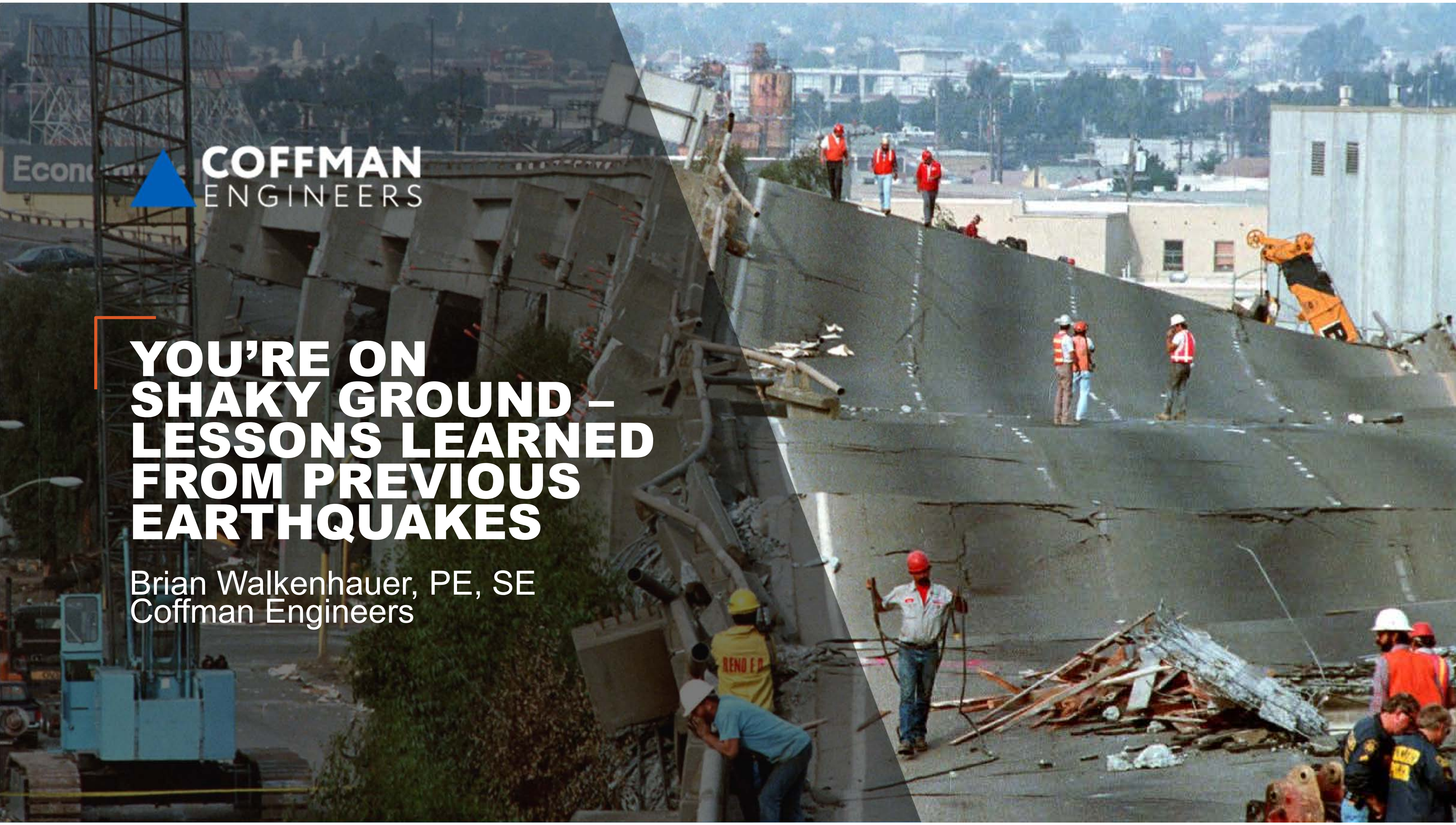


COFFMAN ENGINEERS

YOU'RE ON SHAKY GROUND – LESSONS LEARNED FROM PREVIOUS EARTHQUAKES

Brian Walkenhauer, PE, SE
Coffman Engineers

Coffman Engineers

Coffman Services

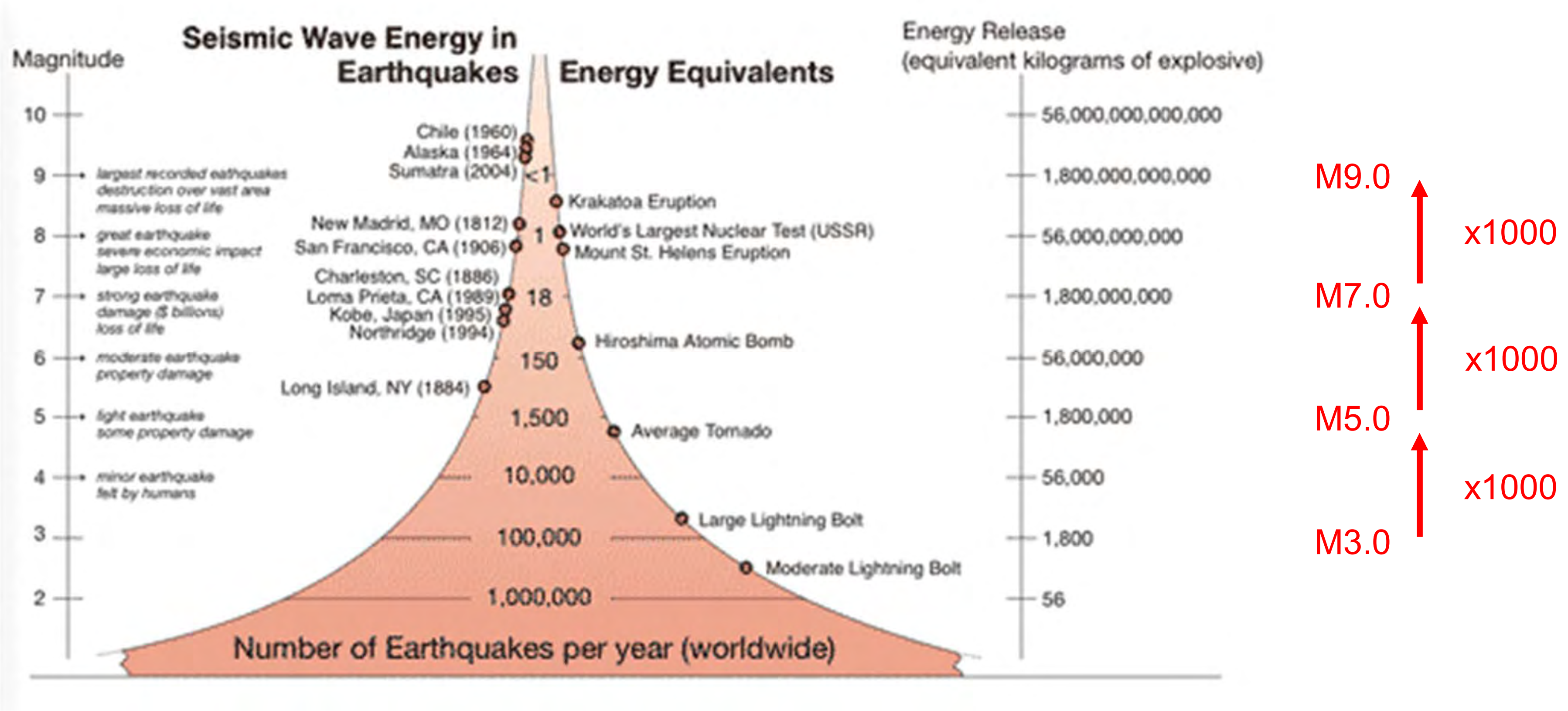
- Bridge Engineering
- Civil Engineering
- Commissioning
- Corrosion Control
- Electrical Engineering
- Energy & Life-Cycle Cost Analysis
- Fire Protection Engineering
- Instrumentation & Controls
- Land Surveying
- Lighting Design
- Mechanical Engineering
- Pipeline Integrity Management & In Line Inspection
- Process Piping
- Project Management
- Structural/Seismic Engineering
- Sustainable Design

