.35 to 0.5	(3)
0.2 to 0.3	(15)
0.1 to 0.2	(5)
0 to 0.1	(15)

Ramp Closure Prob.

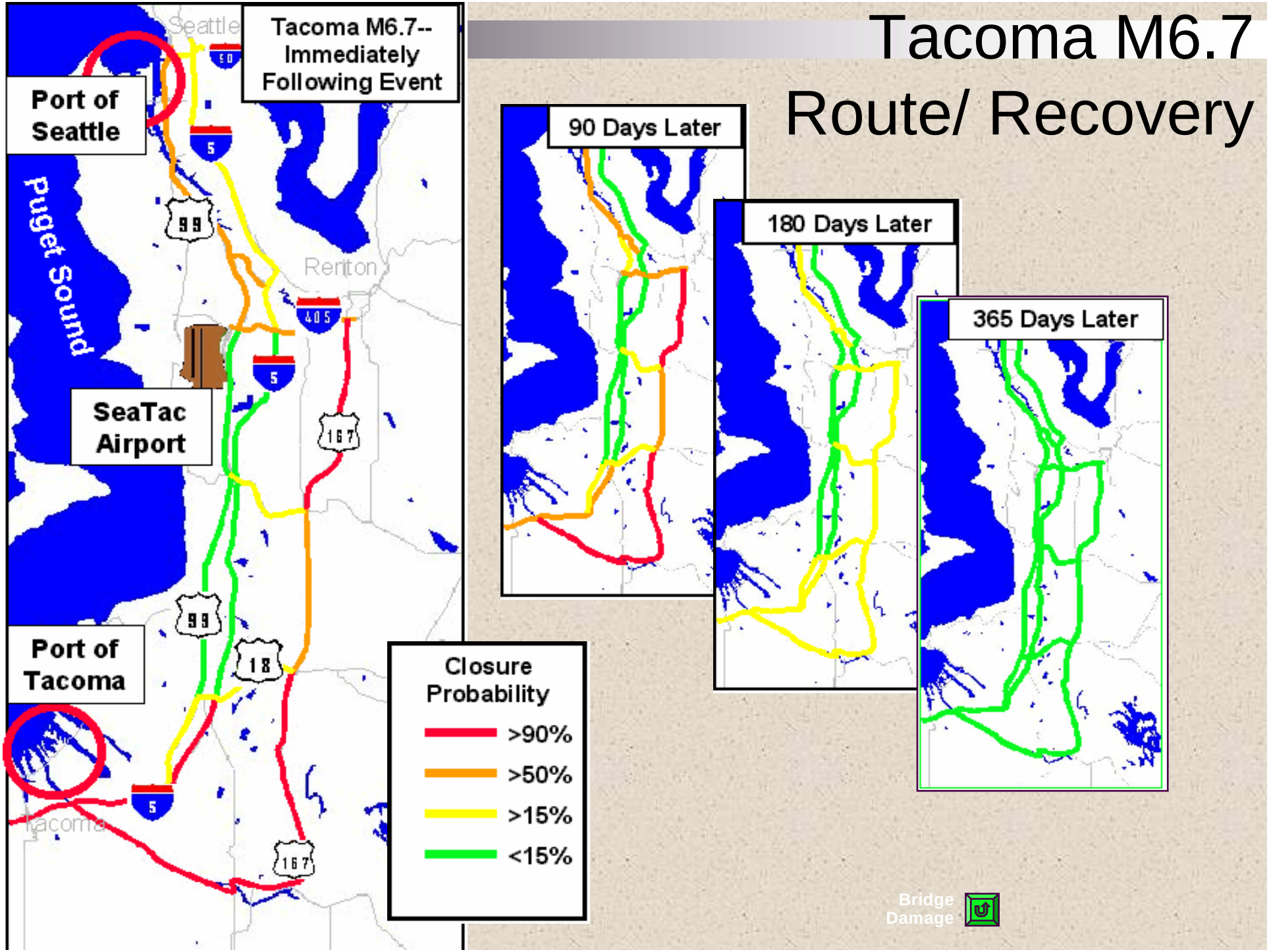
0.75 to 1	(1)
0.35 to 0.5	(5)
0.2 to 0.3	(8)
0.1 to 0.2	(8)
0 to 0.1	(8)

