State DOT Seismic Resiliency Assessment Process and Mitigation Program

Bruce Johnson,
Former ODOT
Bridge Engineer

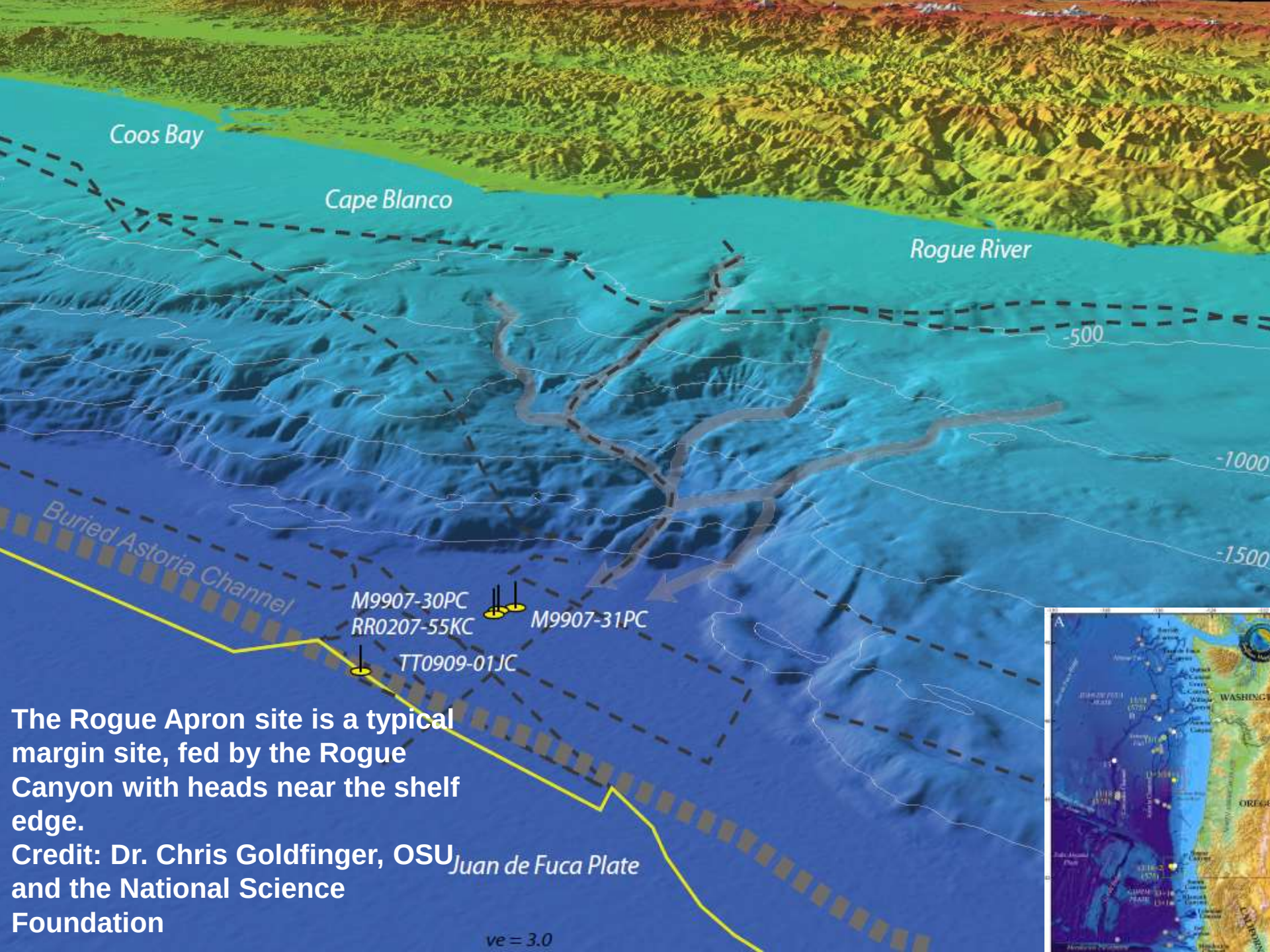
International Seismic Conference, September 2019

10-Step Process for Resiliency Planning

1. Assess Vulnerability of Assets (bridges and landslides)
2. Identify bridge damage states and landslides/rockfall dynamic stability
3. Validate Design Criteria consistency with risk
4. Estimate cost of mitigation (retrofit or replace)
5. Identify Lifeline Routes and Establish priority for rescue, recovery
6. Estimate impact to rescue efforts and economy
7. Prioritize plan for mitigation, considering condition of assets
8. Establish Resiliency Investment options
9. Develop triage approach for reduced level of mobility
10. Coordinate investment plan statewide with other modes/sectors through DHS/TSA Regional Resiliency Assessment Program (RRAP)

Brian Atwater, USGS Confirms John Adams, Canadian paleo seismic researcher's 1990 proposal

Buried grey ghost (Western Red Cedar) tree rings analysis show they died around 1700 and silt deposits along the Chehalis River reflect Japan records of a large earthquake that generated a tsunami in that year. (early 1990's)



The Rogue Apron site is a typical margin site, fed by the Rogue Canyon with heads near the shelf edge.
Credit: Dr. Chris Goldfinger, OSU and the National Science Foundation

In Cascadia, onshore and offshore paleoseismology have revealed a long history of great earthquakes.

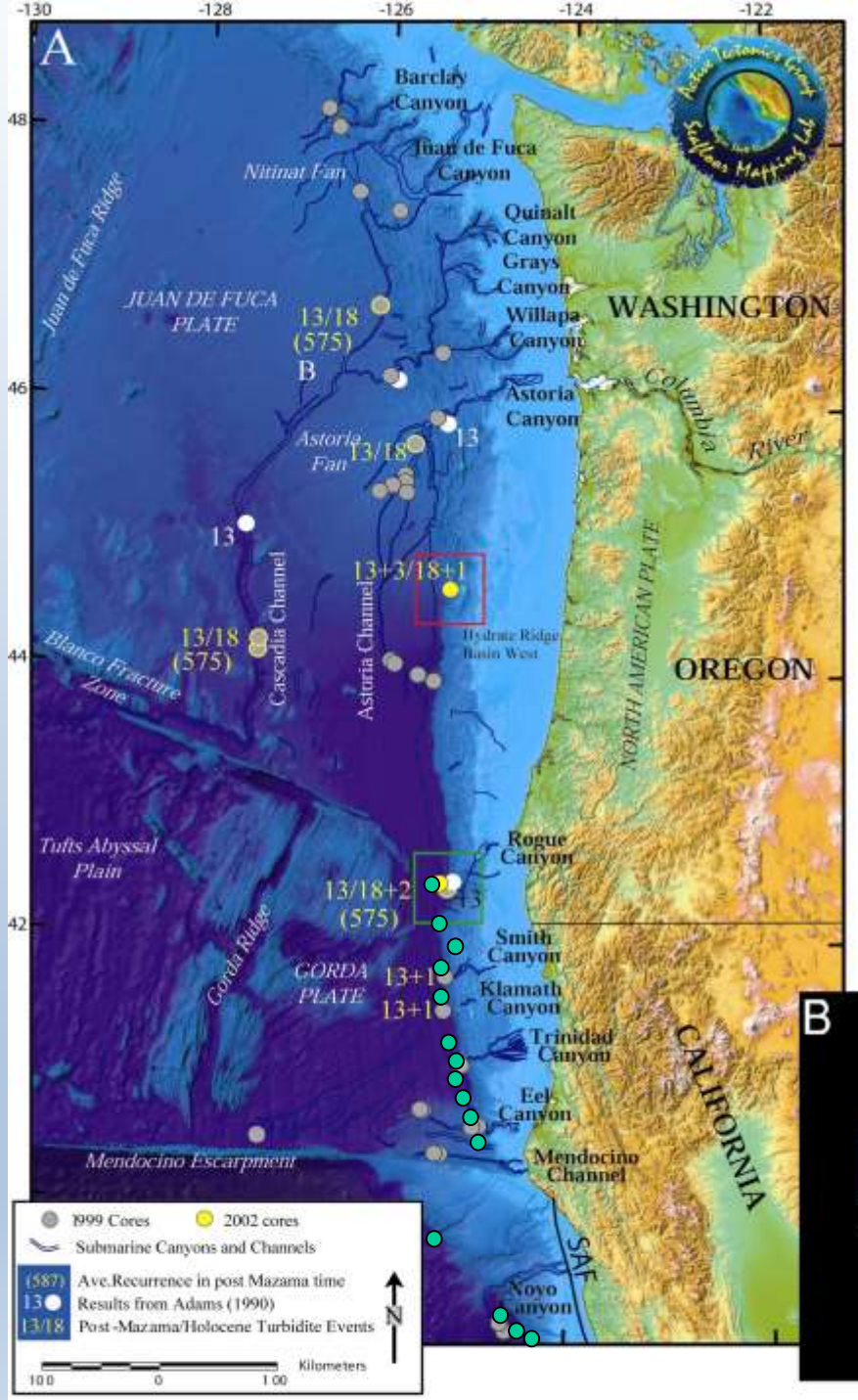
We set out in 1999 to prove the turbidite story wrong, and failed.

Cascadia Turbidite Paleoseismology based on event correlation along strike.

1) Aerial extent
2) Synchroneity, and
3) Sedimentology.

Stratigraphic correlation, tests of synchronous triggering, and 14C ages have led to a credible (we think) record of 43 events of variable size and strike length during the Holocene.

Credit: Dr. Chris Goldfinger, OSU.