Agenda

- History of Pacific NW Earthquakes
- Lessons Learned in Previous Earthquakes
- Common Earthquake Damage
- How to Prepare for Future Earthquakes

Photo: Freeway overpass collapse in 1994 Northridge Earthquake

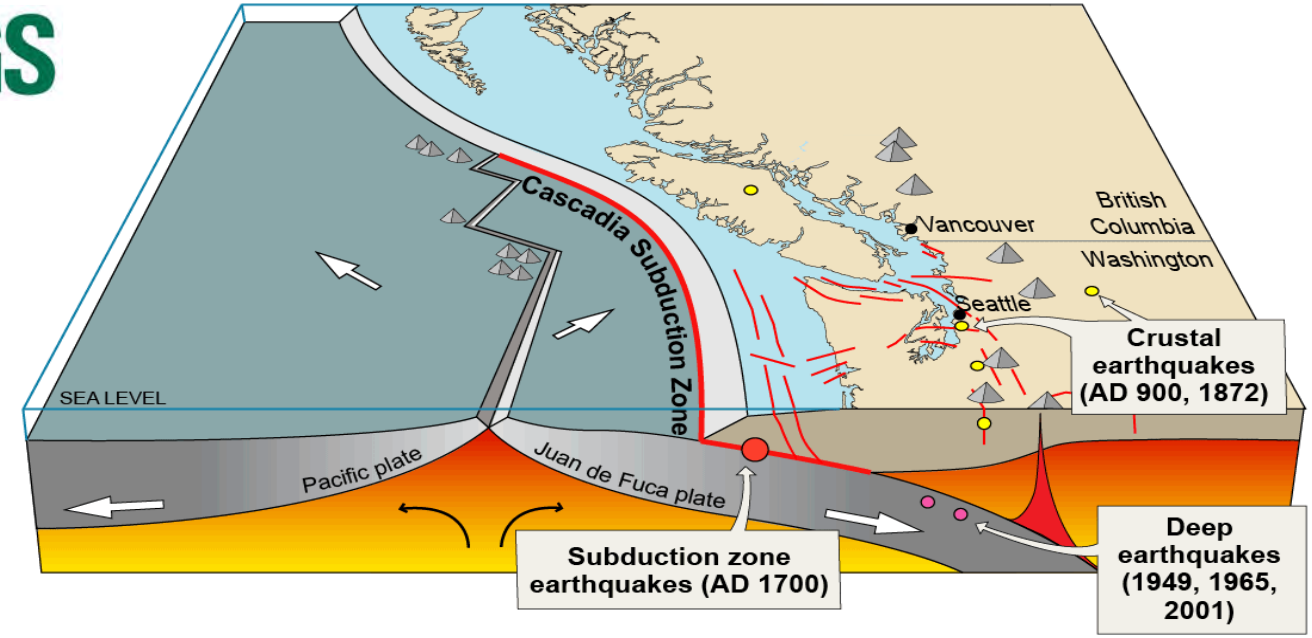
Earthquake Magnitude – Richter Scale



Earthquake Intensity – Modified Mercalli Intensity Index

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	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	Light	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	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	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	Severe	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	Violent	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	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Pacific NW Earthquake Sources



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?

