Seattle Public Utilities
Seismic Study Summary

City of Bellevue
Environmental Services Commission
February 7, 2019

Presentation Outline

- Background
- Seismic Hazards
- Seismic Study Findings
- Seismic Mitigation Recommendations

Importance of Post-Earthquake Water Supply

- Fire Fighting
- Public Health
- Economic Prosperity

Water is essential

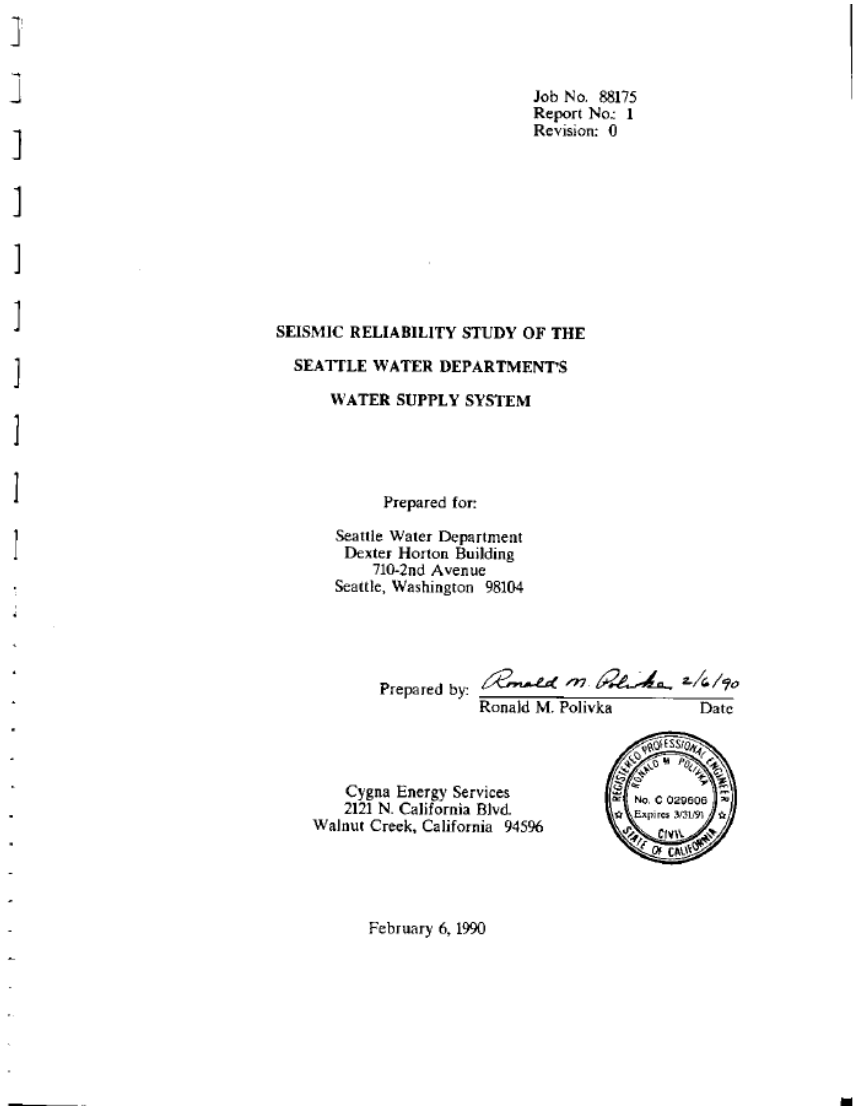
Seismic Hazards - Recent Earthquakes

	Year	Magnitude	Impacts
Loma Prieta, Bay Area	1989	6.9	Water outages mostly less than a few days; fire suppression water was an issue in the Marina District
Northridge, So. Cal	1994	6.7	Over 100 fires; water system damage mostly in areas of poor soils; outage durations 8 to 13+ days
Kobe, Japan	1995	6.9	109 Kobe fires immediately after earthquake (another 88 in surrounding cities); 60+ days for restoration of service
Christchurch, NZ*	2011	6.2	45+ days for restoration of service
Tohoku, Japan*	2011	9.0	345 fires; 45+ days for substantial restoration of service

*15%-20% chance of a Christchurch-like or Tohoku-like type event in Seattle in next 50 years

SPU Seismic Mitigation Program History

- Seismic Reliability Study of the Seattle Water Departments Water Supply System (Cygna Energy Services, 1990)
- Earthquake Loss Modeling of the Seattle Water System (Kennedy Jenks Chilton/USGS, 1990)



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Report No.: 1
Revision: 0

SEISMIC RELIABILITY STUDY OF THE
SEATTLE WATER DEPARTMENT'S
WATER SUPPLY SYSTEM

Prepared for:

Seattle Water Department
Dexter Horton Building
710-2nd Avenue
Seattle, Washington 98104

Prepared by: Ronald M. Polivka 2/6/90
Ronald M. Polivka Date

Cygna Energy Services
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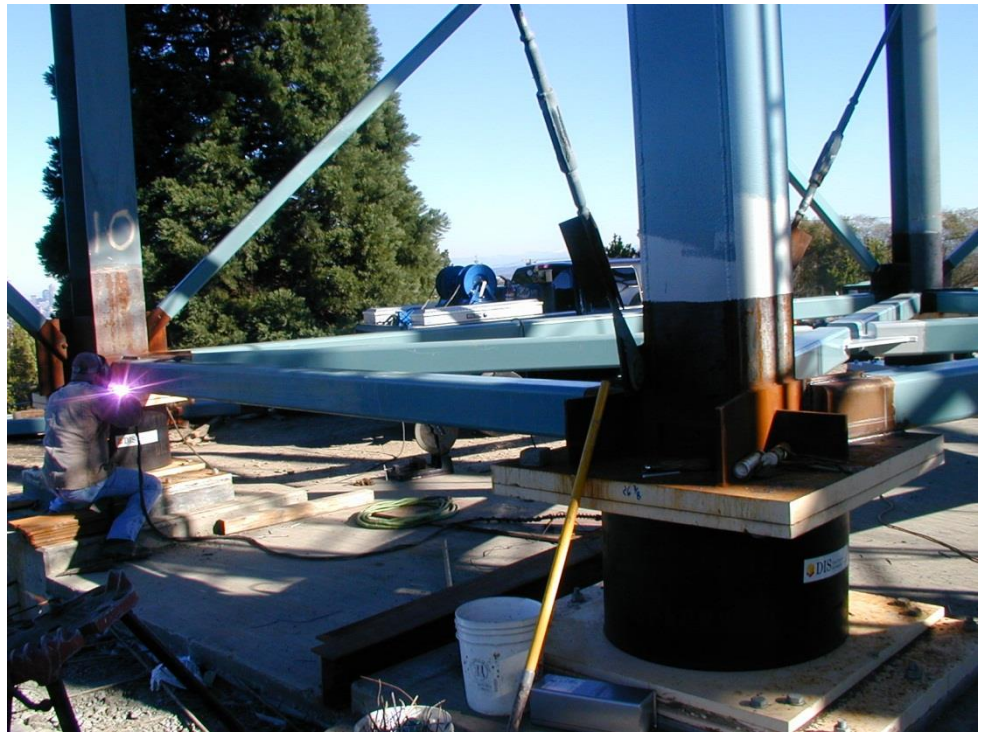
REGISTERED PROFESSIONAL ENGINEER RONALD M. POLIVKA No. C 029606 Expires 3/31/91 CIVIL STATE OF CALIFORNIA

February 6, 1990

SPU Seismic Mitigation Program History (continued)

- SPU Seismic Upgrade Program (e.g., OCC, Myrtle Elevated Tanks, Barton Standpipe, etc.)
- Performance of Water Supply Systems in the February 28, 2001 Nisqually Earthquake (system post-earthquake hydraulic modeling, Water Research Foundation, 2008)

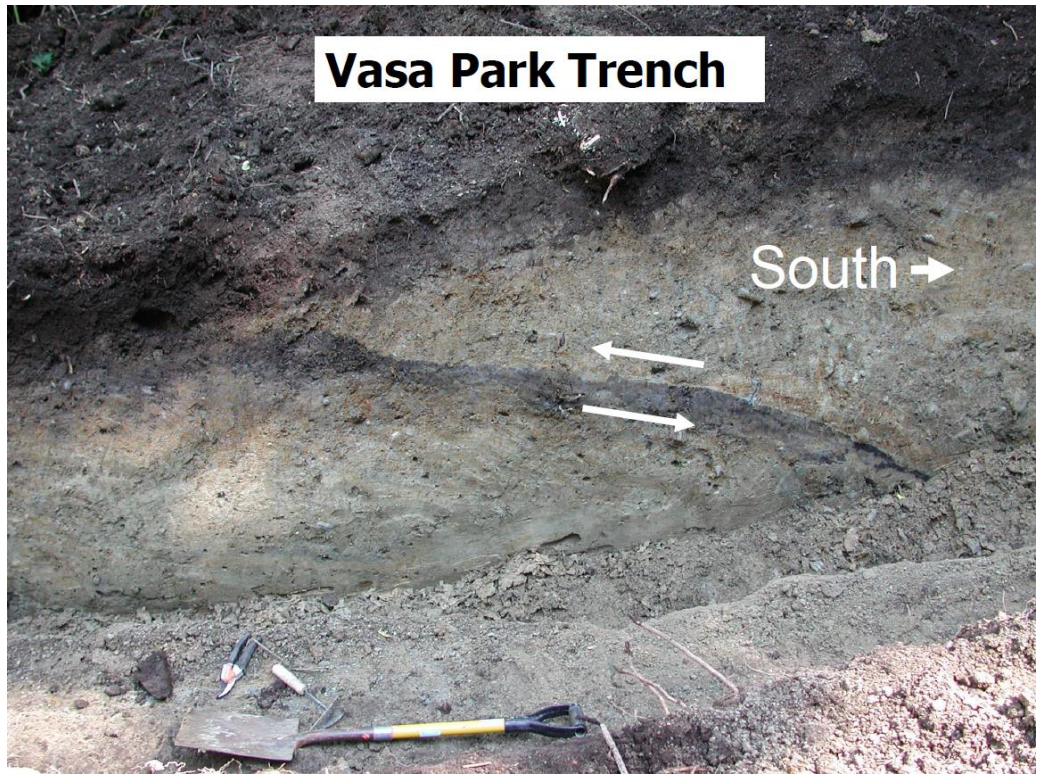


Water Supply Forum – Resilience Study

- Regional analysis of vulnerabilities (Everett, Seattle, Tacoma areas)
- Focus areas: Water quality, drought, climate change, seismic
- Future briefing topic for Operating Board