1 Sec SA % g

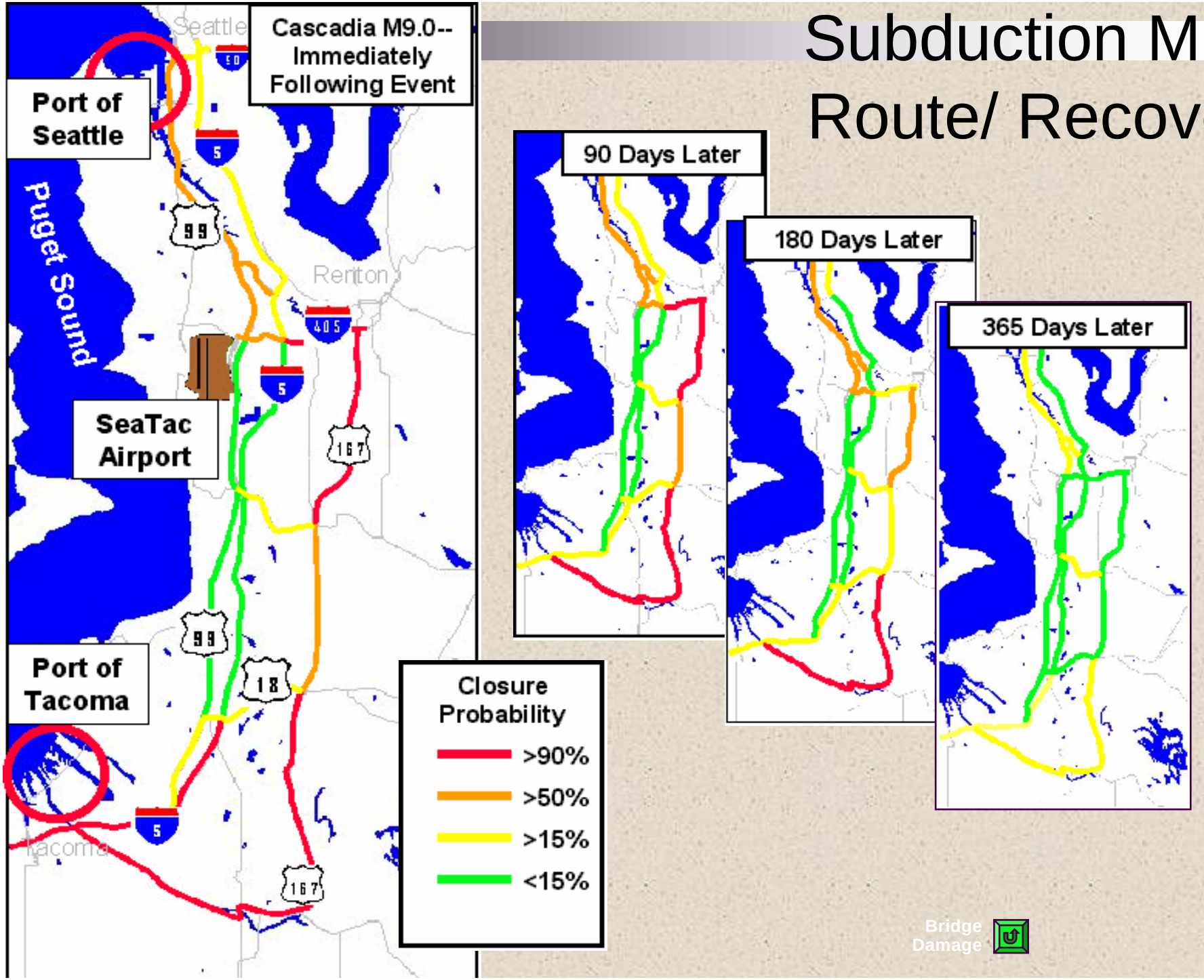
0.7 to 0.9
0.55 to 0.7
0.45 to 0.55
0.35 to 0.45
0.25 to 0.35
0.15 to 0.25
0 to 0.15