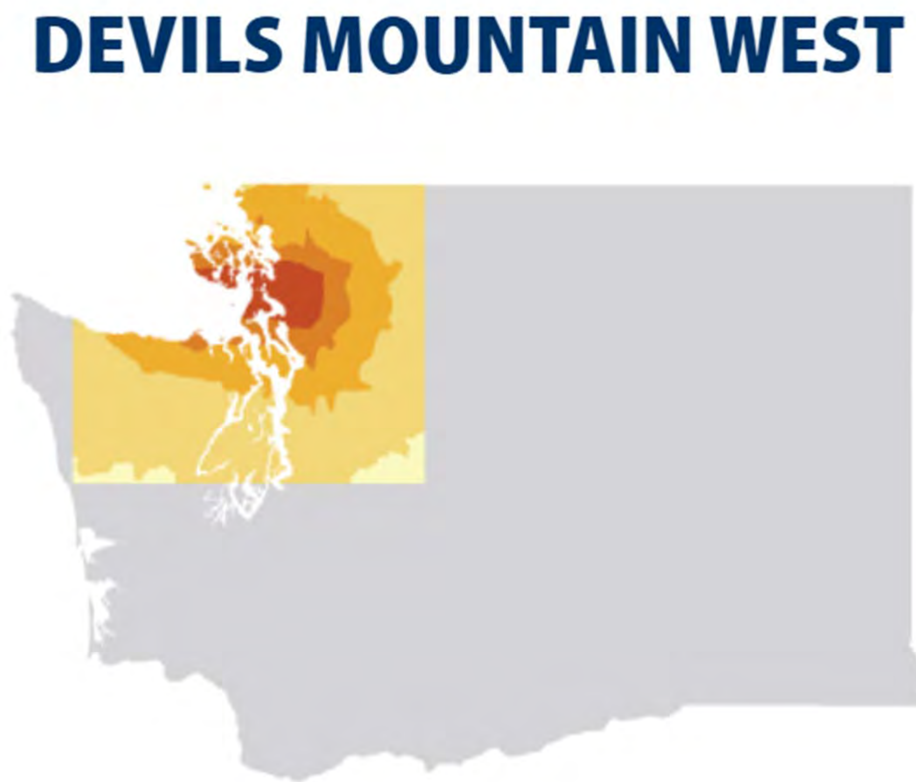
Volcano

Active crustal fault

Active plate boundary fault

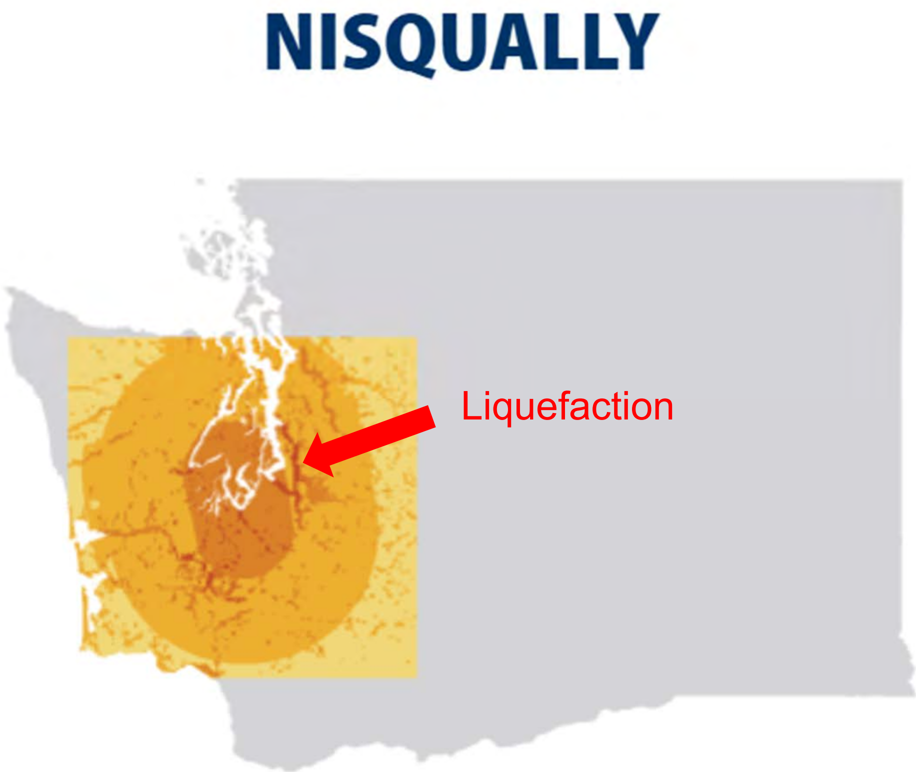
Crustal Earthquakes

Scenario: M7.2 earthquake on the Seattle Fault Zone