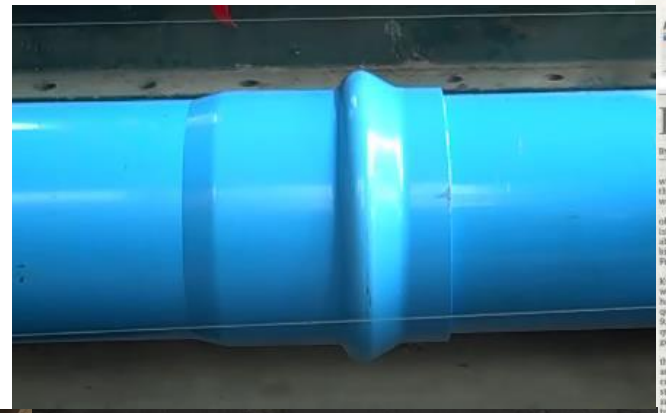
New Developments (since 1990)

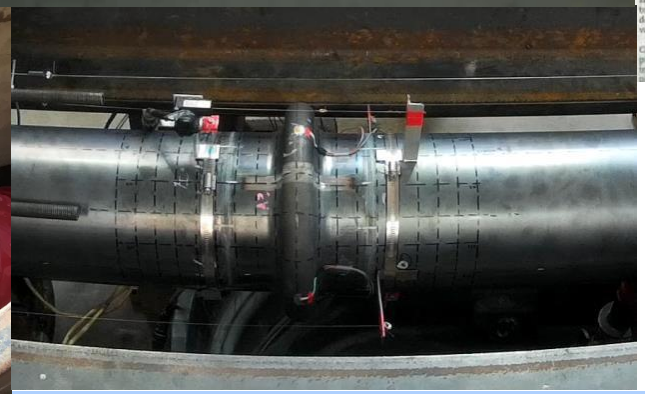
- Active surface faults identified throughout Puget Sound region (e.g., Seattle Fault, South Whidbey Island Fault, Tacoma Fault, etc.)
- Migration from 10% probability of exceedance in 50 years (475 year return interval) design earthquake to 2% probability of exceedance in 50 years (2475 year return interval) design earthquake

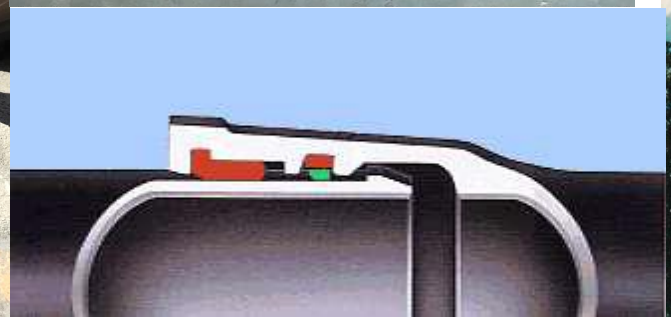


New Developments (since 1990 - cont)

- Earthquake Experience (e.g., Northridge, Japanese, Chilean and New Zealand events)
- Potential for mass availability of earthquake-resistant pipe in U.S.







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U.S. NEWS

Los Angeles Tests Water Pipes That Stand Up to Quakes

By Hamilton Kapp

Los Angeles has a come up with a strategy to prepare for the Big One: earthquake-proof water pipes made only in Japan.

The Los Angeles Department of Water and Power recently finished installing a test patch of about 2,000 feet of a special kind of iron piping in the San Fernando Valley.

The piping, made by Japan's Kubota Corp. and designed to withstand ground deformation, has endured 40 years of earthquakes in Japan—including the 9.0-magnitude Tohoku earthquake that struck in 2011, triggering a tsunami.

Unlike traditional water pipes, these so-called ductile iron pipes are able to withstand quakes because they can bend and flex instead of buckling under pressure. The system, engineered to work like a chain, meaning it doesn't break apart even if its various components are moving.

LADWP supervising engineer Craig Davis learned about the pipes in 2003 and negotiated to import some for the Los Angeles subset project shortly after the

Engineer Craig Davis is overseeing a test of Japanese-made earthquake-resistant water pipes in Los Angeles.

lar projects. "We're just learning about it—it's really only recently that you could identify this pipe system as earthquake-resistant,"

Angeles installation.

Initial y, the city plans to replace only a fraction of its piping—about 2 miles of the total

is expensive, about 2½ times the price of the standard water pipe now in Los Angeles.

The first test installation cost

Los Angeles officials are trying to help Kubota find a manufacturing partner in the U.S.

The Los Angeles Aqueduct, which channels water to Southern California residents from the Sierra Nevada more than 200 miles away, was built a century ago, and the city has worked to replace and retrofit the system's oldest cast-iron pipes in recent years. LADWP said it has installed 2,290 miles of new pipe since 1963 and replaced 107 miles of pipe since 2006.

But work crews have struggled to keep pace with water-main bursts throughout the city. Engineers say bursts may have intensified since rules went into effect limiting outdoor plant watering to certain times during the week, meaning more people are watering at the same time, causing increased pressure.

The Japanese quake-proof piping has endured forces like shaking, landslides and extreme temperature swings because it can expand, contract and bend without leaking or pulling apart, said Thomas O'Rourke, an engineering professor at Cornell University who studies such pipes.

While some U.S. manufacturers also produce ductile iron pipe, those varieties haven't been designed with quakes in mind, nor have they been tested through nearly as many tremblors as in Japan, Mr. O'Rourke said.

Meanwhile, the LADWP is adopting a different kind of plastic-piping technology used in New Zealand to protect Los Angeles's water supply as it crosses the San Andreas fault through a tunnel on its way to the city. Although continuous plastic pipes couldn't be easily integrated into most of the city's cast-iron distribution system, the agency plans to route water through one long tube just as it passes through the Elizabeth Tunnel, which could easily cave in during a major quake. Construction is slated to begin in the fall on the $4 million project.

"This reduces significantly the risk of losing the water supply to Los Angeles, which would be a real threat to the U.S., not just to Southern California," Mr. O'Rourke said.

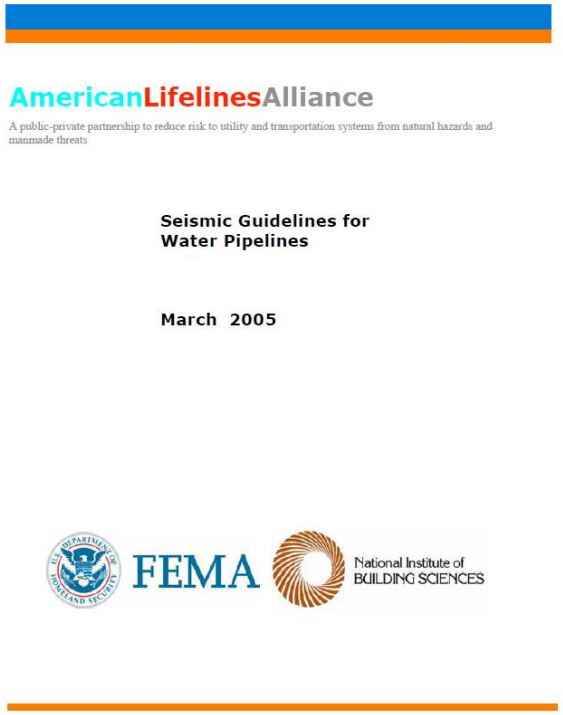
In 1994, the 6.7-magnitude Northridge earthquake cost Los Angeles more than $40 million