Turbidite Paleoseismology:

Extending the earthquake record

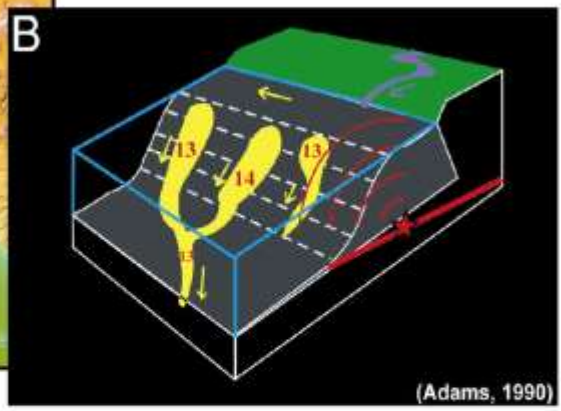
Cascadia Core Sites:

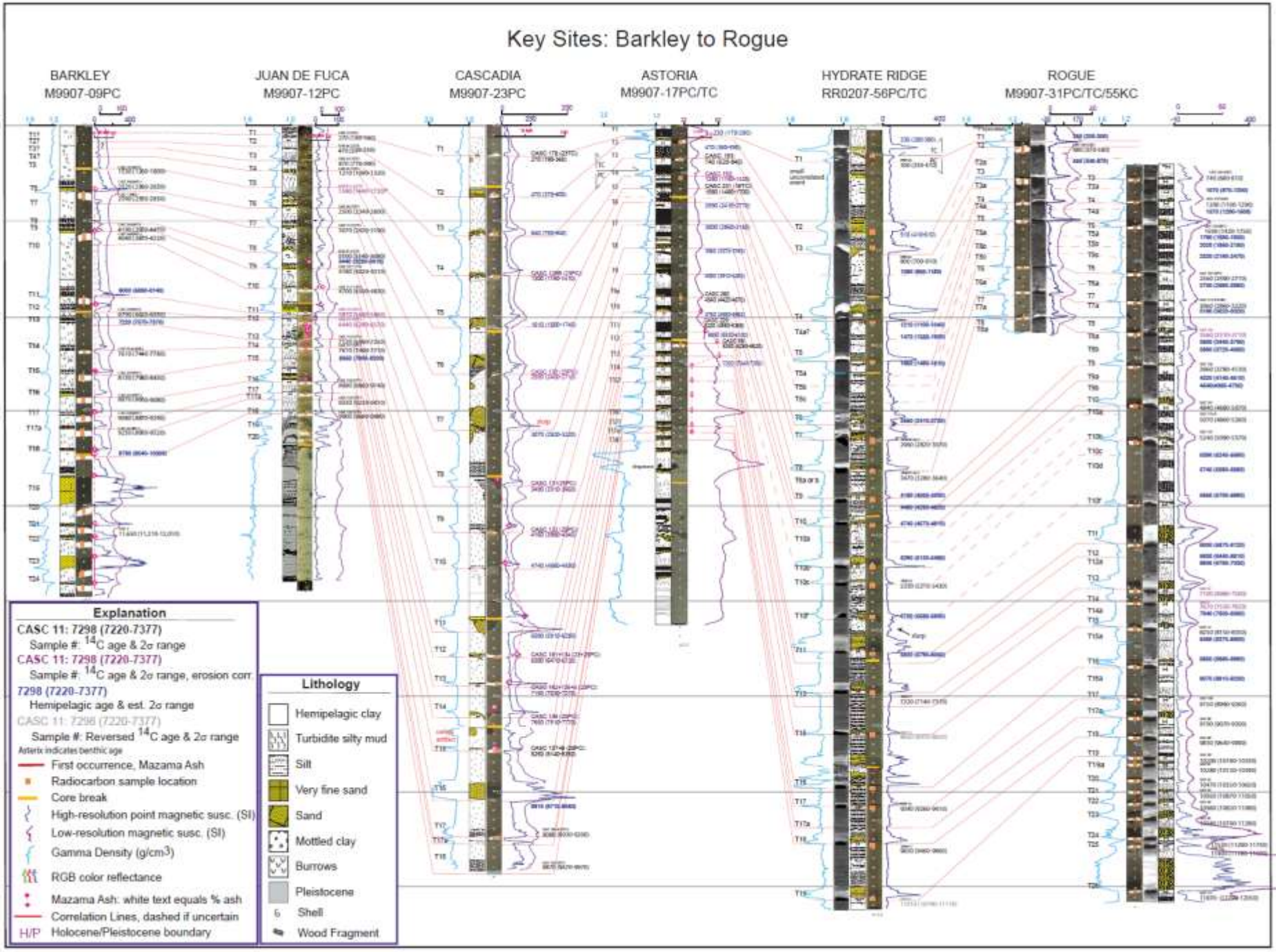
1999 = gray

2002 = yellow

2009 = green

Selected older existing cores = white




Key Sites: Barkley to Rogue
BARKLEY
M9907-09PC
JUAN DE FUCA
M9907-12PC
CASCADIA
M9907-23PC
ASTORIA
M9907-17PC/TC
HYDRATE RIDGE
RR0207-56PC/TC
ROGUE
M9907-31PC/TC/55KC
0 cm
100 cm
200 cm
300 cm
400 cm
500 cm
600 cm
700 cm
800 cm
Explanation
CASC 11: 7298 (7220-7377)
Sample #: 14C age & 2σ range
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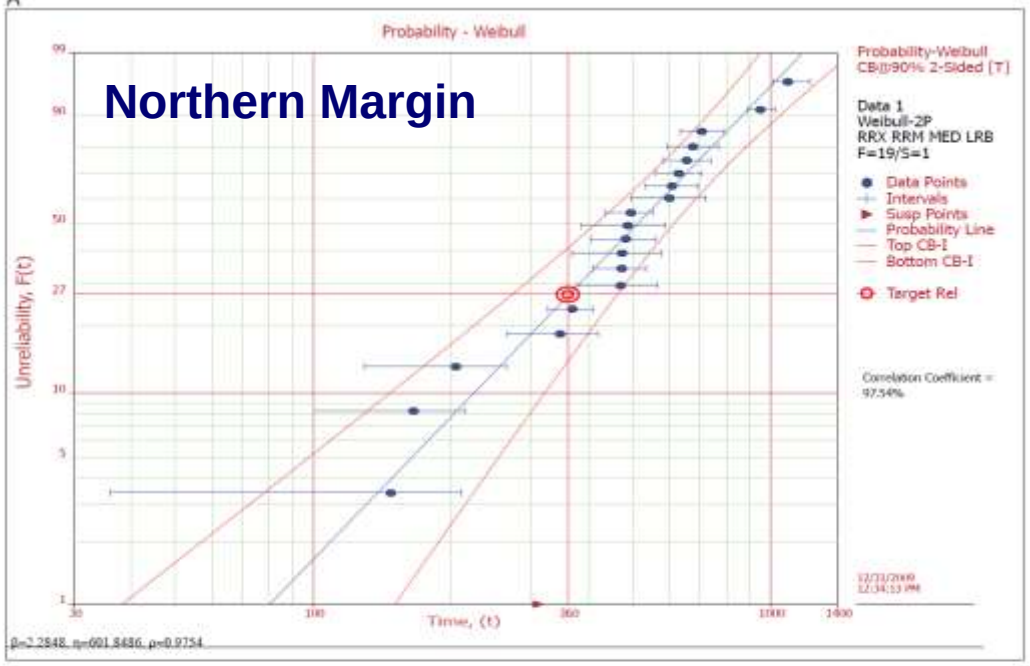
7298 (7220-7377)
Hemipelagic age & est. 2σ range
CASC 11: 7298 (7220-7377)
Sample #: Reversed 14C age & 2σ range
Asterix indicates benthic age
First occurrence, Mazama Ash
Radiocarbon sample location
Core break
High-resolution point magnetic susc. (SI)
Low-resolution magnetic susc. (SI)
Gamma Density (g/cm3)
RGB color reflectance
Mazama Ash: white text equals % ash
Correlation Lines, dashed if uncertain
H/P Holocene/Pleistocene boundary
Lithology
Hemipelagic clay
Turbidite silty mud
Silt
Very fine sand
Sand
Mottled clay
Burrows
Pleistocene
Shell
Wood Fragment

For the northern margin, probabilities are relatively low, many intervals longer than 360 years are in the paleoseismic record. The failure analysis suggests at 360 years, 25% of repeat times will have been exceeded. Conditional probability in 50 years is 12% (7-15%).

For the southern margin, 70-93% of repeat times will have been exceeded. Conditional probability in 50 years is 37% (32-42%).