Estimated Economic Loss = $30.9 Billion

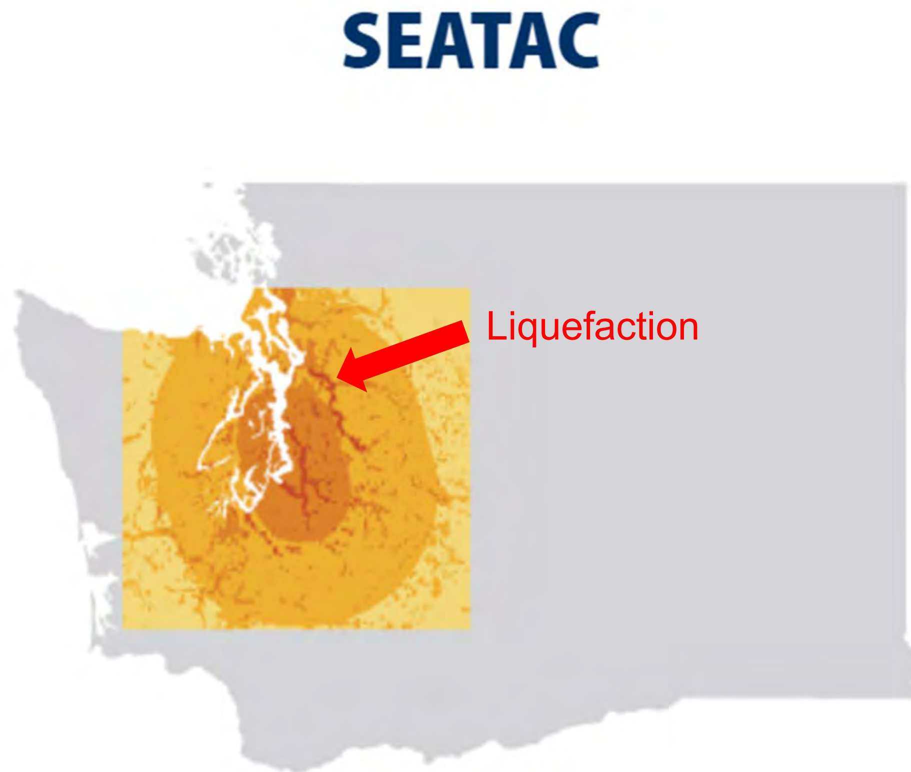


Scenario: M7.4 earthquake on West portion of Darrington-Devil’s Mt. Fault
Estimated Economic Loss = $3.4 Billion