Seismic Vulnerability Assessment - Project Goals

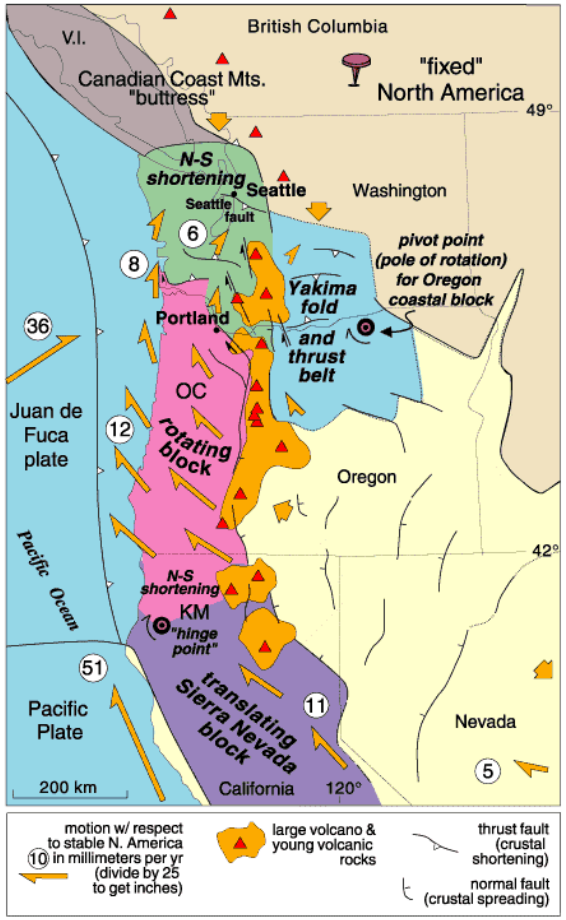
- Preliminary seismic vulnerability assessments for all critical water transmission and distribution system facilities.
  - Defined earthquake scenarios
  - ASCE/SEI 7-10 (Building Code)
- Hydraulic modeling of post-earthquake water system performance
- Establish post-earthquake water transmission and distribution system performance goals

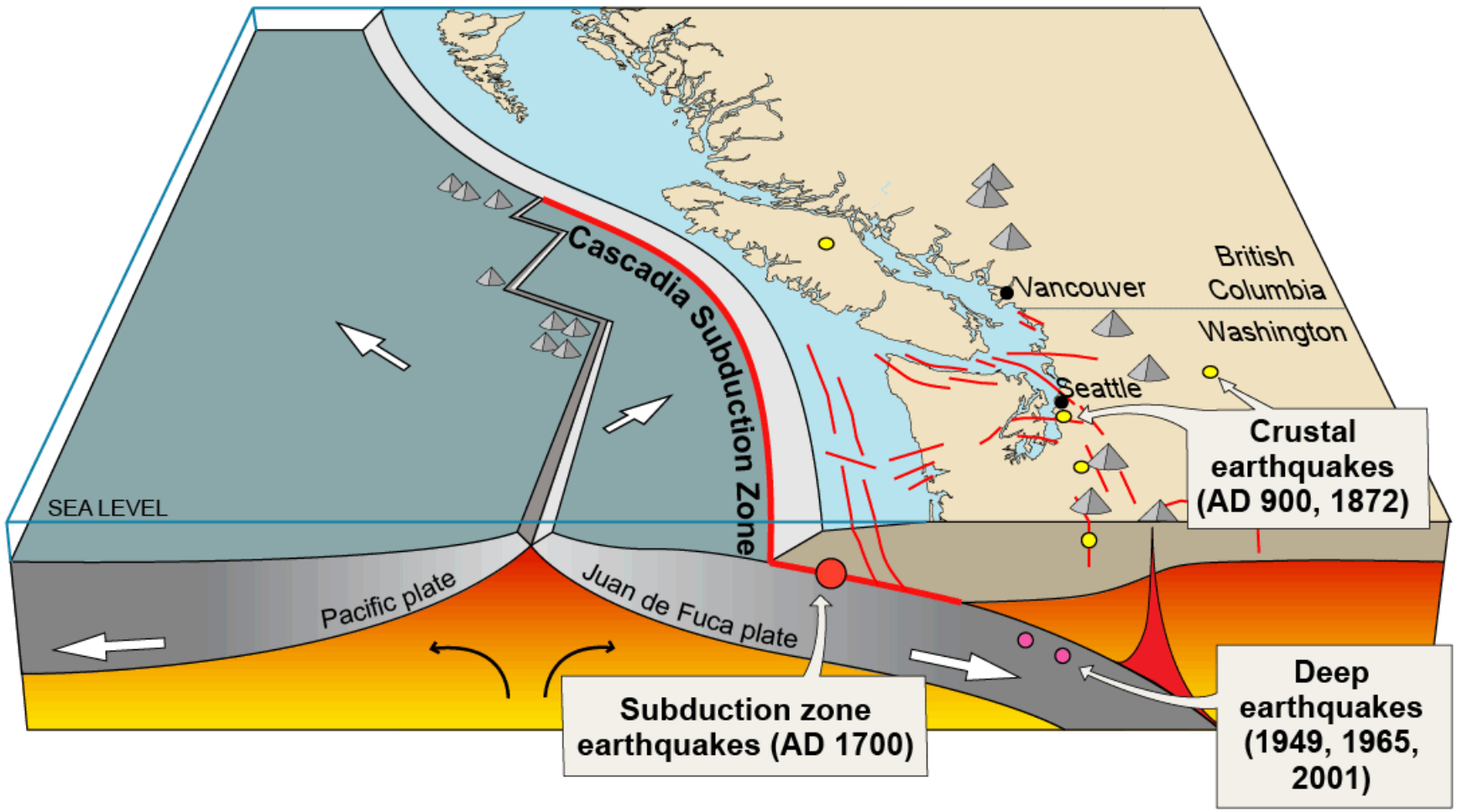
Seismic Vulnerability Assessment - Project Goals (continued)

- Develop planning level mitigation measures, cost estimates and timeframe to meet service level goals.
- Define seismic design standards for water transmission and distribution pipelines.



Earthquake Source Zones





Source	Max. Size	Recurrence
Subduction zone	M 9+	200–600 years
Deep Juan de Fuca plate	M 7+	30–50 years
Crustal faults	M 7+	Hundreds of years?

Volcano

Active crustal fault

Active plate boundary fault

*figure modified from USGS Cascadia earthquake graphics at http://geomaps.wr.usgs.gov/pacnw/pacnweq/index.html

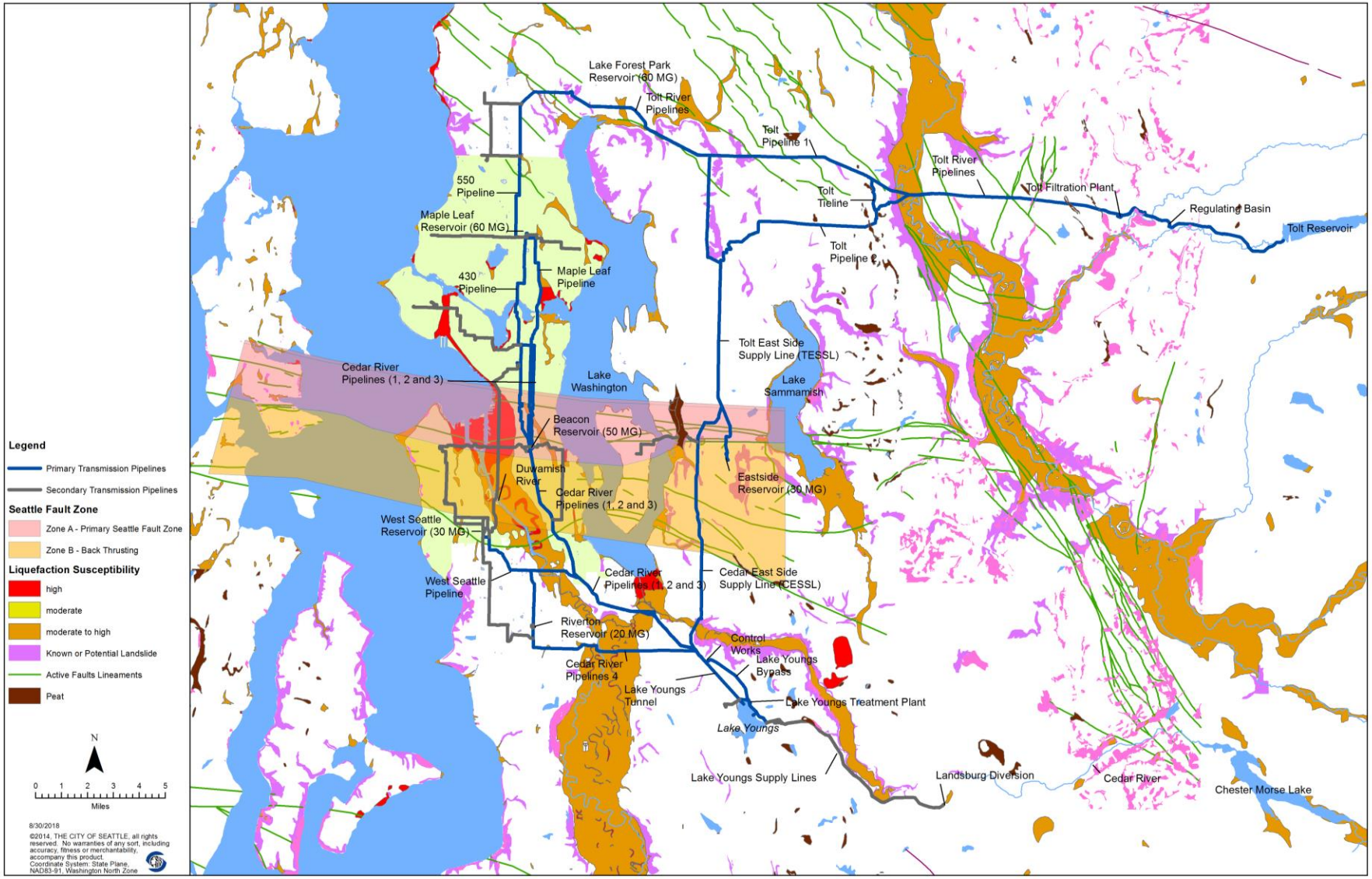
Seattle Earthquake Likelihood in the Next 50 Years