A



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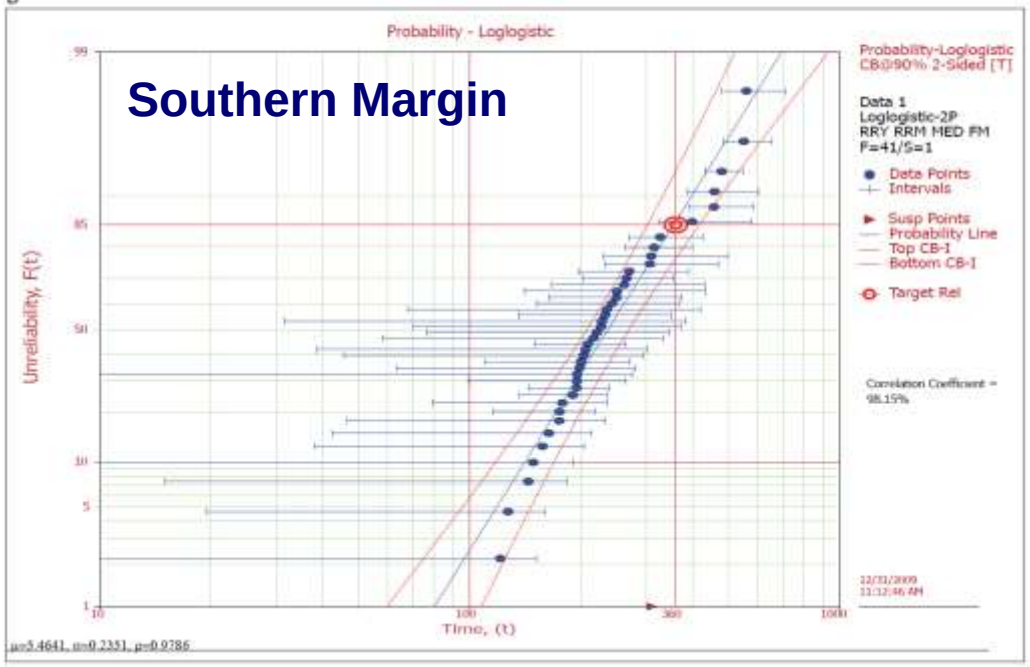
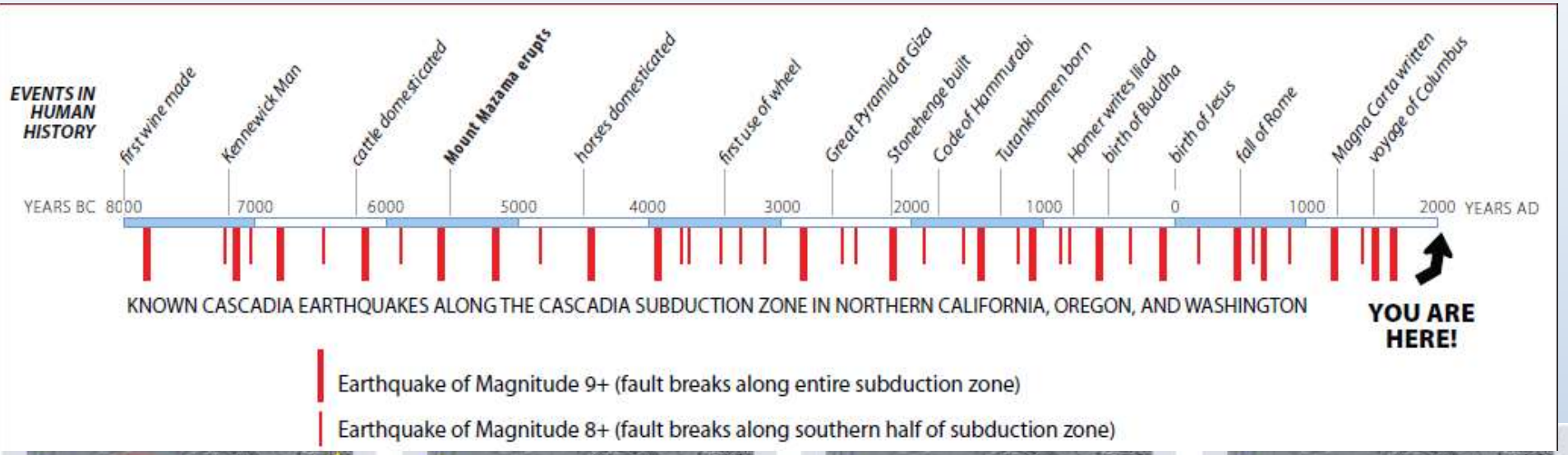
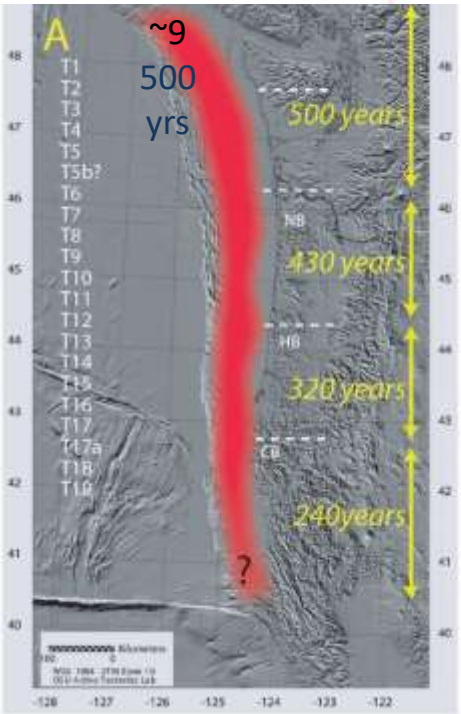
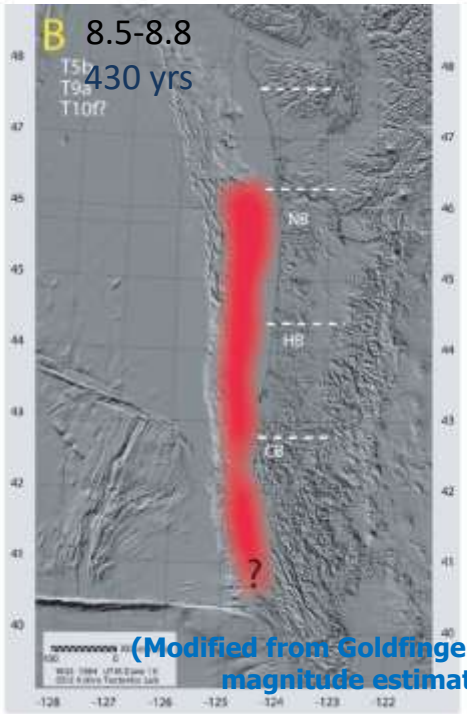
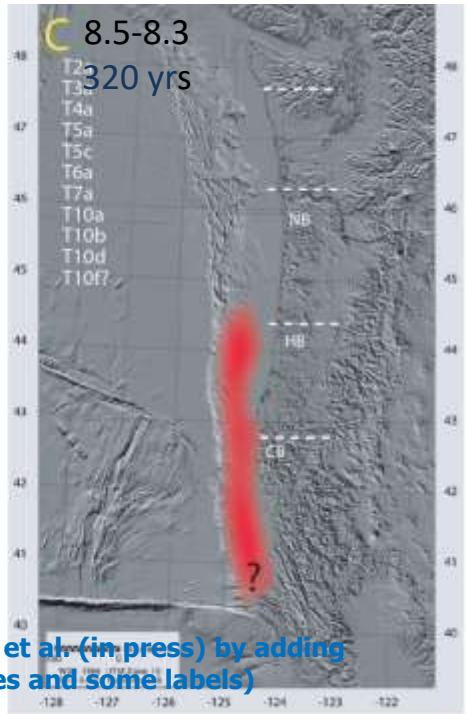


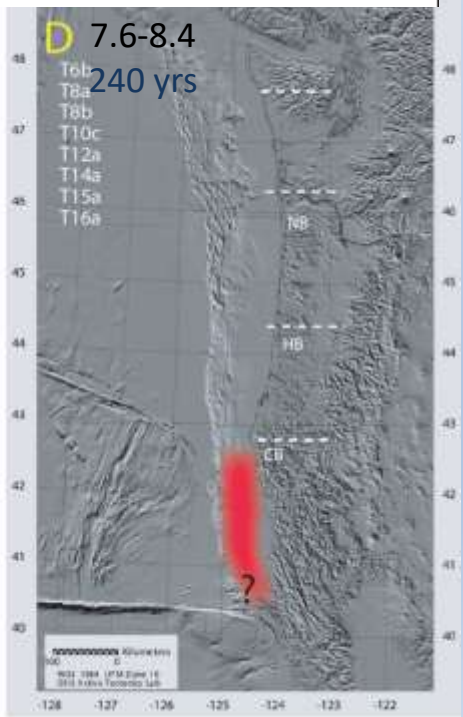
Cascadia Subduction Zone Earthquakes











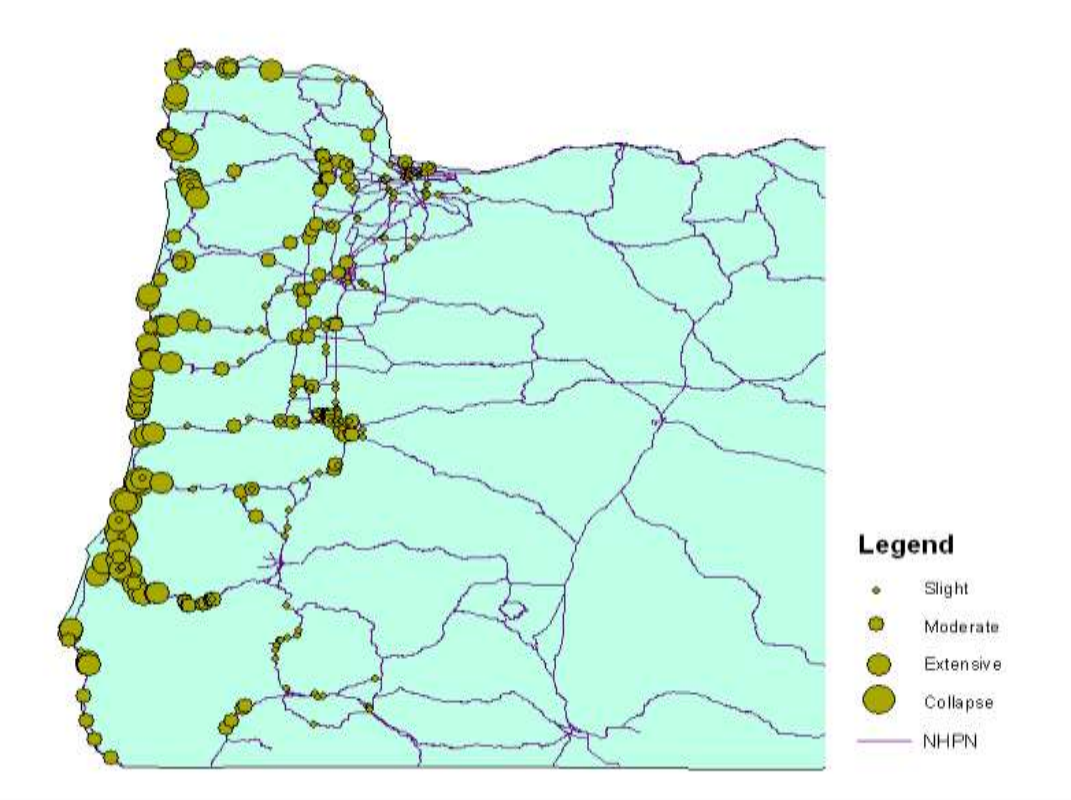
(Modified from Goldfinger et al. (in press) by adding magnitude estimates and some labels)

FOCUS ON HIGHWAY BRIDGES
Cascadia Subduction Zone Earthquake (Magnitude 9.0)

6 complete collapses
64 extensive
106 major
164 slight

Estimates Loss:

- **$1,080** million for bridge repair and replacement
- **Significant Economic losses** (travel time related losses)



Route	Damage States			
	Slight	Moderate	Extensive	Complete
I-5 (MWC)	4	1	0	0
I-5 (MLL)	16	3	1	0
I-5 (DJJ)	27	0	0	0
I-84	13	1	0	0
US-101	7	14	36	5
US-26	7	5	0	0
I-205	8	2	0	0
I-405	7	0	0	0
US-30	4	2	2	0
US-20	5	3	5	0
OR-38	3	2	1	0
OR-42	4	13	13	1
Others	59	60	6	0
Total	164	106	64	6

Transportation Resiliency depends on Landslides, as well as Bridges

New & Retrofit Highway Bridge Seismic Design Criteria

"Life Safety" (no collapse) connects beams to the columns.

"Serviceability" strengthens the substructure for use within 72 hours after an event. (Building code – "Immediate occupancy")

Hazard Level - Recurrence Interval for Highway Bridges

National Code (AASHTO) - Design for "Life Safety" (no collapse) at a 1000-year recurrence interval using USGS 2002 Hazard Maps.