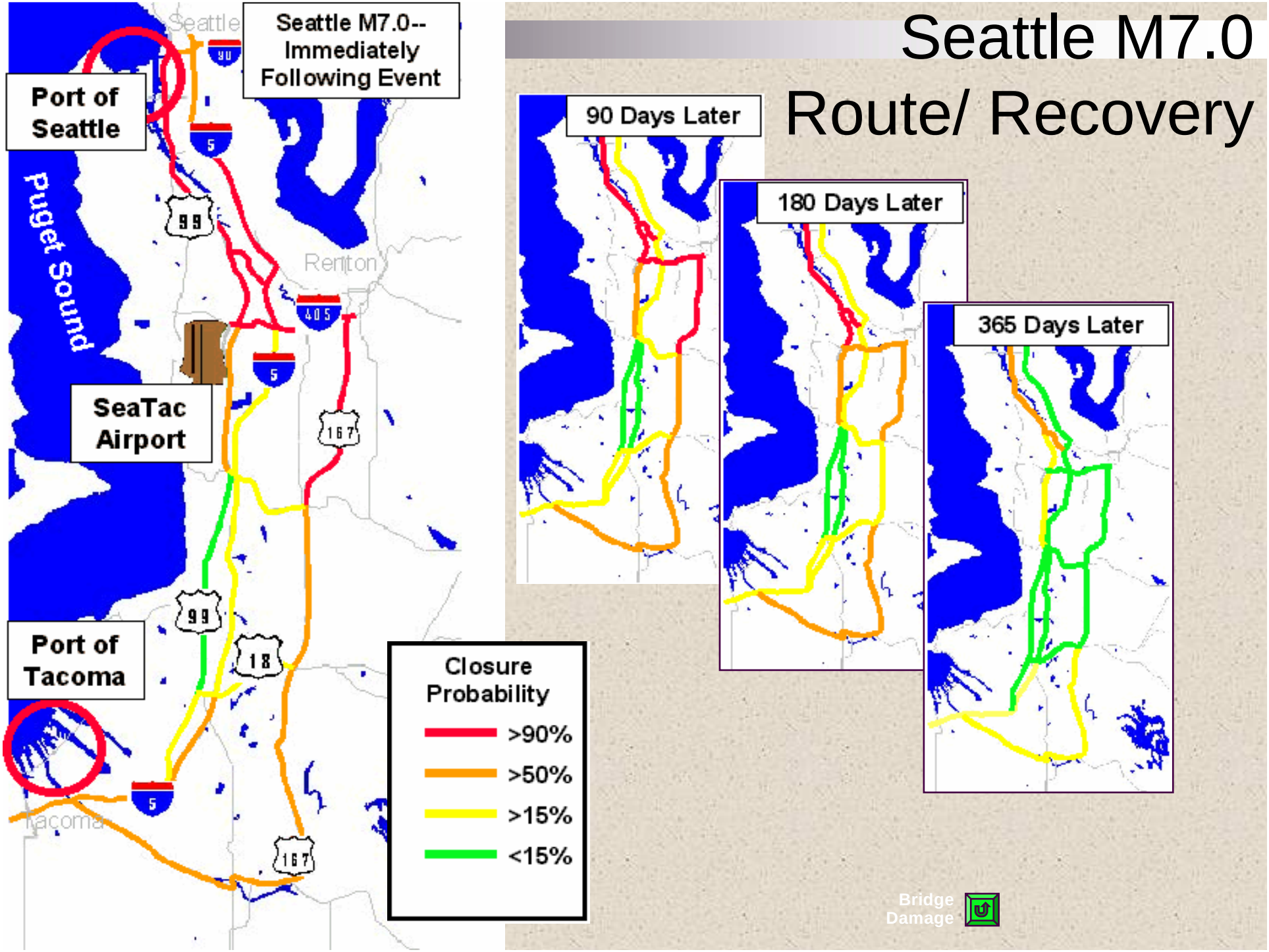
Tacoma M6.7 Route/ Recovery



Subduction M9.0 Route/ Recovery



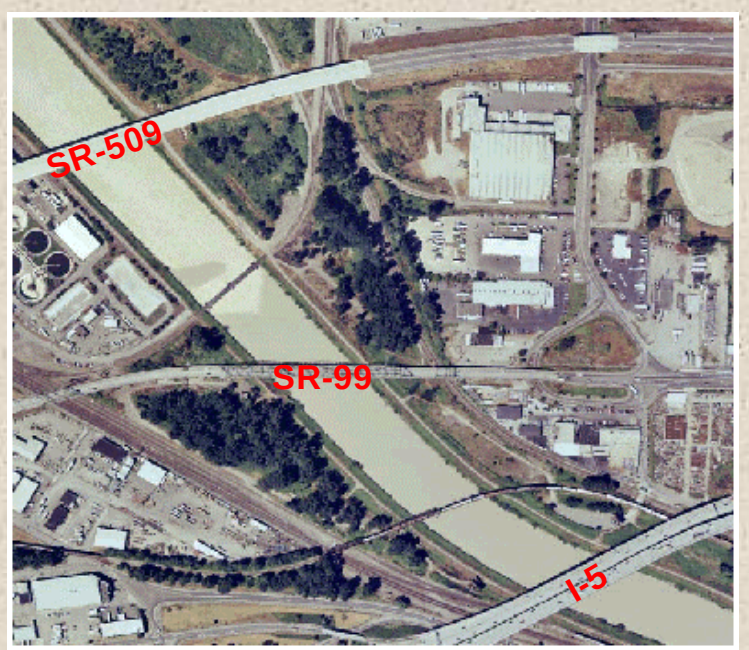
Seattle M7.0 Route/ Recovery



Emergency Response and Recovery

- **Contingency planning – particularly river crossings**
- **Corridor restoration approaches**