- 15% to 20% chance of catastrophic earthquake, similar to 2011 Christchurch or Tohoku earthquakes
  - 14% chance of M9 (plus or minus) Cascadia subduction earthquake
  - 5% chance of M6.5 or larger Seattle Fault earthquake
- 85% chance of at least one intraplate earthquake “similar” to the 2001 Nisqually earthquake

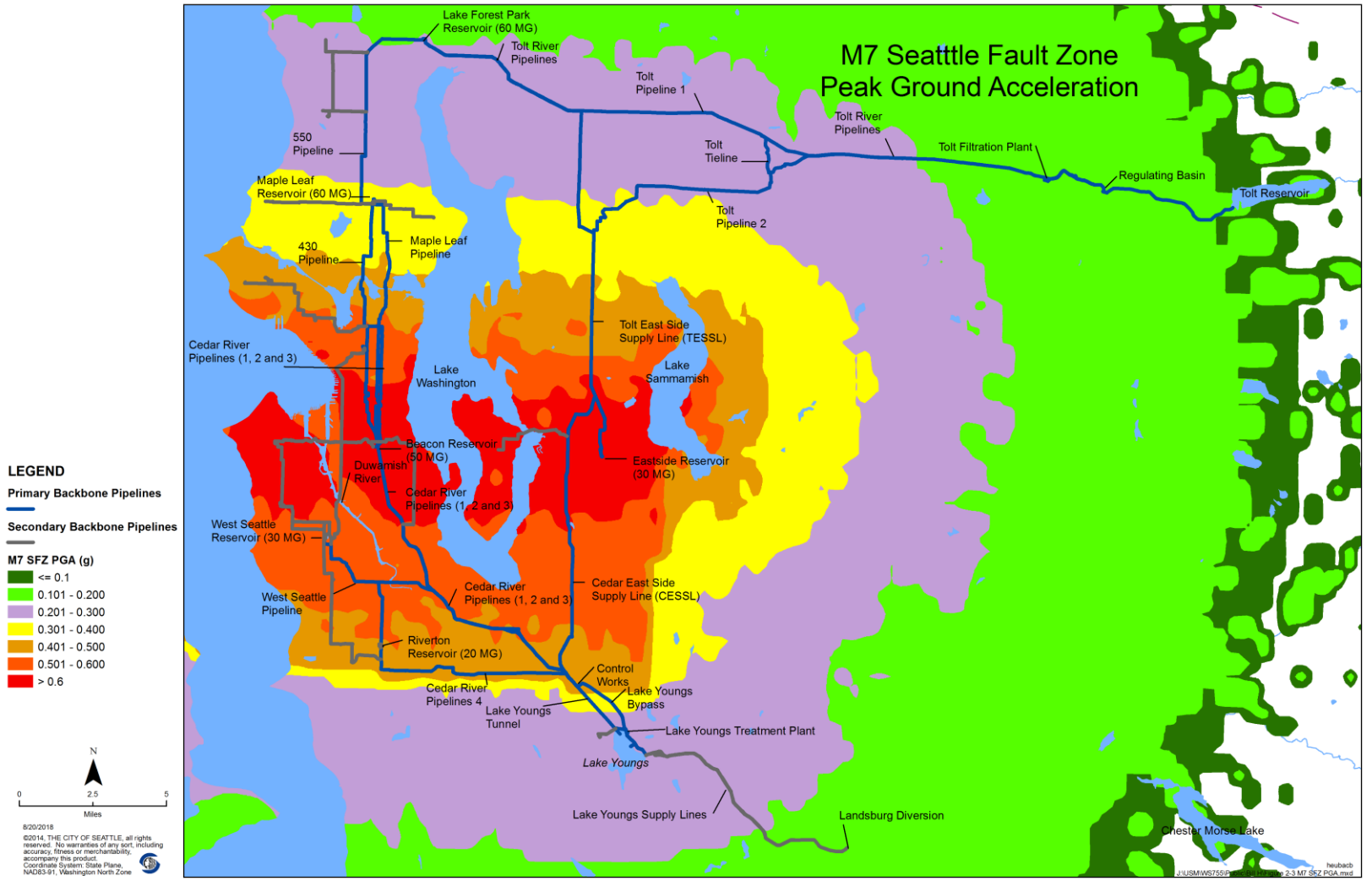
Seismic Hazard Analysis - Scenarios

- Three Scenarios
  - M7.0 Seattle Fault
  - M9.0 Cascadia Subduction Zone
  - 0.02 Probability of Exceedance in 50 Years Ground Motions
- Hazards Evaluated
  - Ground Shaking Intensity (PGA)
  - Permanent Ground Displacements