Deep Earthquakes

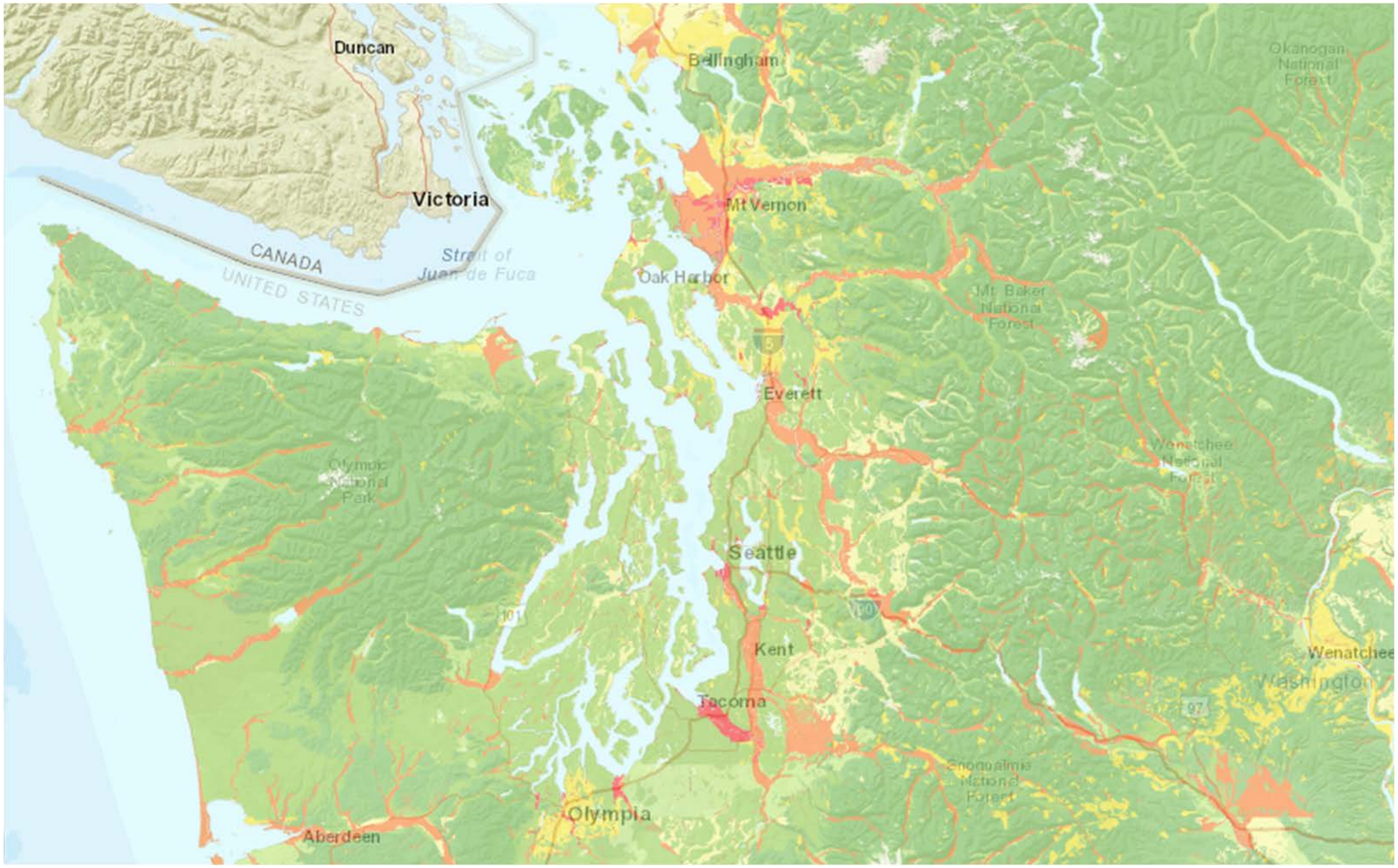


Scenario: M7.2 deep earthquake centered below the Nisqually delta
Estimated Economic Loss = $8.8 Billion



Scenario: M7.2 deep earthquake centered below Seatac
Estimated Economic Loss = $13.4 Billion