The Puyallup River in Pierce County poses a major geographic barrier. The river is bounded by liquefiable soils, making the I-5 bridge in particular vulnerable to earthquakes. The County is developing contingency plans for detours on parallel bridges should the I-5 bridge fail. Detour capacity is much less than the capacity of I-5.



The Duwamish River in King County is another major barrier along the north-south corridor. The I-5 bridge is a critical structure because it also crosses the BNSF Railroad track that provides an alternate form of transportation between Tacoma and Seattle. The next major bridge that crosses the Duwamish River is 6 miles downstream.

Summary of Project Elements

- Business and government partnership
- Evaluate post-earthquake transportation system survivability
- Develop an emergency response and recovery plan
- Estimate the economic impact of transportation system outage
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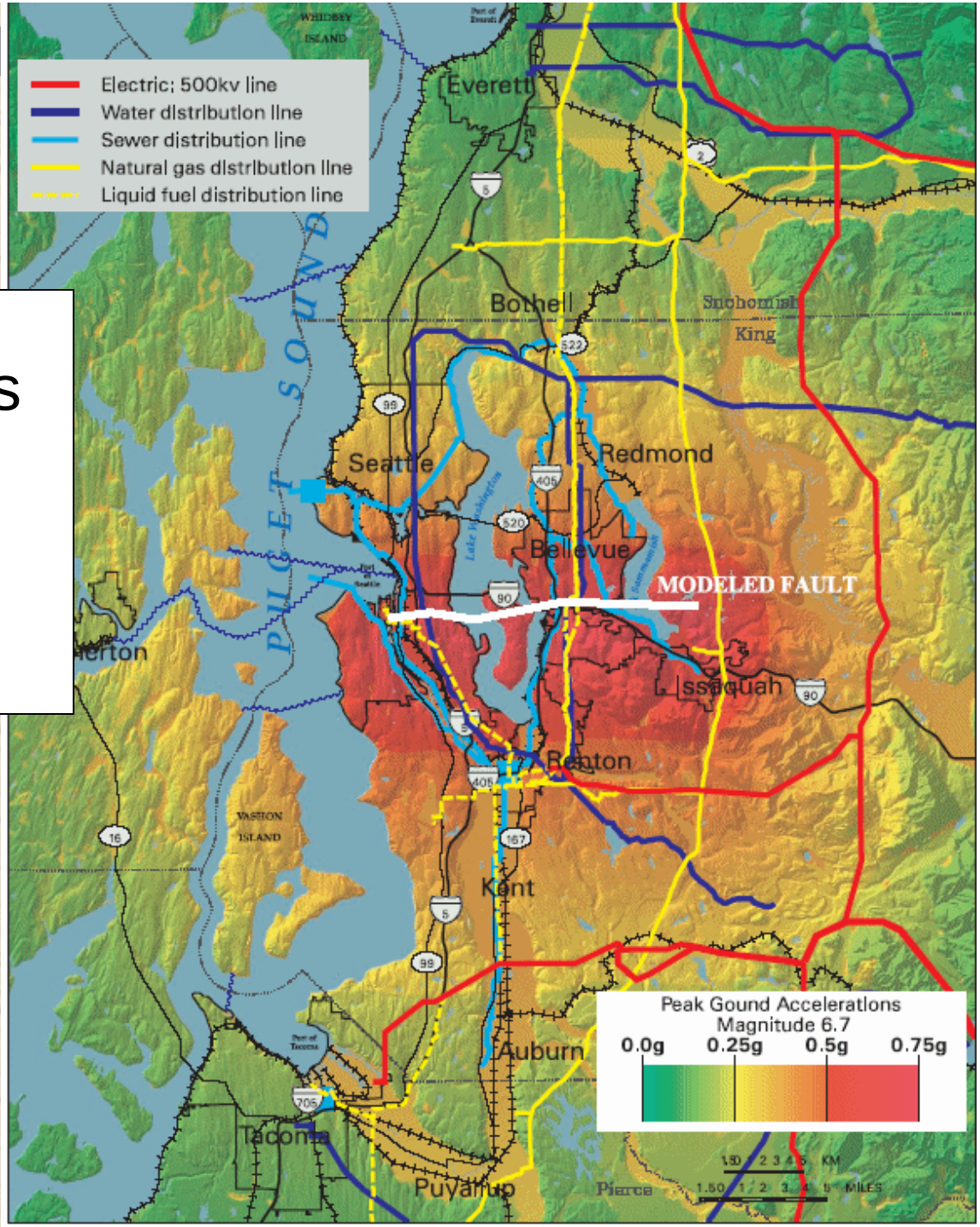
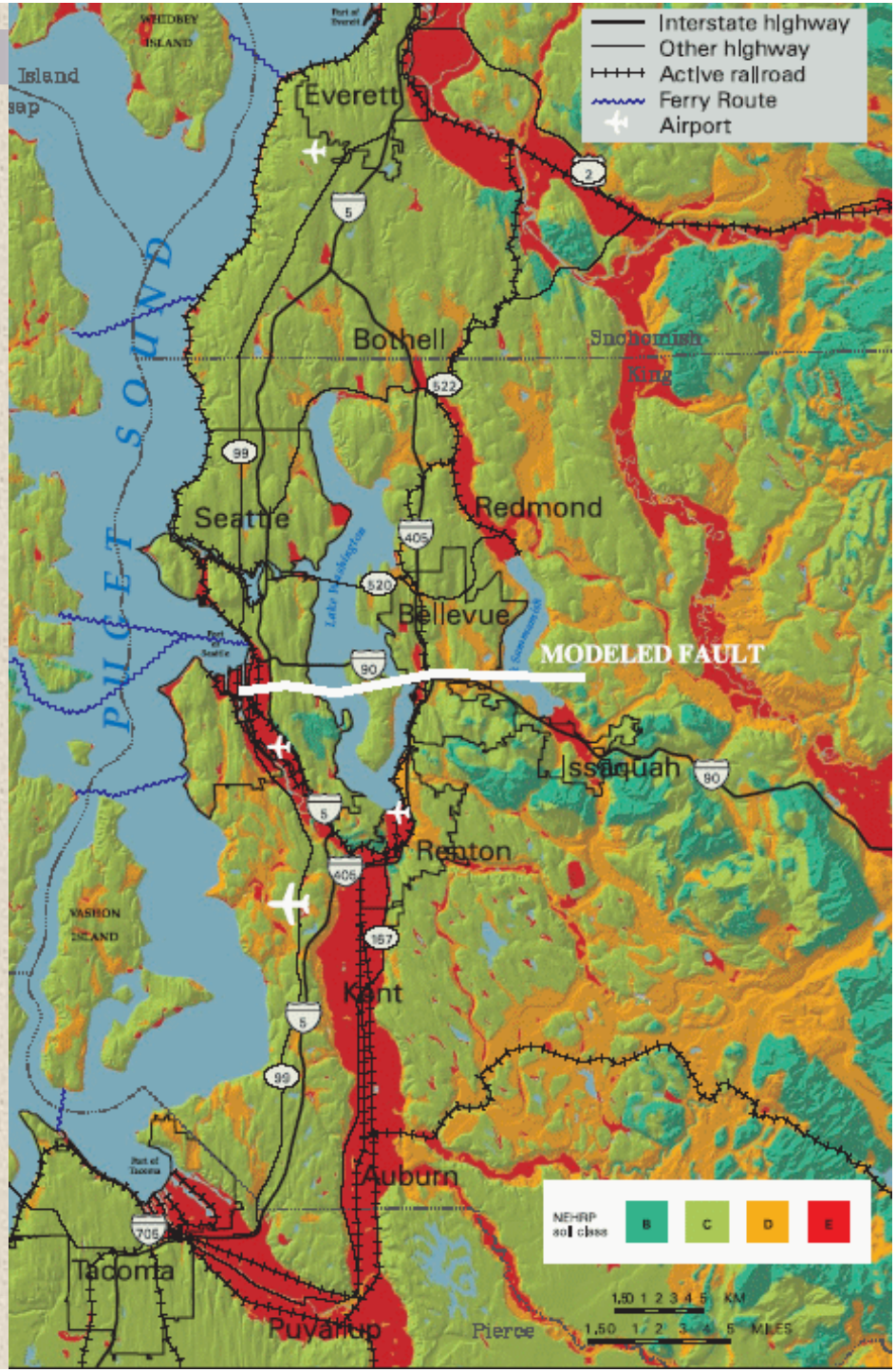
Lifelines