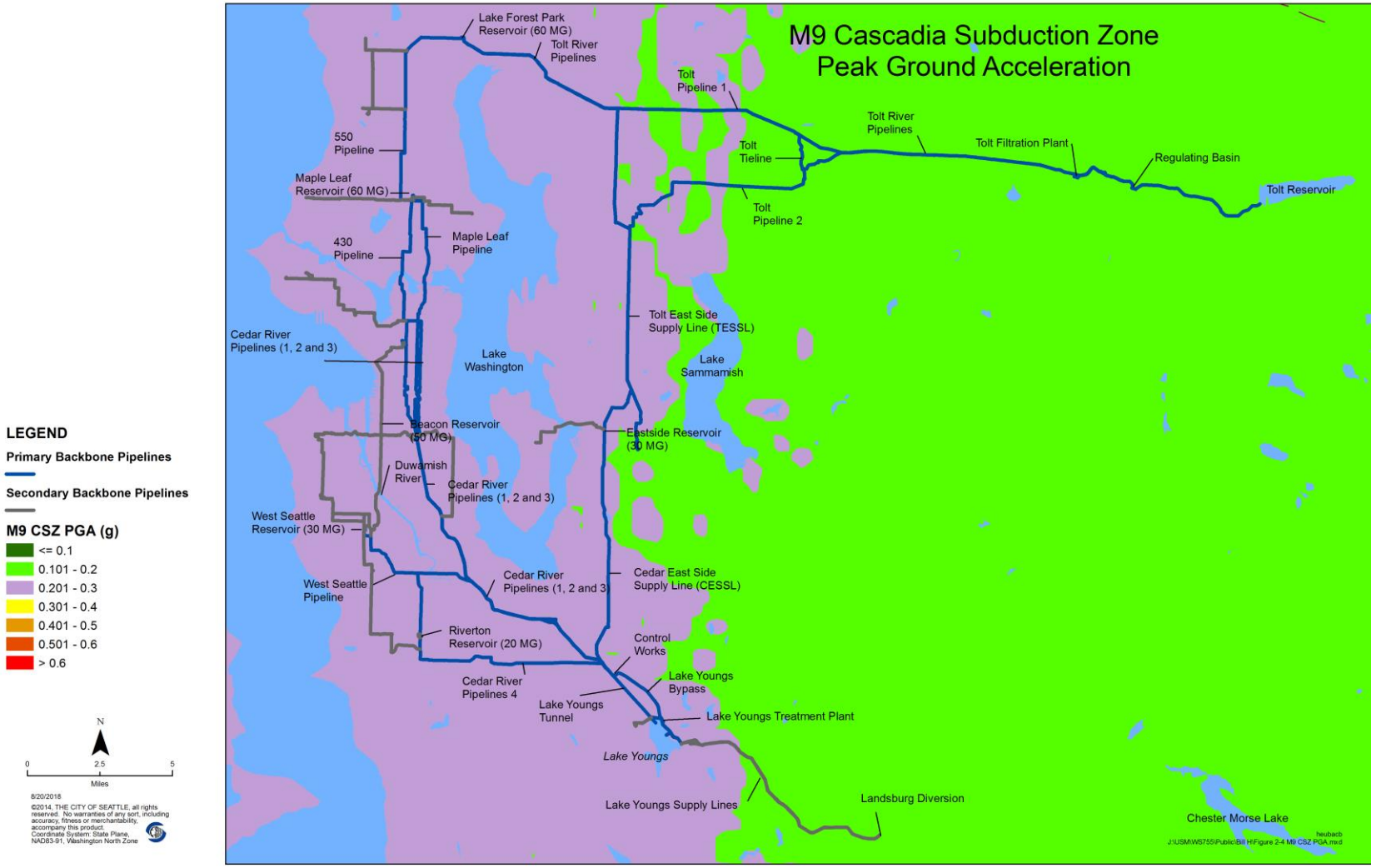
SPU Water System Seismic Hazard Map



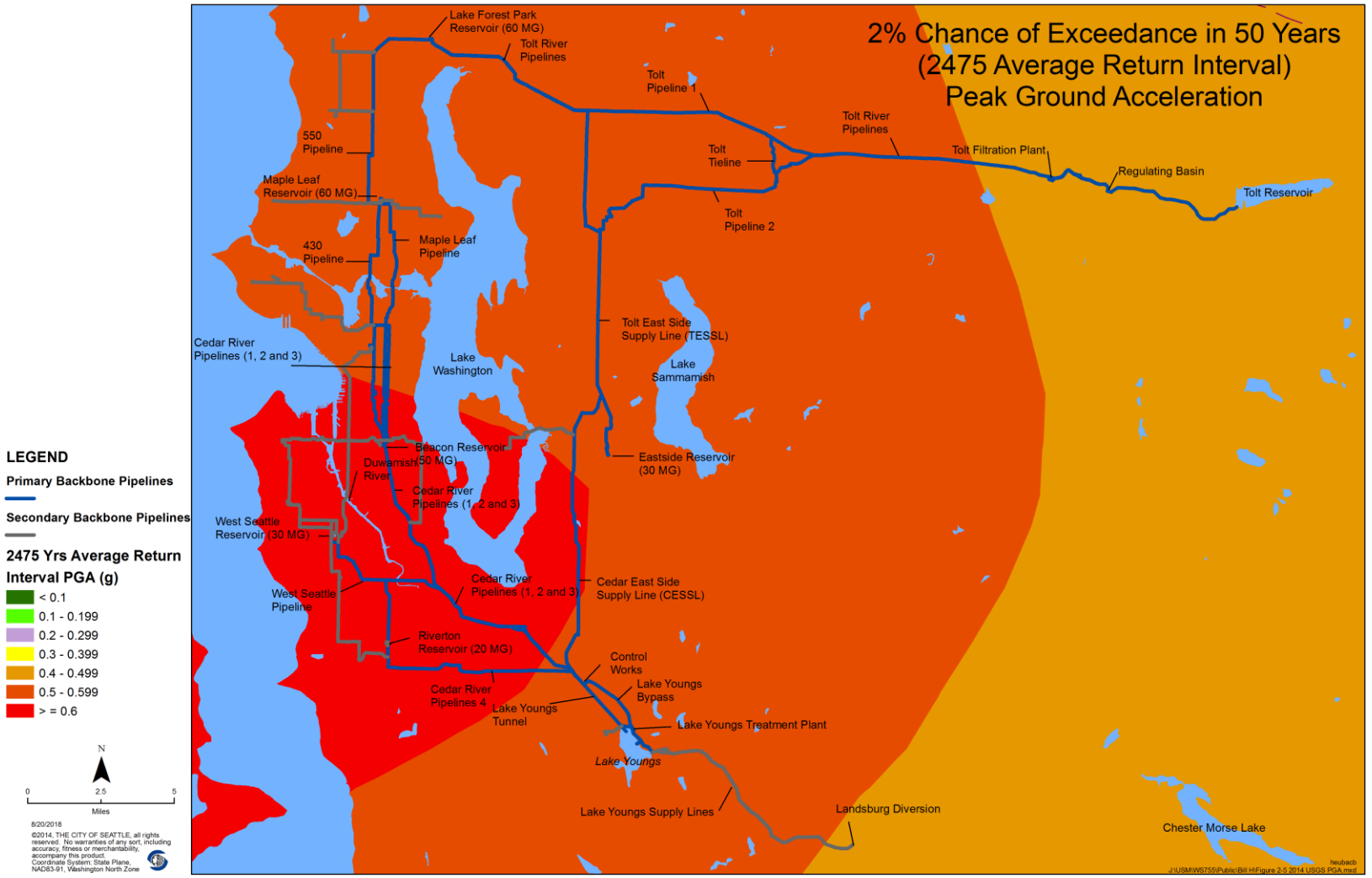
M7 Seattle Fault Zone Peak Ground Acceleration



M9.0 Cascadia Subduction Zone Peak Ground Acceleration

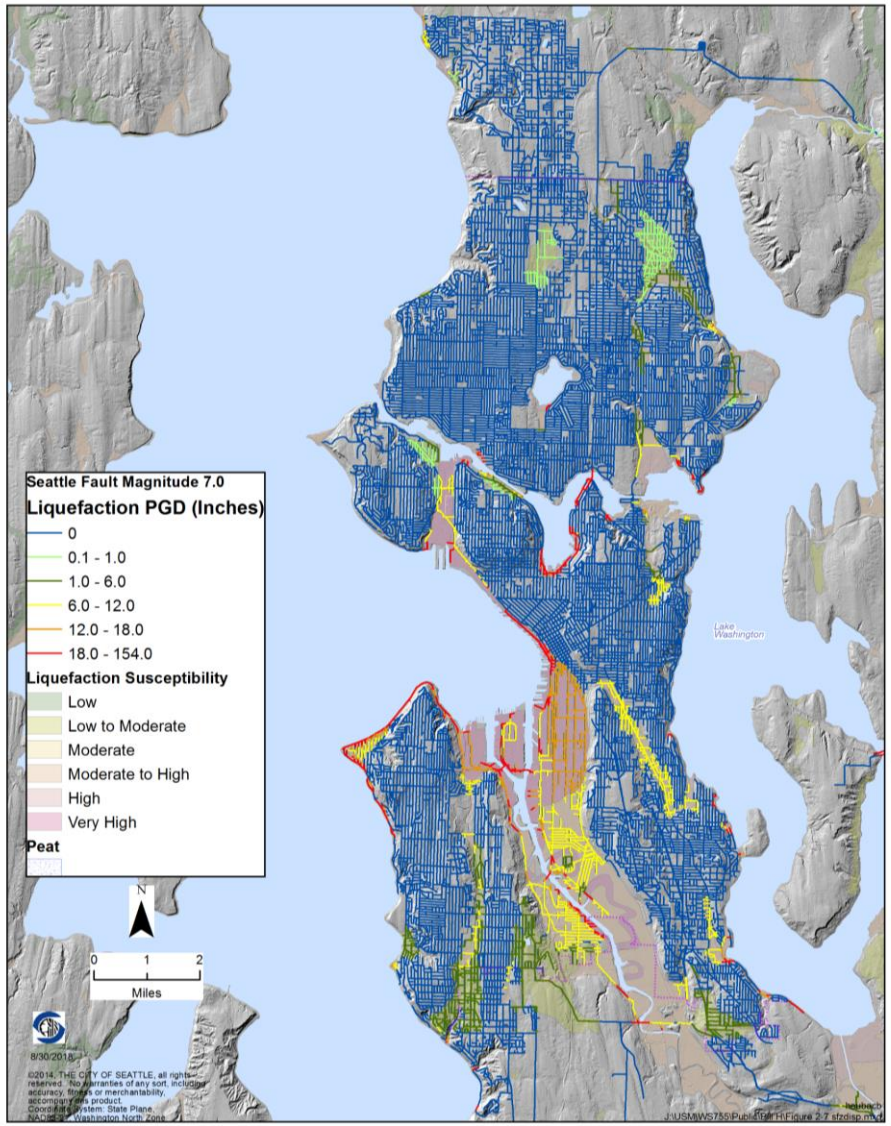


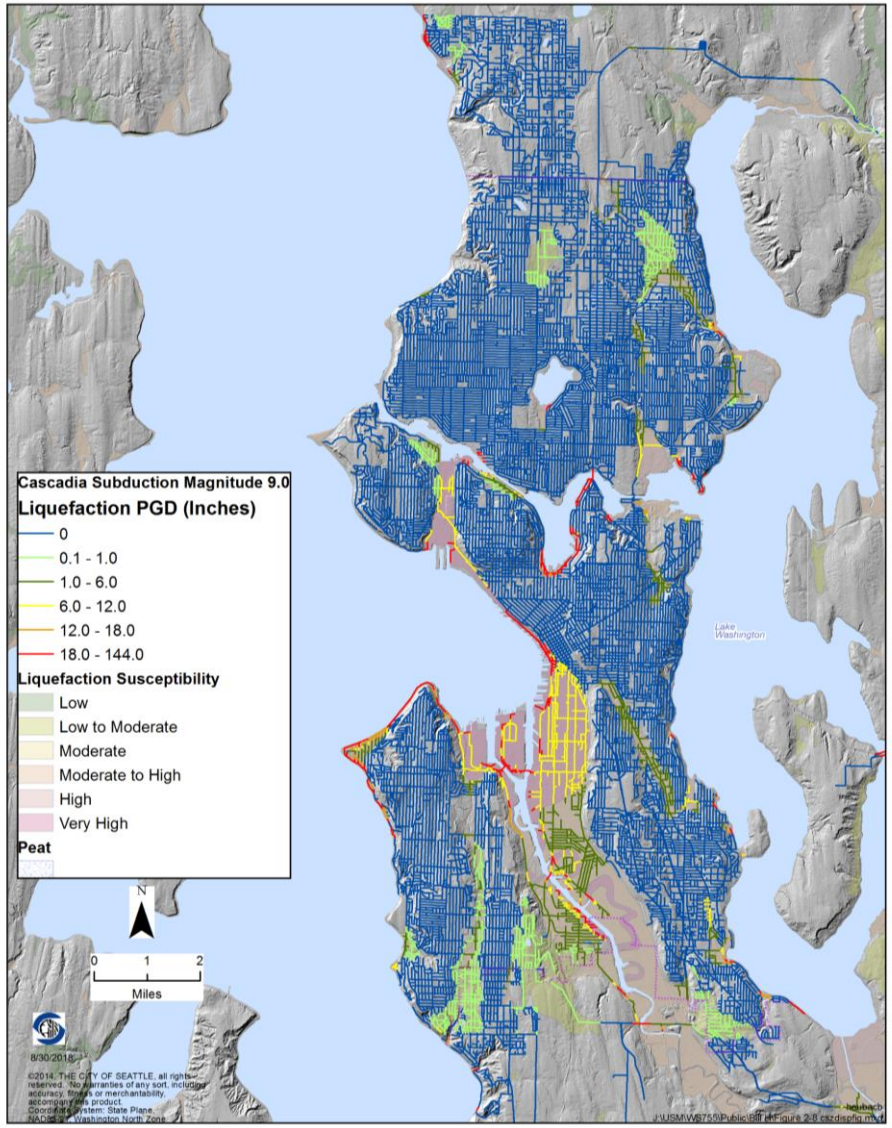
USGS 0.02 Probability of Exceedance in 50 Years Ground Motions