Oregon Code – Design for "no collapse" at a 1000-year recurrence interval using 2014 USGS Hazard Maps and "Serviceability" Design for usability within 72 hours after a CSZ Scenario event, 2014 (USGS) . (2-level design criteria)


Collapse
I-5 Interstate Bridge


Slight to
Moderate
I-205 Glenn Jackson Bridge

Retrofitting progress

First 16 years since vulnerability was identified

Years	Actions	
1994/1997	Prioritized total bridge needs	1155
1985-2012	Phase 1 retrofit added to projects (STIP & OTIA III program) bridges addressed	355
Future	Bridges still needing retrofitting (Over 200 years at current funding)	800

Oregon's Seismic Design Development

Adopt FHWA 2009 LRFD Seismic Design Guide Specs

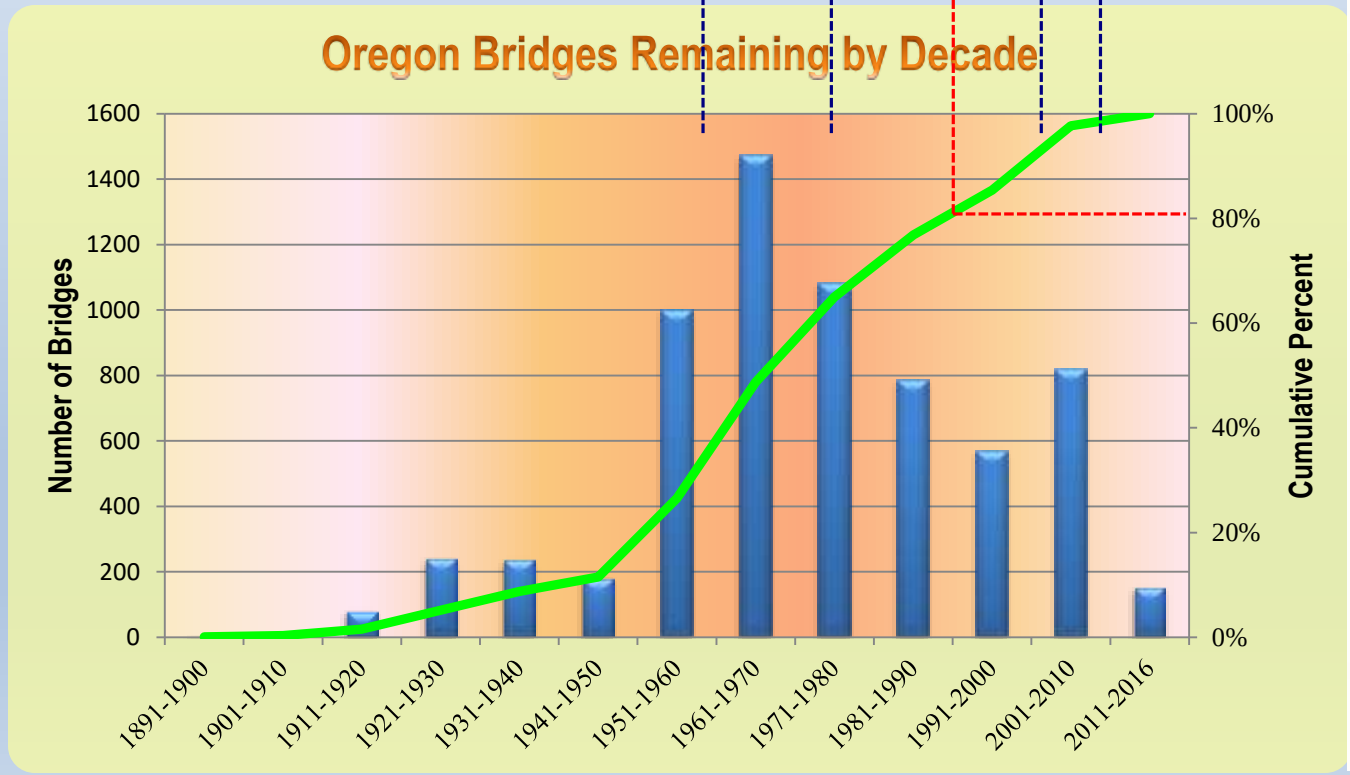
Adopt USGS 2002 Seismic Hazard Maps

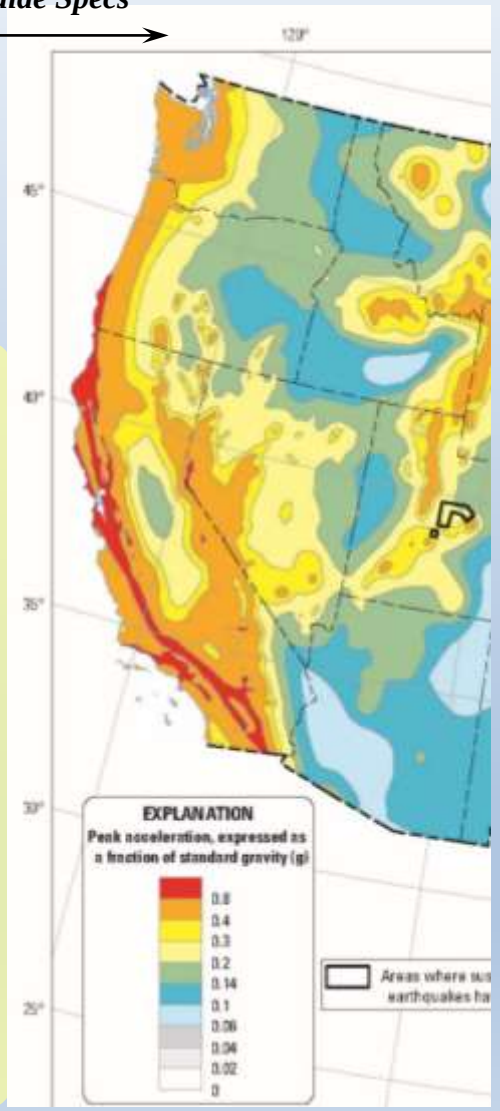
Adopt Seismic Hazard Maps & FHWA '83 Seismic Design Specs

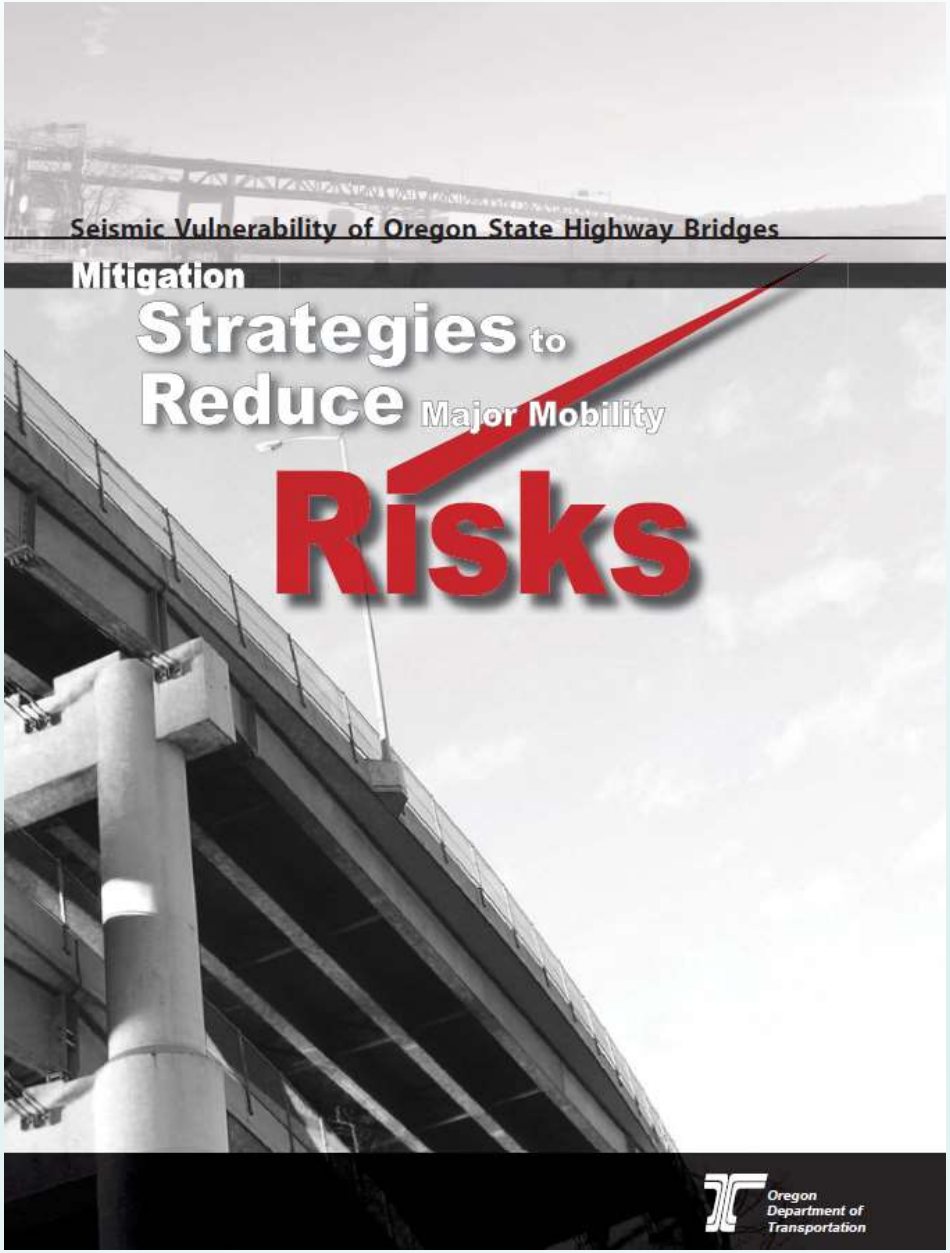
Seismic force up to 12%g

Seismic force up to 6%g

Seismic loads typically not considered







Available on the ODOT Bridge Engineering Section website at:

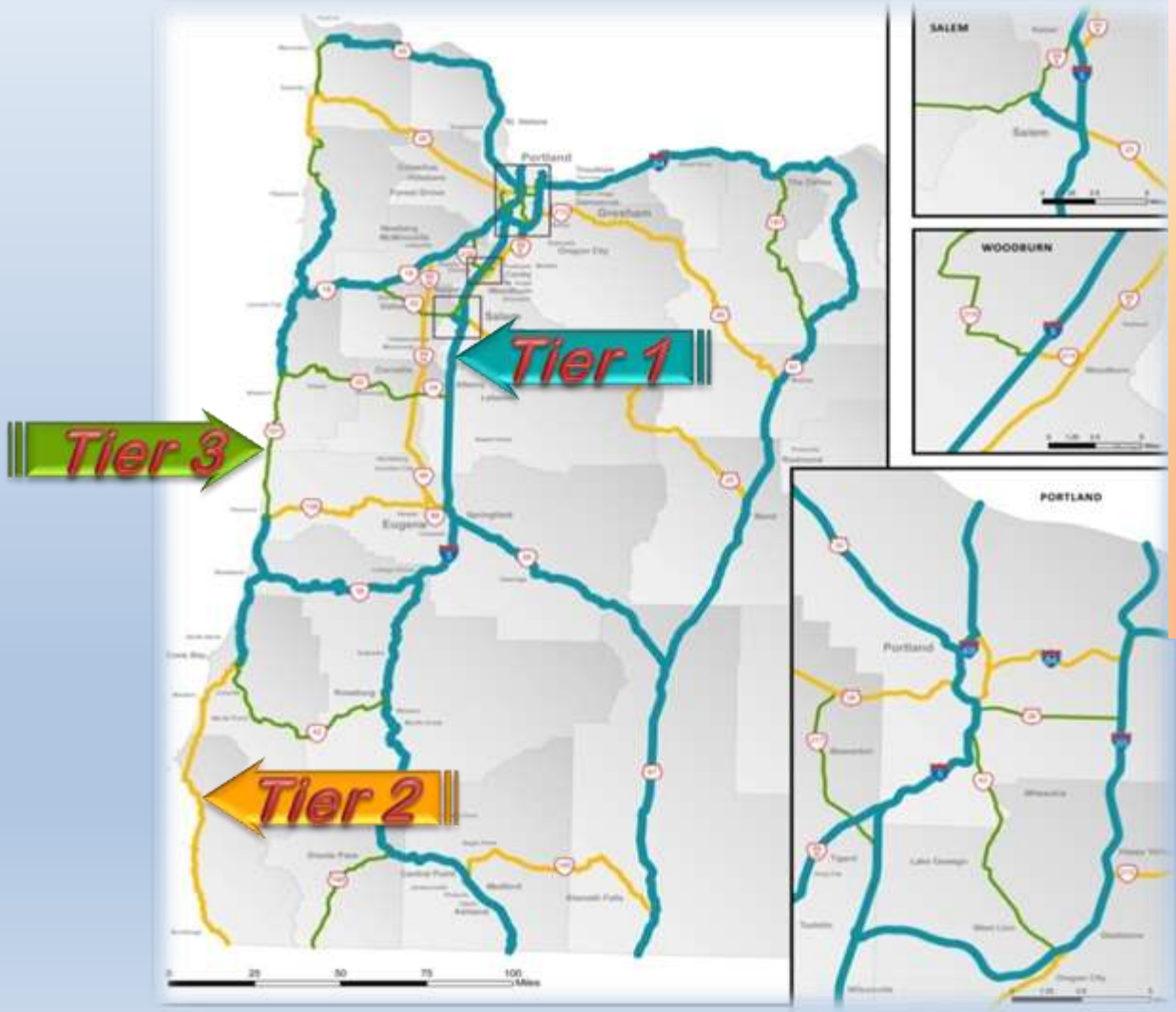
http://egov.oregon.gov/ODOT/HWY/BRIDGE/

November 2009

- Identify strategic lifeline routes
- Minimize long term economic damage
- Estimate Cost to address overall bridge condition

-Oregon Highway Seismic Options Report

Recommended Lifeline Routes



- **2012** – Seismic Lifelines evaluation
- **2012** – First "Full" (Phase 2) seismic retrofit project for ODOT

Lifelines – Their Function

Facilitate:

- ***<u>Rescue</u> – Emergency response to treat casualties and evacuate survivors***
- ***<u>Relief</u> – Provide basic necessities, restore social equilibrium, and assess damage***
- ***<u>Recovery</u> – Restoring commerce and the economy; bring things back to "normal"***

Lifeline Goals

1. ***Support Survivability and Emergency Response Efforts Immediately Following the Event***

2. ***Provide Transportation Facilities that are Critical to Life Support Functions for an Interim Period After the Event***

3. ***Support Statewide Economic Recovery***

SEISMIC PLUS PROGRAM
State Highway Network

LEGEND

- Program Phase 1
- Program Phase 2
- Program Phase 3
- Program Phase 4

Phase 5 (replacements) not shown for clarity

- Interstate
- U.S. Routes
- Oregon Routes
- County
- City Limits

1 in = 39 miles

0 20 40 80 Miles

N

GIS

August 2014

ODOT's Seismic Retrofit Program

By the numbers:

- *138 bridges to be replaced*
- *390 bridges to be retrofitted*
- *190 bridges to be rehabilitated and retrofitted*
- *1185 landslides and rockfalls to be mitigated*

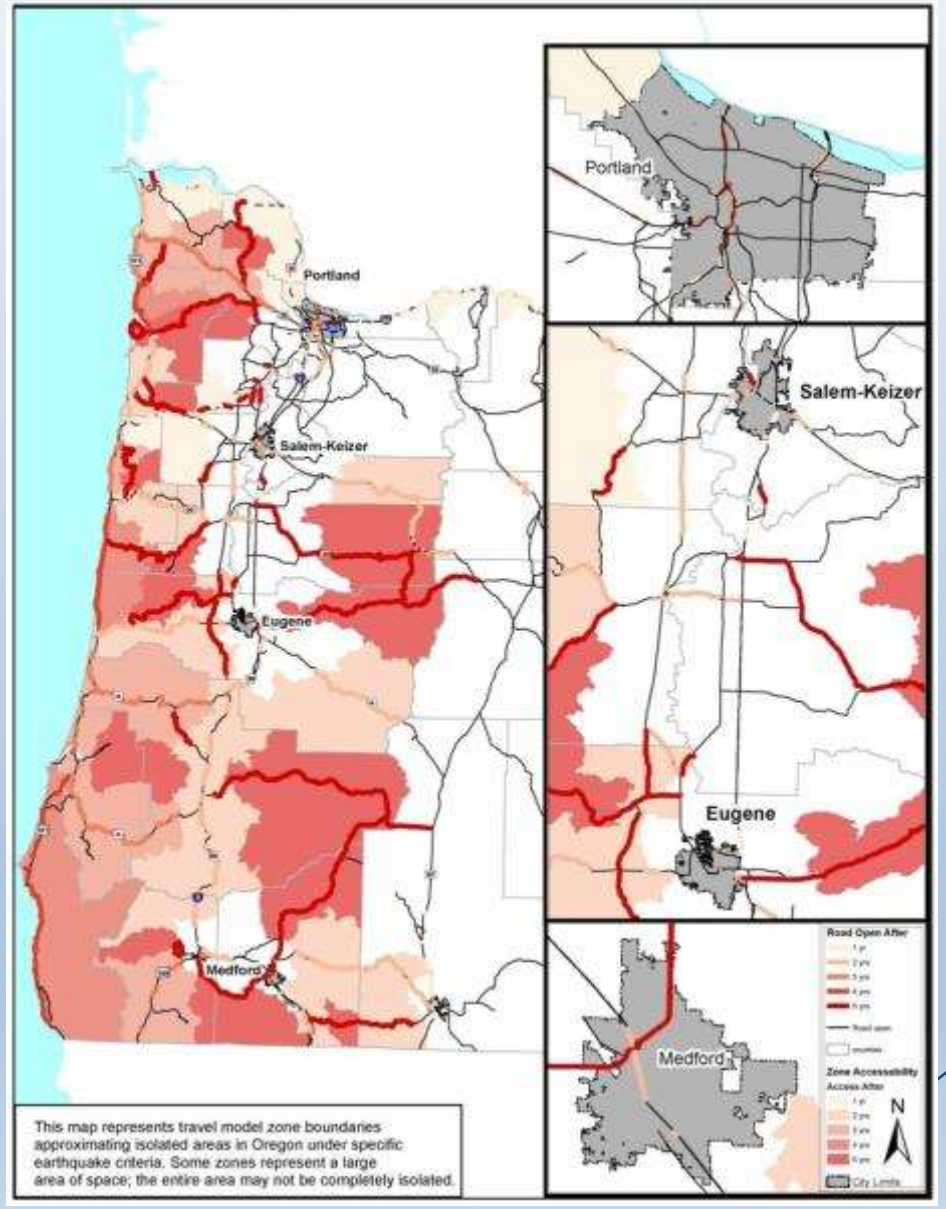
- *Program Cost ~ $5.2B*

Total Seismic PLUS Program Cost

Program Phases	Total Bridge Cost	Landslides/Rockfalls Cost	Total Seismic PLUS Program Costs
1	$738 Million	$197 Million	**$935 Million**
2	$632 Million	$272 Million	**$904 Million**
3	$612 Million	$483 Million	**$1,095 Million**
4	$640 Million	$126 Million	**$766 Million**
5	$1,432 Million	$0	**$1,432 Million**
Total	**$4.1 Billion**	**$1.0 Billion**	**$5.1 Billion**