Liquefaction Maps



Source: WA Department of Natural Resources

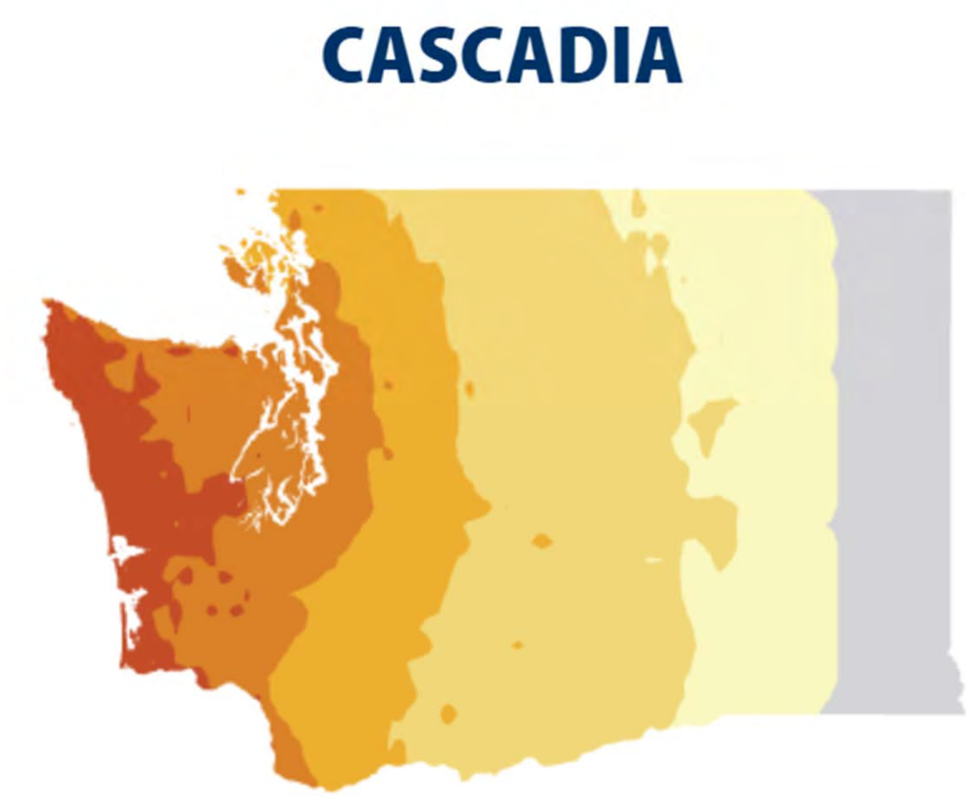
2001 Nisqually Earthquake

- M6.8 Deep Earthquake
- February 28, 2001
- Duration: 45 sec
- Damage = $1-4 Billion
- 1 death (heart attack)

Photo: Fenix Café, Seattle, WA

Subduction Zone Earthquakes

- Impact to the entire region
- Very long duration
- Often result in tsunamis



Scenario: M9.0 earthquake on the Cascadia megathrust
Estimated Economic Loss = $21.0 Billion

1964 Great Alaska Earthquake & Tsunami

- M9.2 Subduction Zone Earthquake
- Duration: 4 min 38 sec
- Damage = $2.8 Billion
- 131 deaths
- Massive landslides and 27ft high tsunami