Earthquake Hazards - Liquefaction

Permanent Ground Displacement





Seismic Vulnerability Assessments

- “Vertical” Facilities
  - Watersheds
  - Treatment Plants
  - Reservoirs/Tanks
  - Pump Stations and Gatehouses
  - Support Facilities
- Pipelines
  - Transmission
  - Distribution

Watersheds

- Dams – Meet FERC requirements
- Landslides
  - Minor impacts in M7.0 SFZ and M9.0 CSZ events
  - Moderate or more severe impacts possible for building code ground motions
- Other Facilities
  - Tolt intake bridge connections
  - Tolt screenhouse
  - Landsburg Tunnel Gatehouse

Treatment Plants

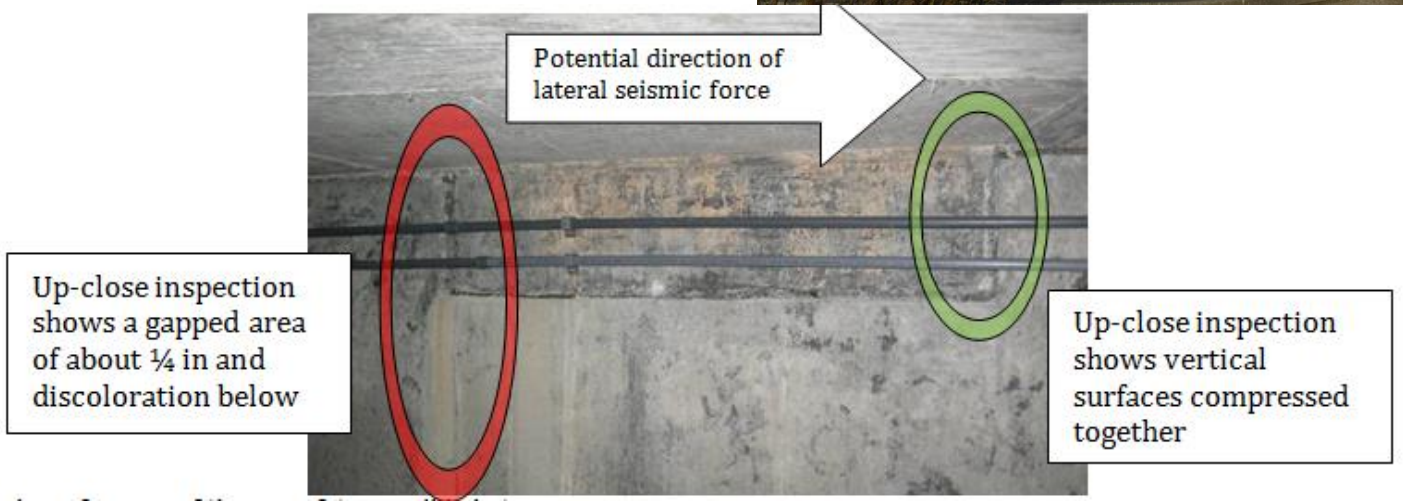
- Structural Performance – generally good
- Some Nonstructural Concerns
- Sloshing in Basins
- Emergency Power
- Clearwells – some damage (particularly for building code ground motions) but expected to remain functional

Regional Reservoirs and Tanks

- Reservoirs
  - Riverton Reservoirs Is Most Vulnerable
  - Eastside Reservoir Also A Concern
  - Damage Possible to Other Reservoirs But Most or All Others Are Expected to Remain Functional
- Elevated Tanks and Standpipes: All Are Vulnerable to Code Level Ground Motions

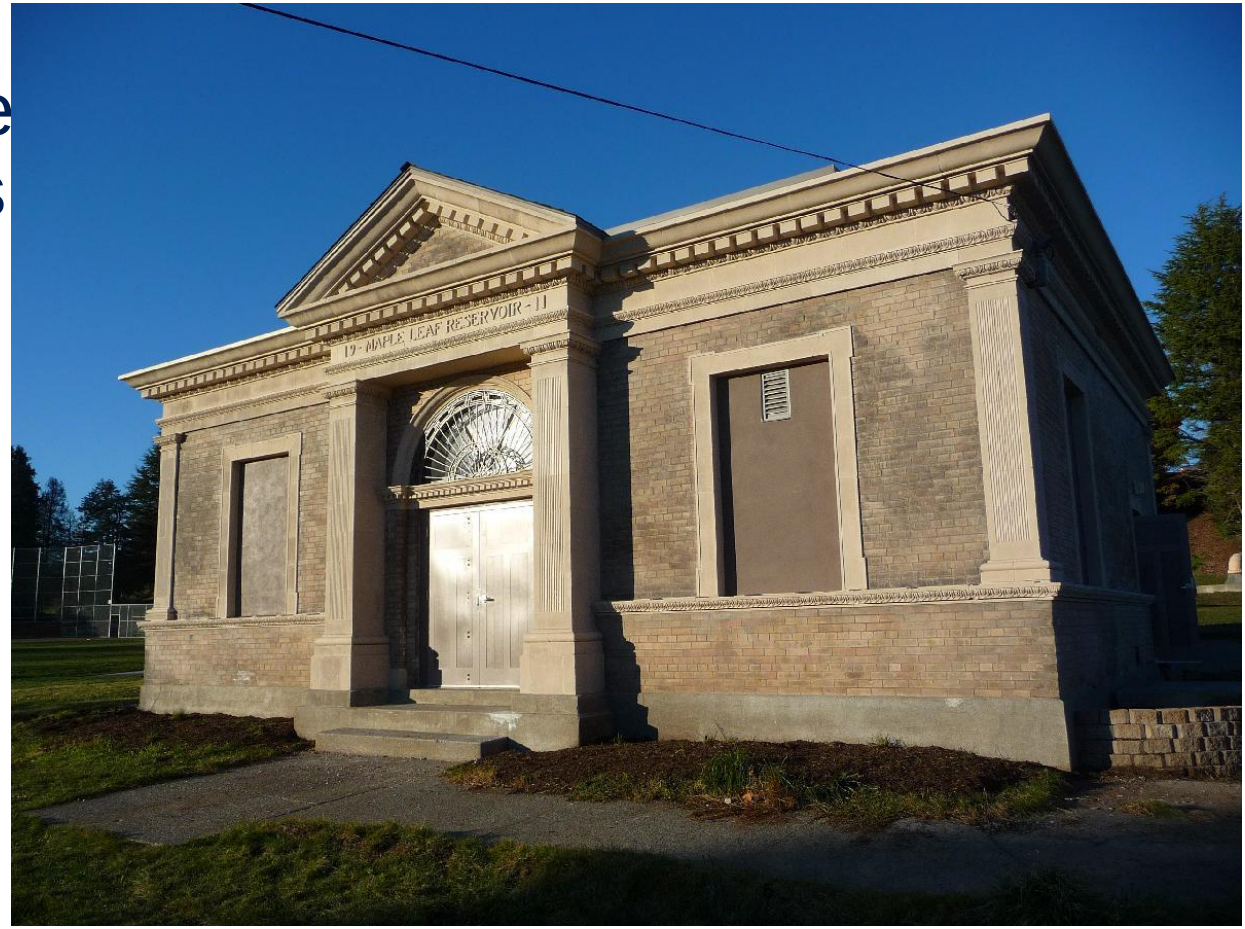
Myrtle #2

Eastside Reservoir After Nisqually Earthquake:

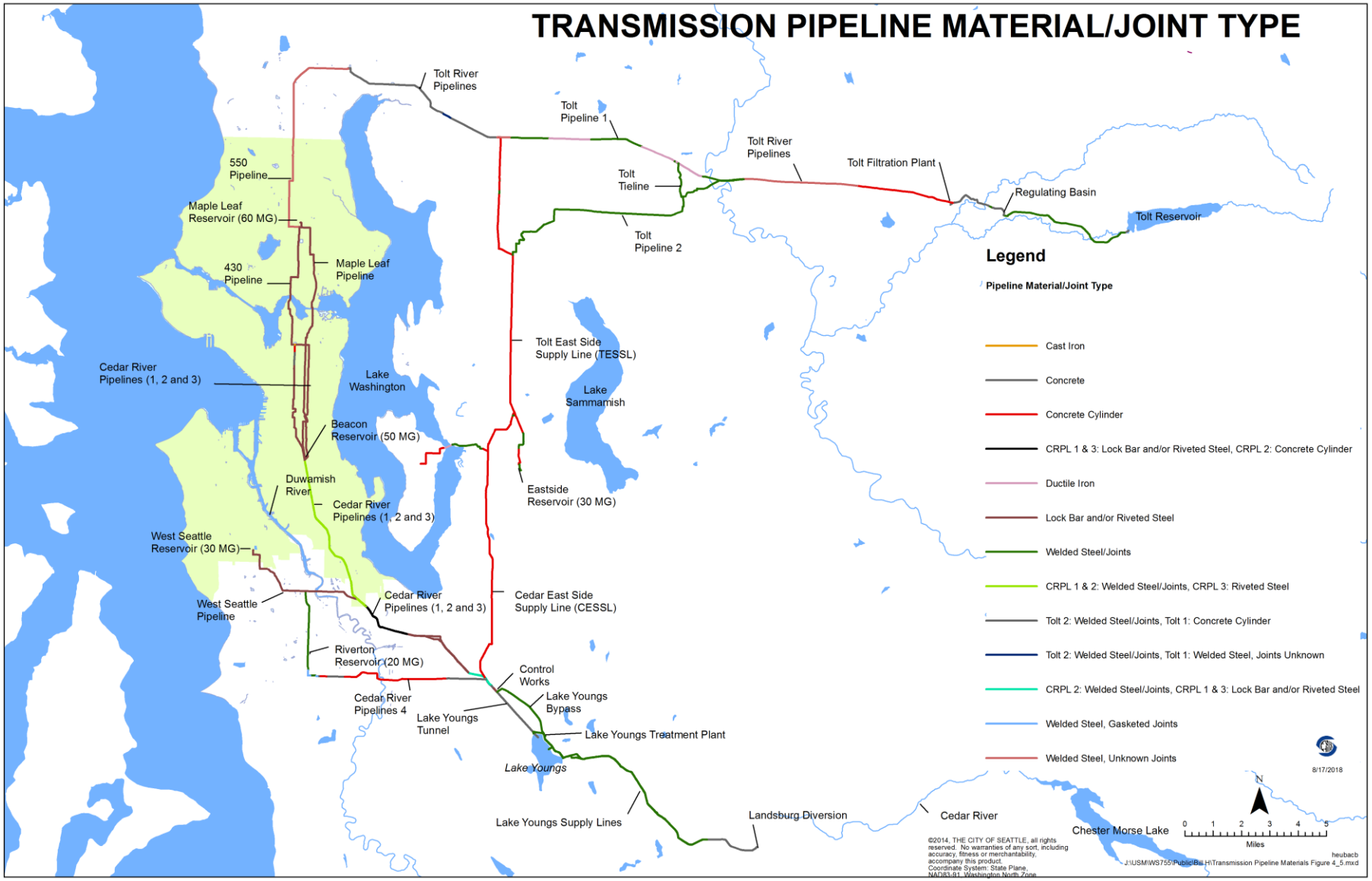


Regional Pump Stations

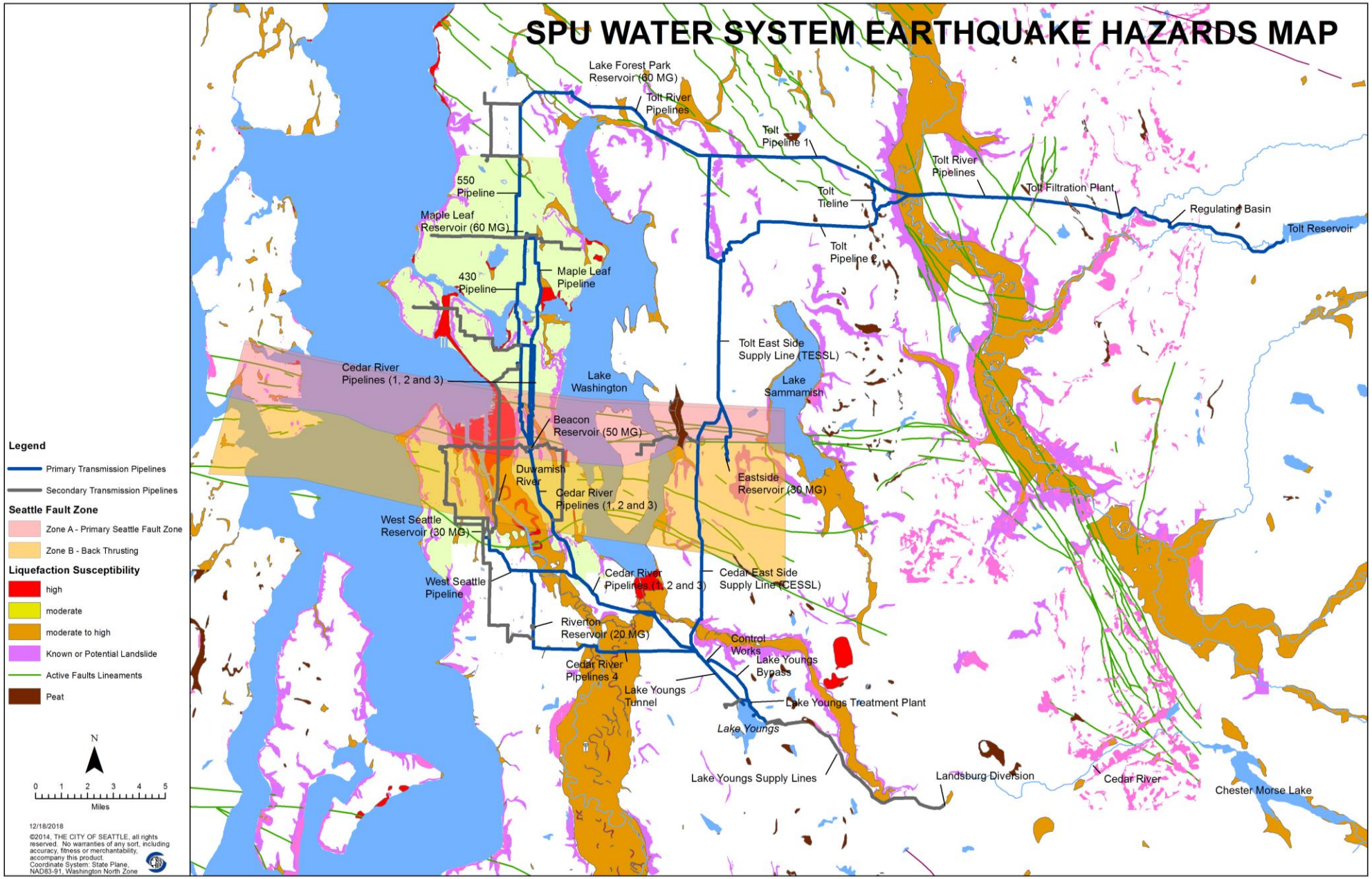
Several Pump Stations Are Vulnerable
But Most of Vulnerable Pump Stations
Are Not Critical