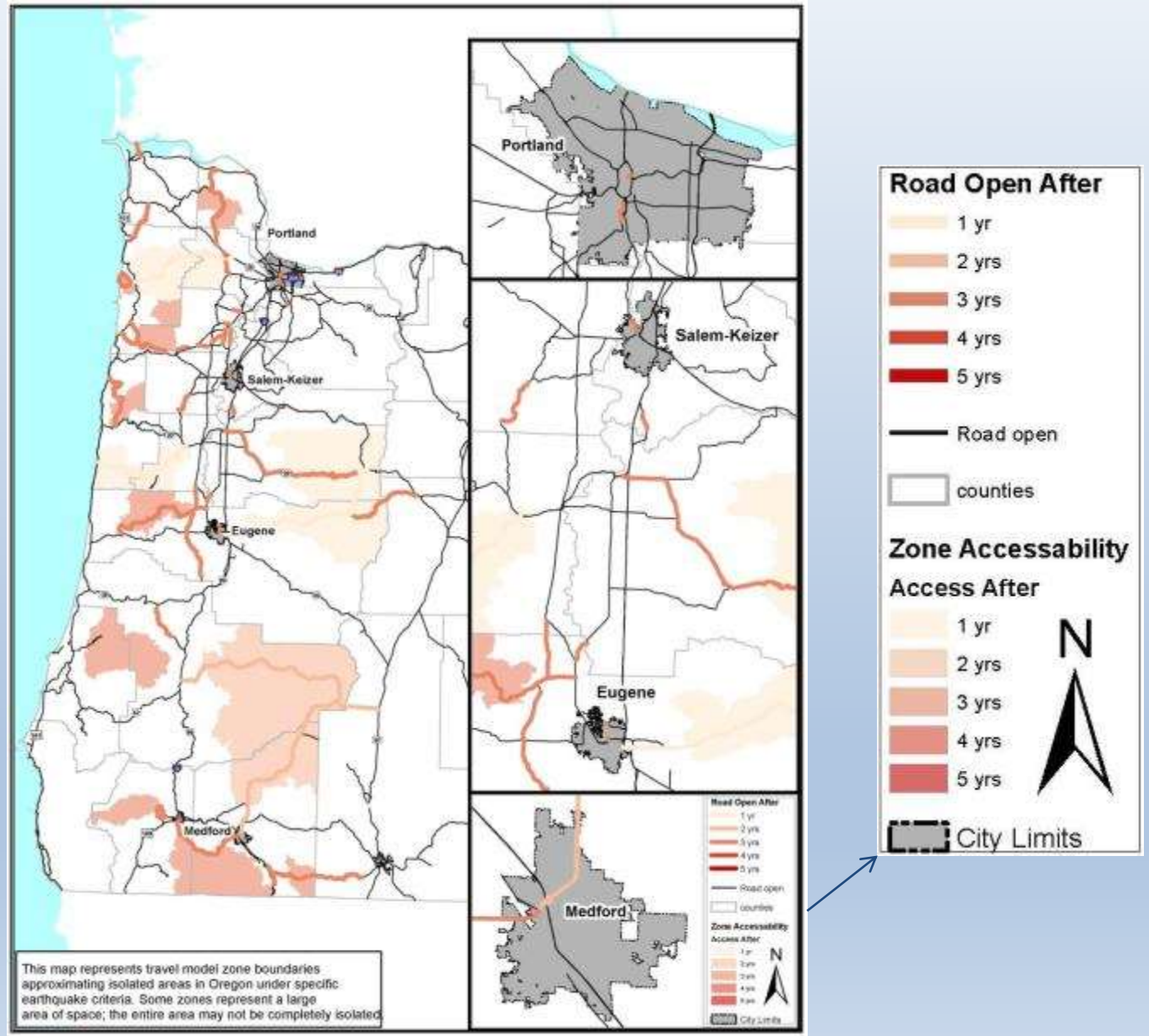
Major Seismic Event: Isolated Areas

Total economic loss: $350 B



Isolated Zones: Full Seismic Program

Reduce economic loss by:
$84 B



Cost = $5.1 Billion
Economic Loss Avoided = $84 Billion

Take Home Learnings… Next Steps

- Bridge condition – include seismic
- Bridge funding
- Engage local communities for Triage Approach

ODOT Seismic Expenditures In HB2017

Example: $500 million/yr from HB2017

State funds: $250 million

Seismic: $61 million/yr ($31 bridges, $15 unstable slopes and $15 facilities)

- Goal is to complete Phase 1 in 25 years
    - Study Triage Approach using lower cost alternative local routes for Phases 2-5
- Earmarked funding for Southern Oregon Triage and Center Street Bridge in Salem

Overall Seismic Resiliency Triage Strategy

$200 M over 20 years

Southern Oregon triage
(bridges and unstable slopes on I-5 and OR 140)

Coastal forward supplies & seismic response kits

1. Astoria
2. Newport
3. Coos Bay

Local ODOT triage
(address strategic ODOT and local bridges/major river crossings)

Seismic Options Report
(not part of $200 M total above)

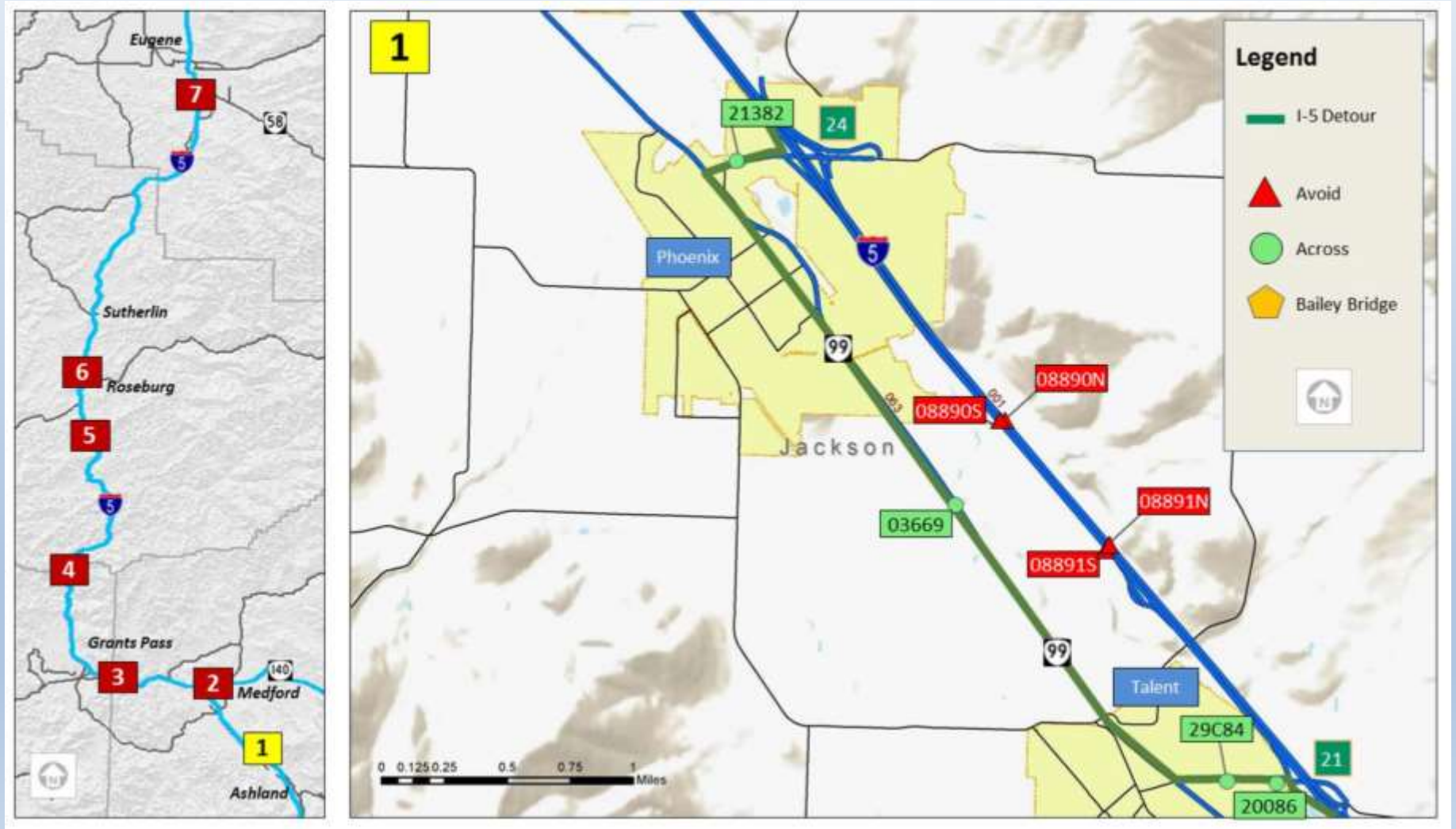
- Phase 1 – partially funded
- Phase 2

Southern Oregon Triage Routes

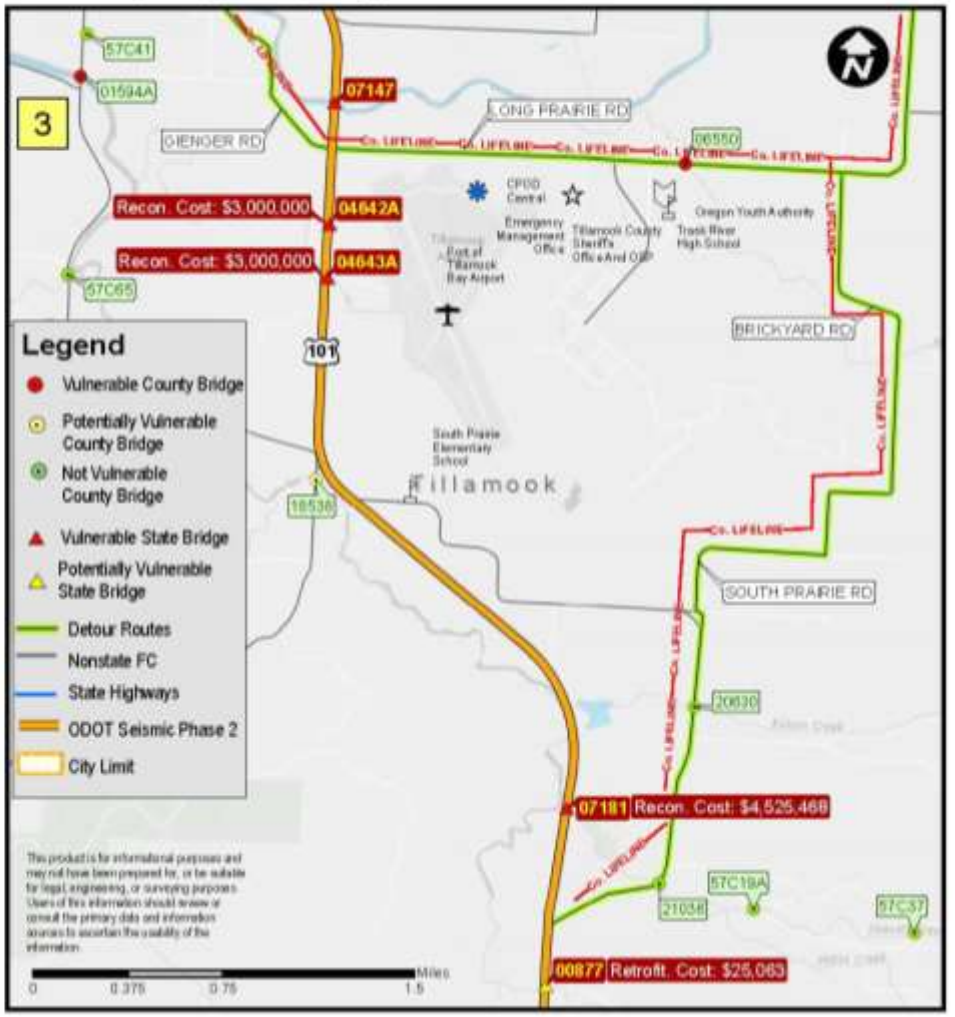
Interstate 5 and OR 140

- I-5 and OR 140 *(key lifeline routes)*
- 17 bridges
  7 unstable slopes
- $35 million