- Lifelines with major conduits crossing fault
  - Water
  - Wastewater
  - Liquid fuel

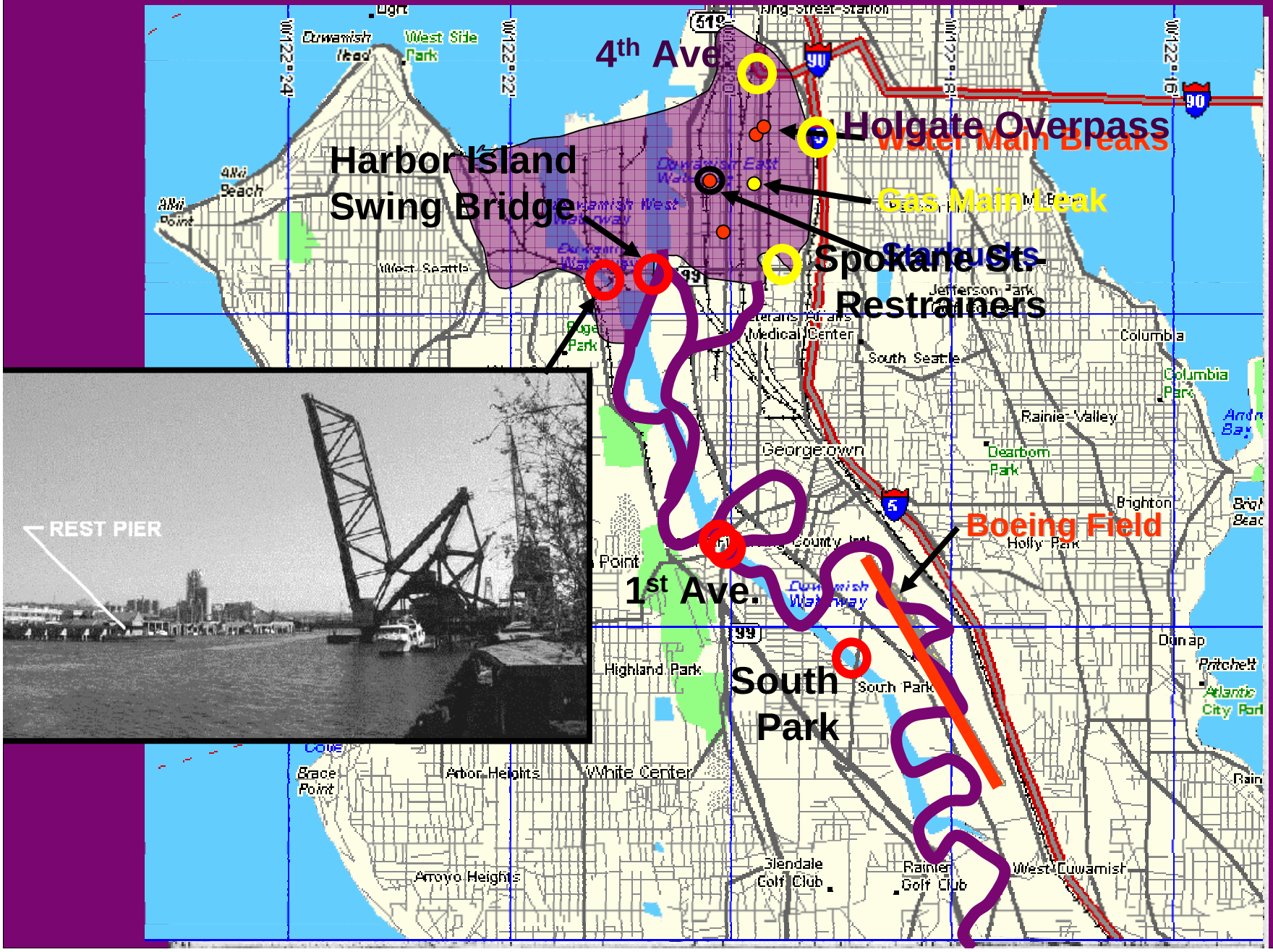


Liquefaction

- Lifelines in liquefiable areas
  - Sewer
  - Water
  - Liquid Fuel
- Weeks to recover