Photo: Fourth Avenue in Anchorage, AK

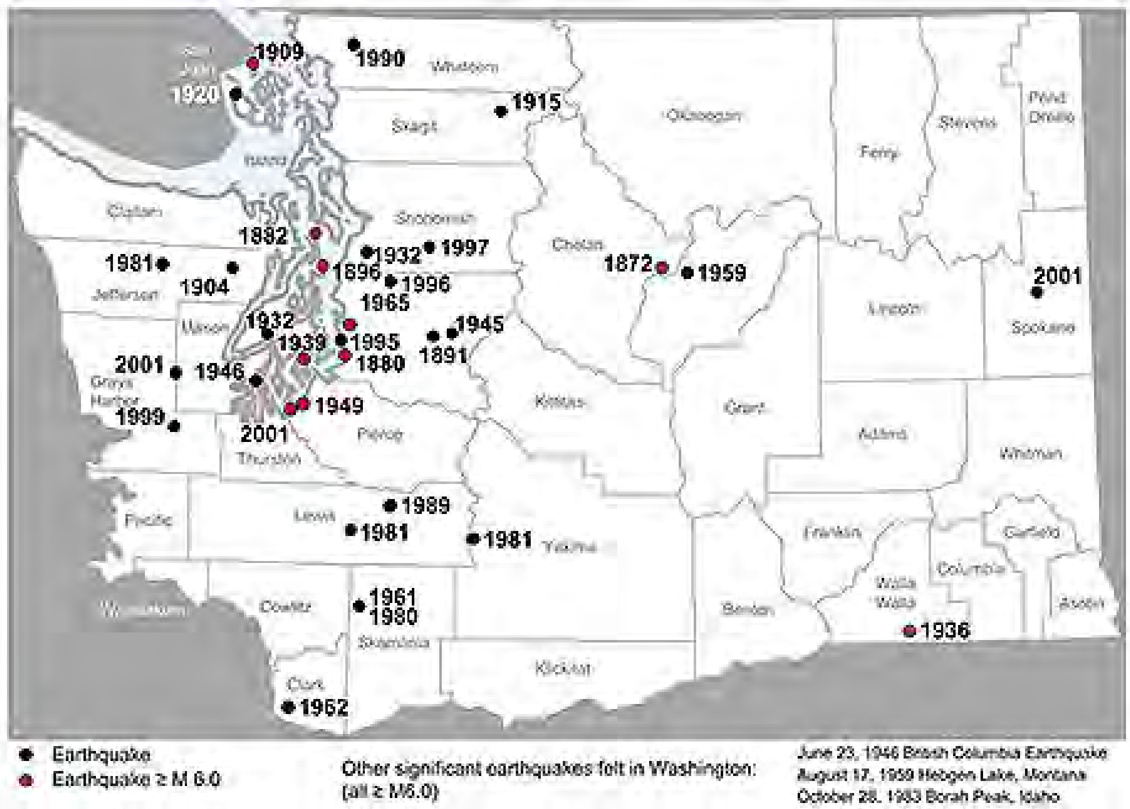
2018 Anchorage Earthquake

- M7.1 Crustal Fault Earthquake
- Damage ~ $100 Million
- 0 deaths
- Structural damage was limited
- Utility service maintained
- Strict building codes, seismic retrofits, population awareness

Photo: Vine Road near Wasilla, AK

History of Washington State Earthquakes

- 1946 M7.3 Vancouver Island
- 1949 M7.0 Olympia, WA
- 1965 M6.5 Kent/Des Moines
- 2001 M6.8 Nisqually



Learning From the Past

- 1906 M8.3 San Francisco Earthquake
  - Much of San Fran destroyed by fire, US govt. recognizes the problem
- 1933 M6.4 Long Beach, CA Earthquake
  - 120 schools destroyed → Field Act standards for school design
- 1964 M9.2 Great Alaska Earthquake
  - First discovery of subduction zones, led to significant development of US seismic design codes
- 1971 M6.5 San Frenando Earthquake (Los Angeles, CA)
  - Destroyed several hospitals → OSHPD established
  - Code changes for wall anchorage in tilt-up concrete buildings

Learning From the Past

- 1977 National Earthquake Hazard Reduction Program established (NEHRP)
    - Improve earthquake hazard identification and seismic design practices

- 1989 M6.9 Loma Prieta Earthquake (Santa Cruz, CA)
    - Understanding of soft-soil amplification effects on seismic forces

- 1994 M6.7 Northridge Earthquake (Los Angeles, CA)
    - Significant investment in seismic fault mapping and seismicity
    - Code changes for steel moment frame design

History of Seismic Design Codes

- 1961 UBC – (8) pages of seismic provisions (based on 500 yr return period)
- 1976 UBC – (12) pages of seismic provisions, introduced importance factor
- 1988 UBC – (30) pages of seismic provisions, building type specific factors
- 2000 IBC – (74) pages of seismic provisions, site-specific site class & spectral response (Sds), based on 2500 yr return period (MCE)
- 2006 IBC – (120) pages just on seismic loads (ASCE 7 adopted as reference)
- 2018 IBC – (162) pages just on seismic loads (ASCE 7)