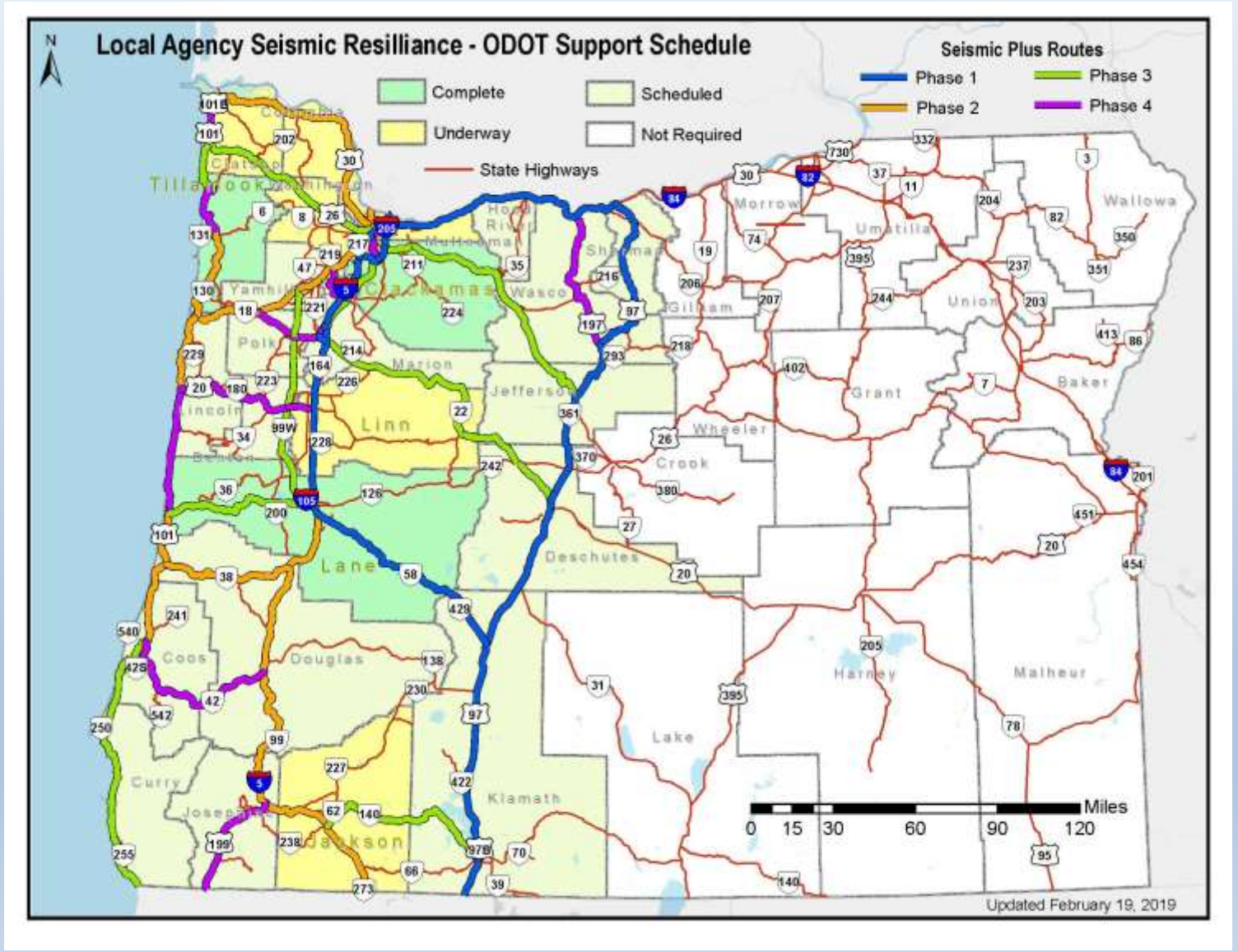
Rogue Valley Triage Lifeline Routes



ODOT – Local Agency Triage Routes



Local Agency Seismic Triage Project

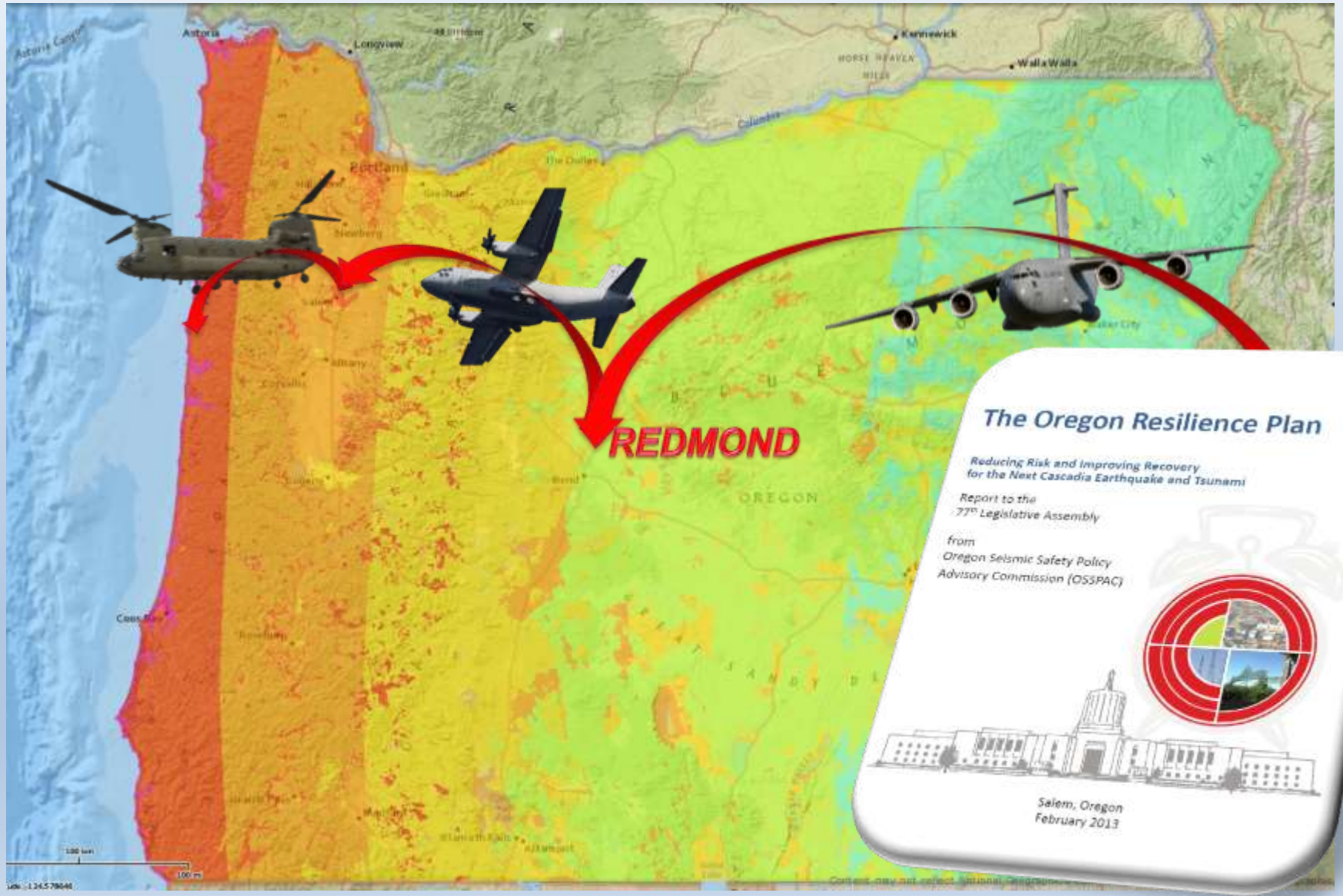


Other Modes Coordination

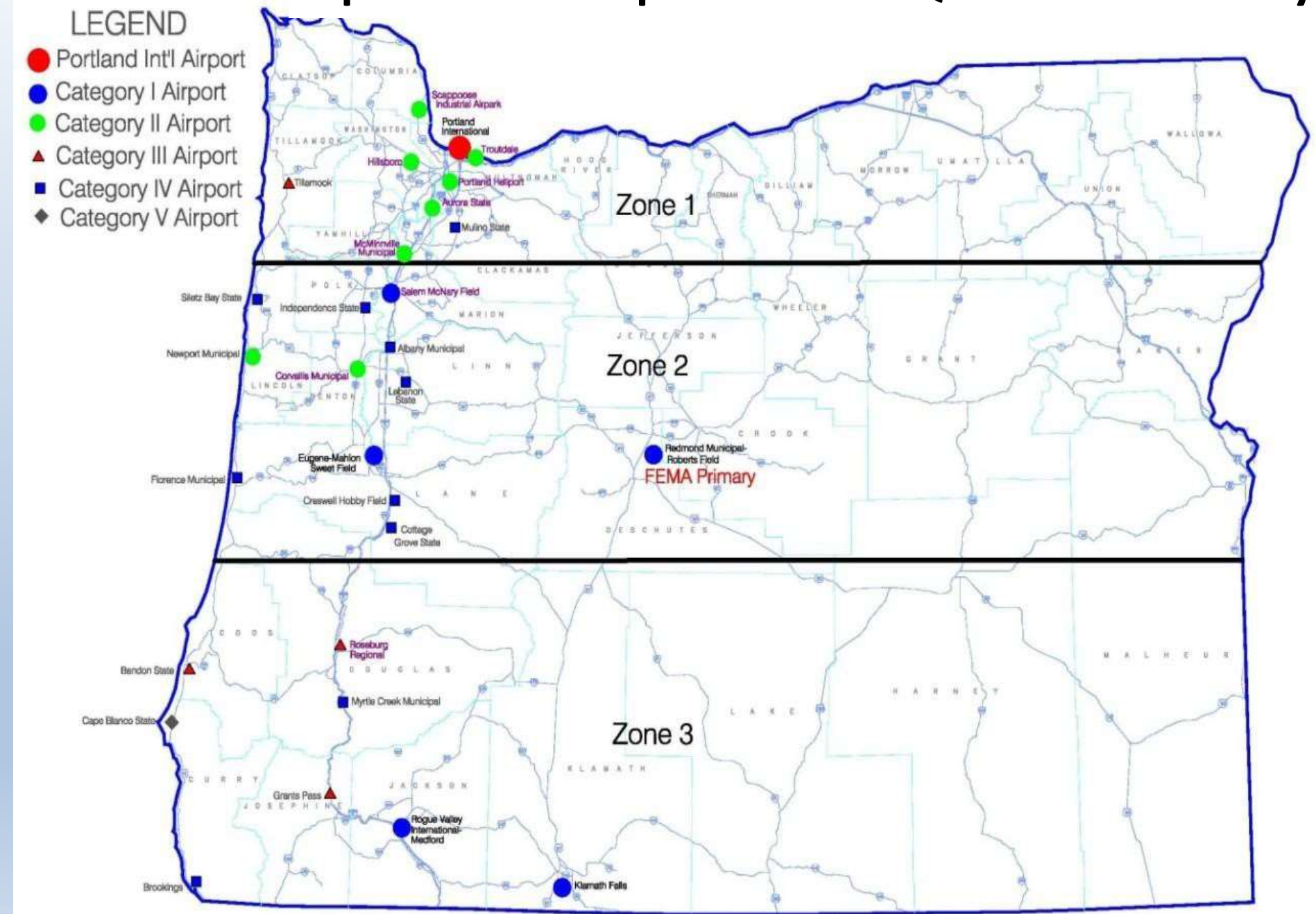
1. ***The Redmond Airport will be the nexus of relief supplies entering Oregon (Other states may have their own supply issues and may not be able to help)***

2. ***Relief supplies will come overland to the valley and the coast***

Post-Earthquake Response



Operational Airports After EQ-Tsunami – Valley