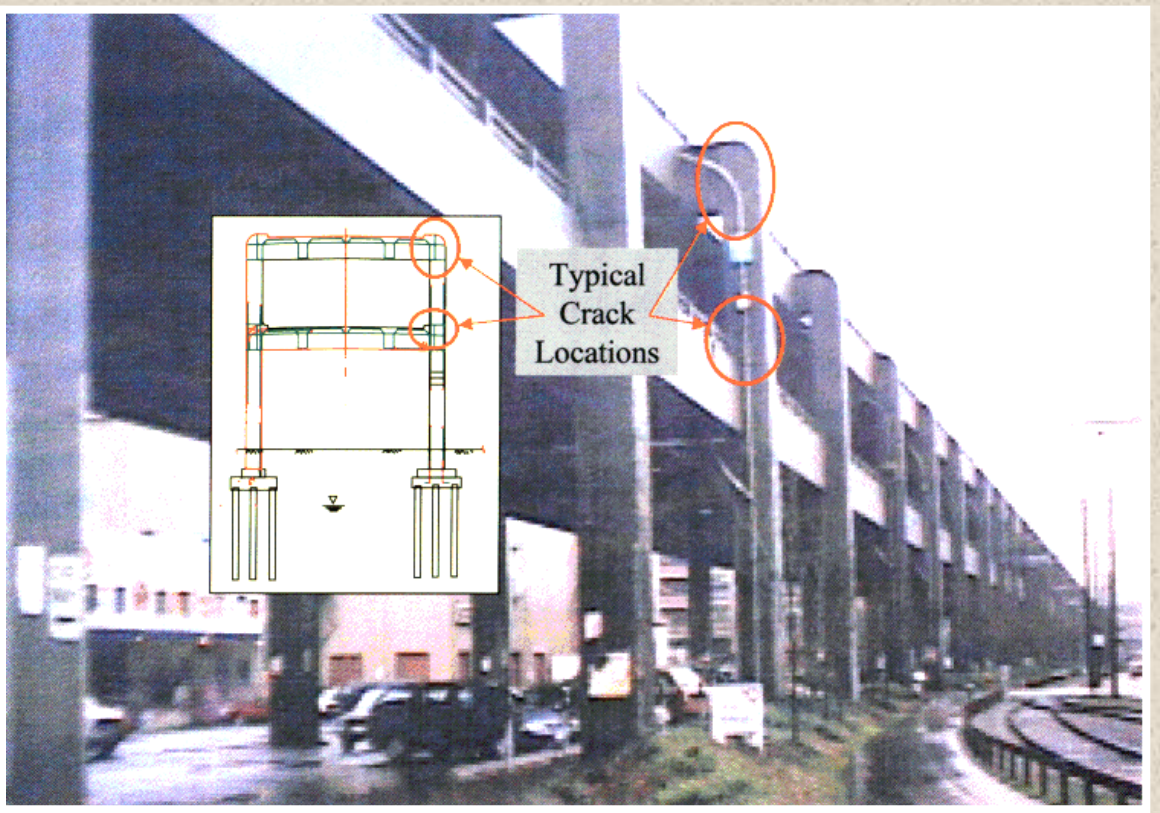
Fill/Liquefaction Impacts on Bridges

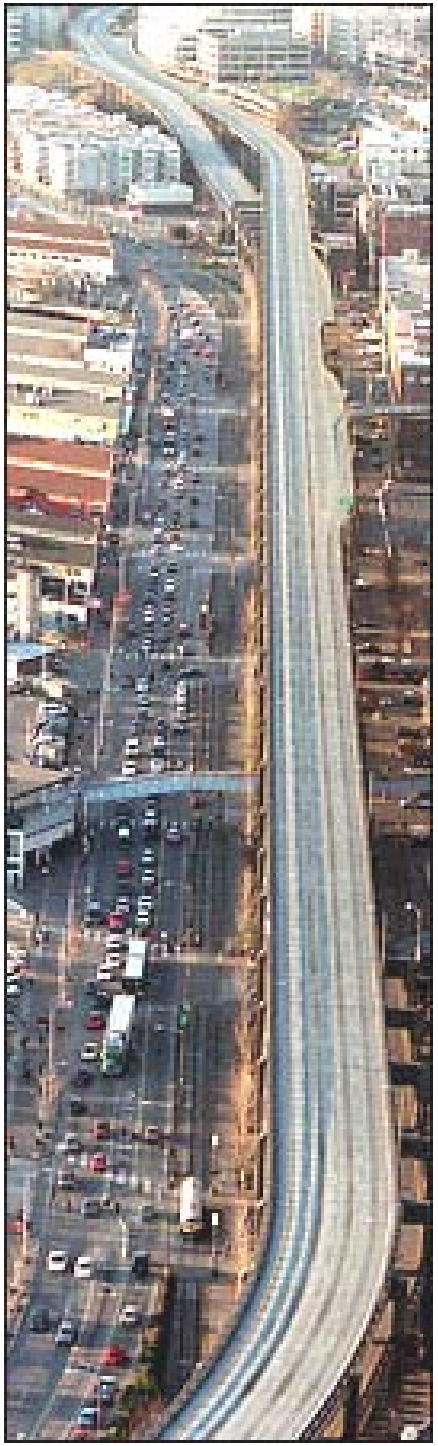



Hwy 302
Hwy 202
Hwy 101
Highway Landslides

Alaska Way Viaduct

Alaska Way Viaduct closure will cause further congestion in downtown Seattle. Businesses depending on it to move goods will turn to surface streets.



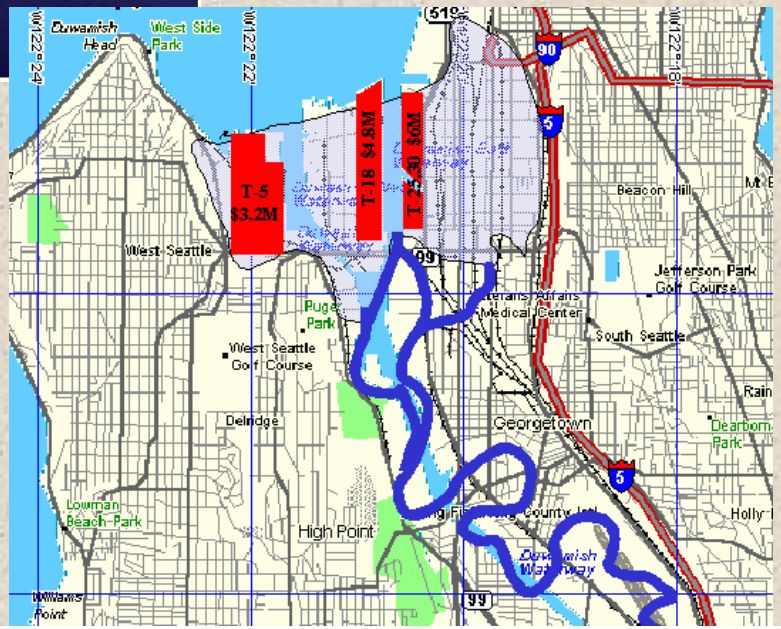


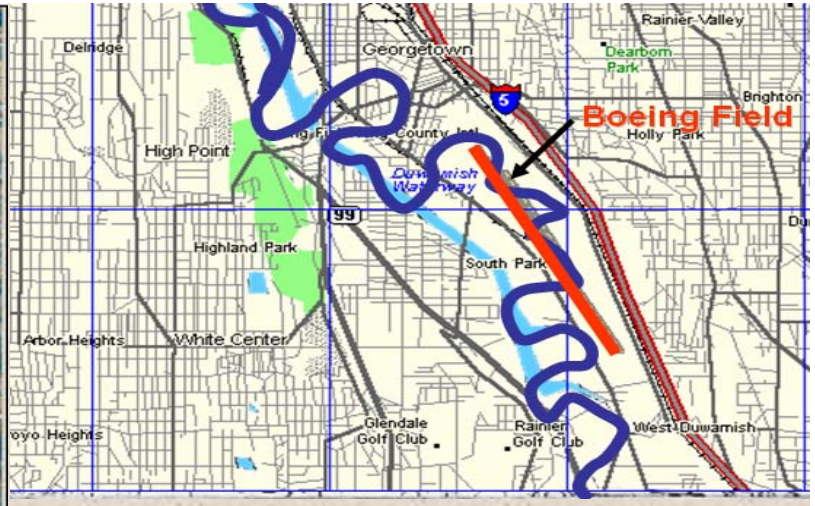
Washington State Ferries

Ferry docks in downtown Seattle will close due to liquefaction damage, with traffic temporarily rerouted to terminals to the north and south.

Port of Seattle

The Port of Seattle, 5th largest container port in the country, will be heavily damaged – reopening some terminals may take months or years. Customers will move elsewhere.





- **Northern end of runway closed for two weeks following Nisqually Earthquake.**
- **Similar performance expected.**

Peru M 8.0 Subduction – 8/15/07