Transmission Pipelines

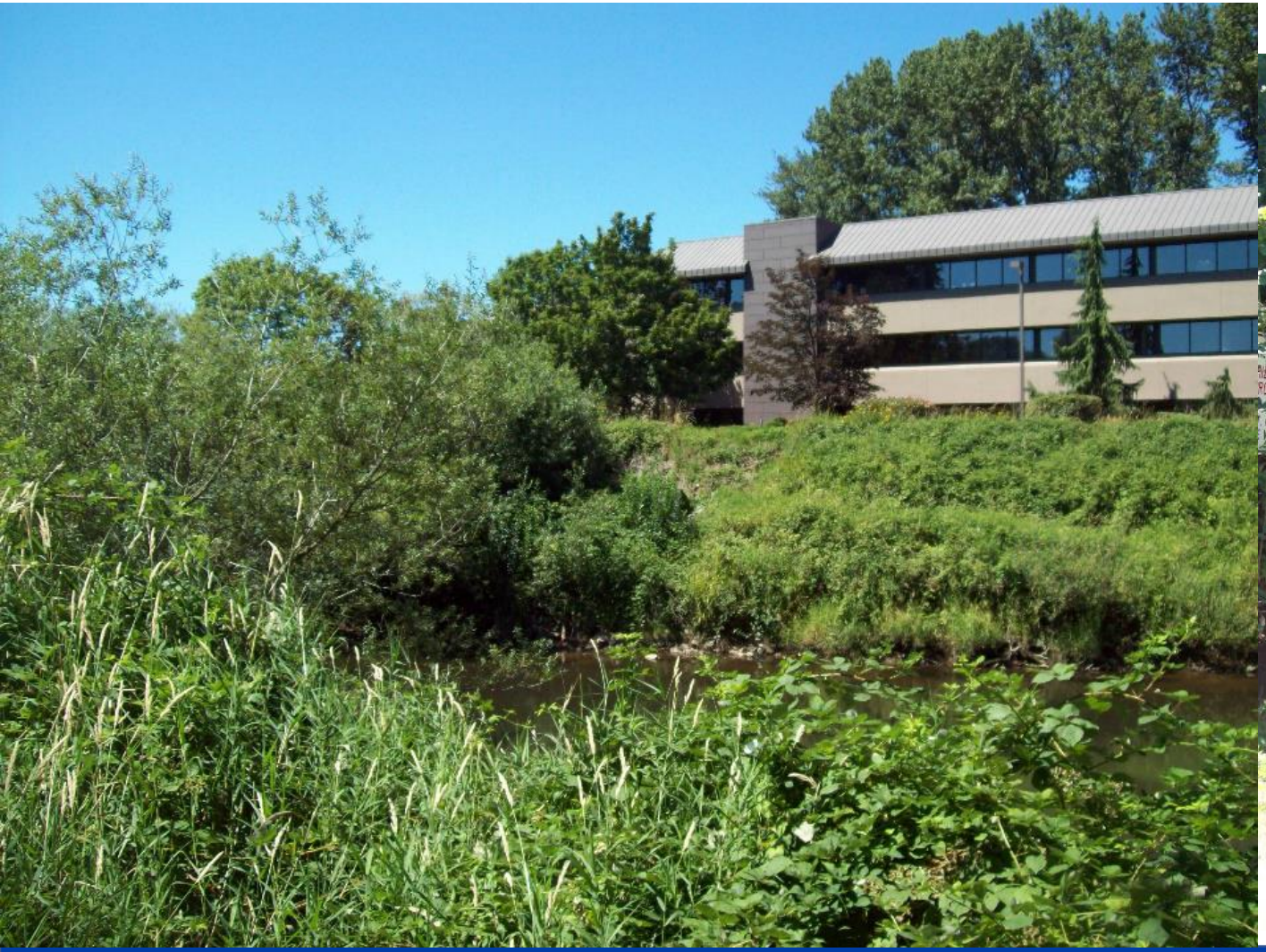


SPU Water System Seismic Hazard Map



Transmission Pipelines – Steep Slopes

Transmission Pipelines – River Crossings



Transmission Pipelines – Swamps and Piles

Vulnerability Assessment Findings Summary

- For a catastrophic earthquake (15% to 20% chance in next 50 years)
  - Loss of Cedar and Tolt Transmission Systems Likely
  - Loss of Eastside Supply Line Likely
  - Distribution Pipeline Failures
    - M7 SFZ Scenario: ± 2000 failures
    - M9 CSZ Scenario: ± 1400 failures
  - Most Terminal Reservoirs Remain Functional
  - Loss of Over One Dozen Critical Facilities
  - Loss of Water Pressure Throughout Direct Service Area Within ± 24 Hours
- Mitigation plans balancing risk vs cost

Mitigation Approach – Short Term Measures (Next 15 to 20 Years)

- Enhance emergency preparedness and response planning
  - Earthquake-specific response plan
  - Significantly augment pipeline repair material stocks
  - Assess adequacy/improve emergency drinking water
- Develop/implement isolation and control strategies
  - Reservoir isolation valves
  - Explore isolating areas of large amounts of pipe damage
  - Add valves to make isolation easier

Mitigation Approach – Long Term Measures (Next 50 Plus Years)

- Build It Right (Now Until Forever)
  - Use earthquake-resistant pipe when pipe is replaced
  - Design new facilities to remain functional
- Upgrade Vulnerable Critical Facilities (Next 50 Plus Years)
  - Most vulnerable transmission pipelines locations (Cedar system has top priority)
  - Critical facilities
    - Large volume reservoirs
    - Key pump stations and support facilities
    - Life-safety

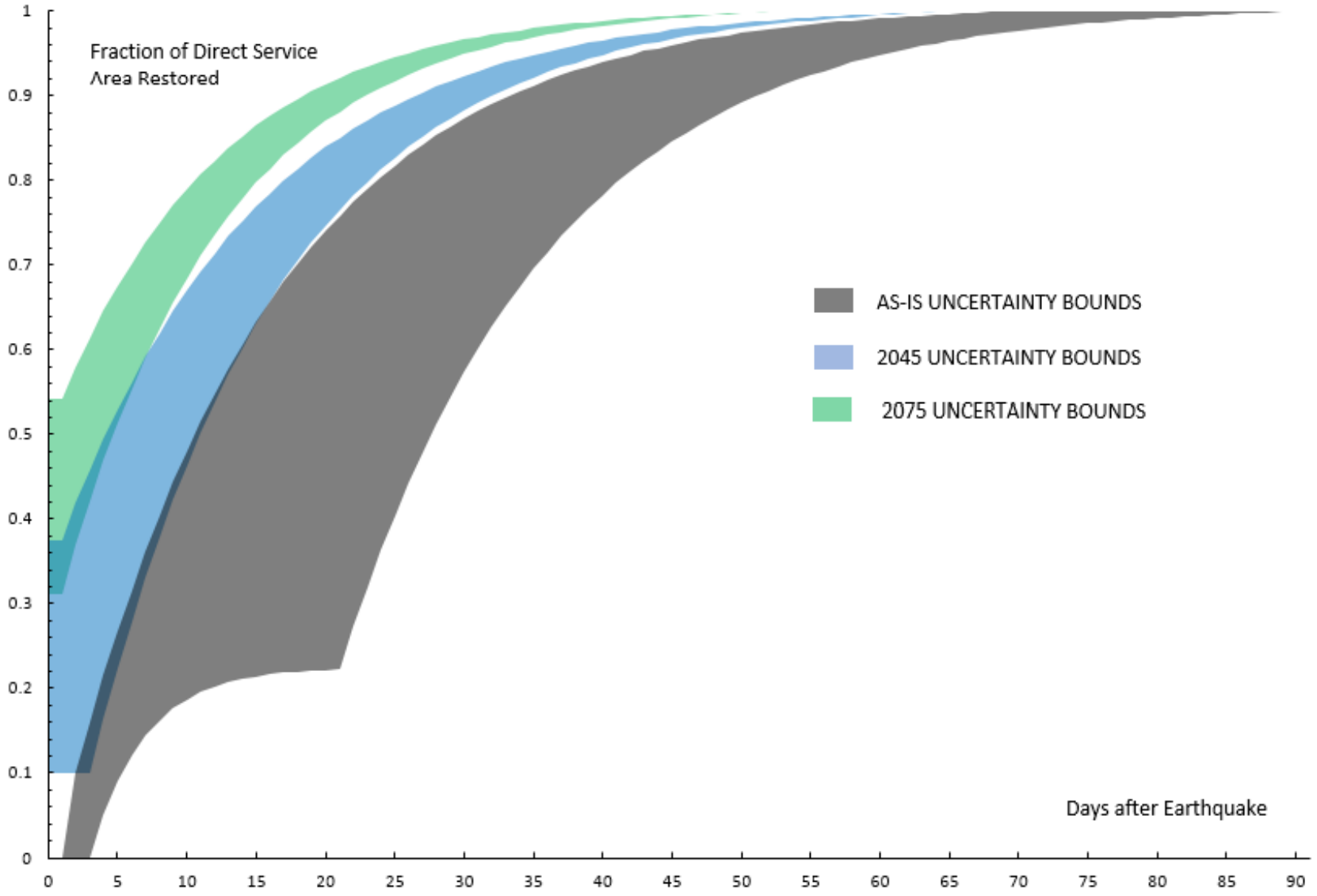
Seismic Resilience Recommendations

- $15 to $20 million per year – 50+ years
- Options analysis for all projects
  - Cost and functional tradeoff between:
    - Full upgrades – functional after design EQ
    - Upgrades – non-functional but repairable
    - Operational/response: expect significant damage, but able to repair quickly
  - Example: a vulnerable pipe crossing
    - Full replacement/seismic upgrade of pipe
    - Slip-line pipe
    - Install emergency connections
    - Place spare pipe immediately adjacent

Transmission System Mitigation Recommendation Summary

Mitigation Element	Order of Magnitude Cost Estimate	2018 - 2022	2023 - 2027	2028 - 2032	2033 - 2037	2038 - 2042	2043 - 2047	2048 - 2052	2053 - 2057	2058 - 2062	2063 - 2067	2068 - 2072
Transmission Pipelines												
Emergency Repair Materials	$6,000,000											
Transmission Pipe Analysis/Pre Eng	$500,000											
Transmission Line Valves/Manifolds	$10,000,000											
CRPLs in Renton	$75,000,000											
CESSL Cedar River Crossing	$20,000,000											
TPLS at Norway Hill	$30,000,000											
Seismic Resistant CRPL	$120,000,000											
Seismic Resistant TPL	$72,000,000											
Seimic Resistant CESSL/TESSL	$90,000,000											
Misc Transmission Pipe Upgrades	$19,000,000											
Other Facilities												
Eastside Reservoir	$12,000,000											
Riverton Heights	$10,000,000											
Maple Leaf PS/Gatehouse	$2,000,000											
Beverly Park Elevated Tank	$12,000,000											
Control Works Surge Tanks	$5,000,000											
Cascades Dam	$10,000,000											
Richmond Highlands #2	$5,000,000											
Foy Standpipe	$4,000,000											
Landsburg Tunnel Gatehouse	$1,000,000											
West Seattle Pump Station	$1,000,000											
Trenton Pump Station	$2,000,000											
Fairwood Pump Station	$1,000,000											

Direct Service Area Restoration Projected Improvement



Questions?