Columbia River Ports

Port of Portland Facilities

Coastal Ports

PORT OF GARIBALDI 1910 100 2010

PORT OF TILLAMOOK BAY

Port of Newport

PORT OF TOLEDO OREGON

PORT OF ALSEA

PORT OF SIUSLAW CAMPGROUND & MARINA

PORT OF BANDON CHARLESTON AND BANDON

OREGON INTERNATIONAL Port of Coos Bay

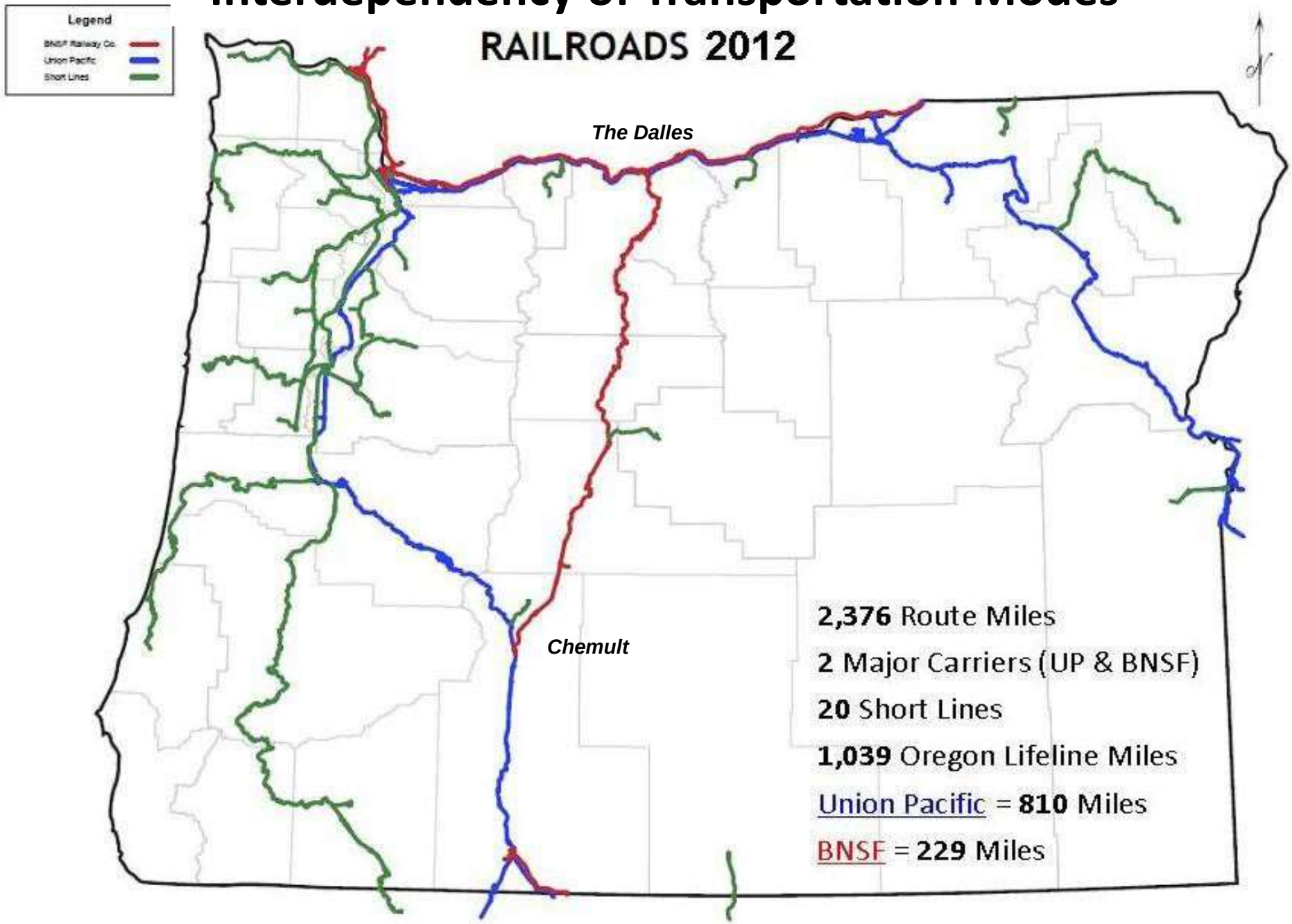
PORT OF UMPQUA

Port of Port Orford Port Orford, Oregon, USA

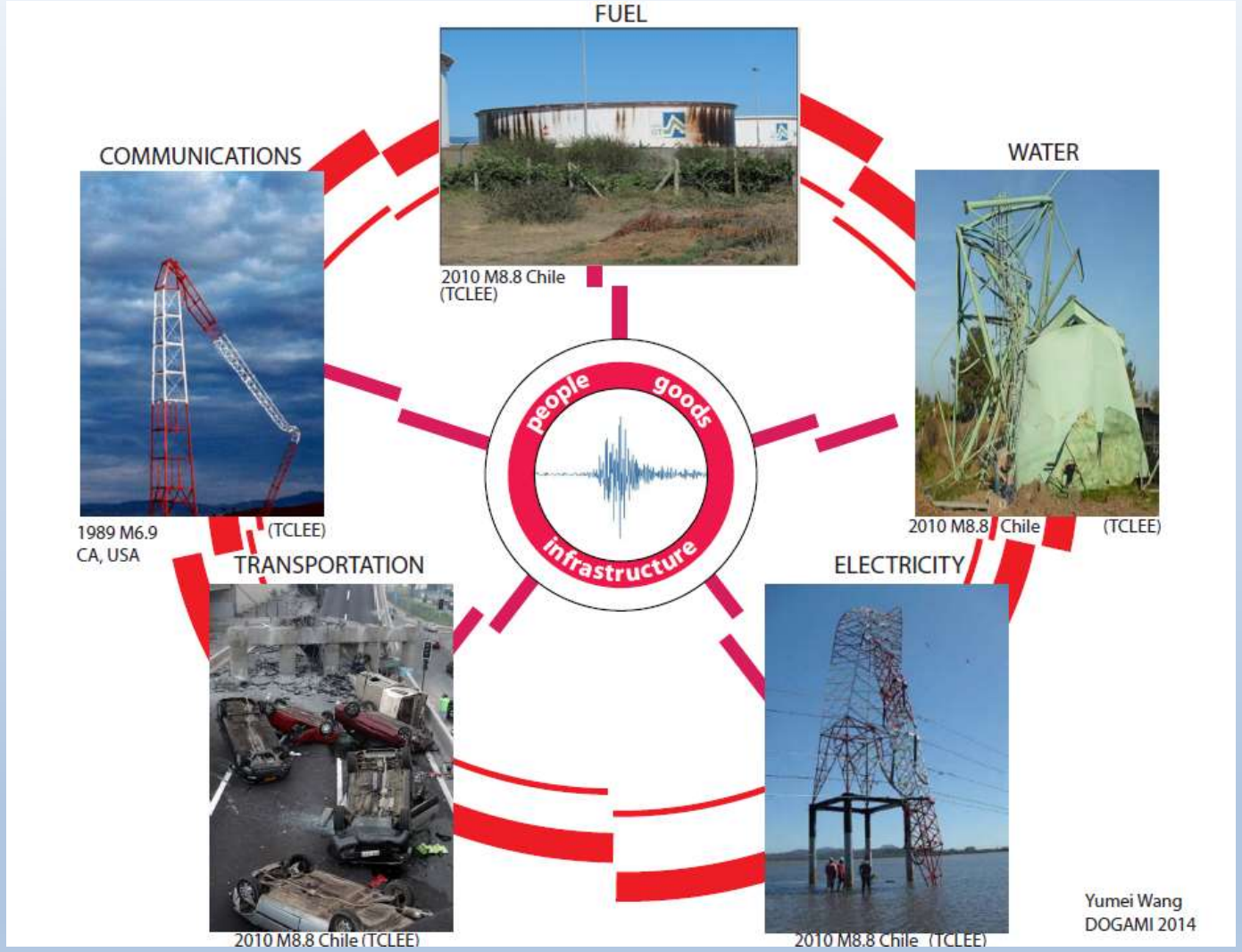
PORT OF BROOKINGS HARBOR

WELCOME PORT OF GOLD BEACH

Interdependency of Transportation Modes



Damage to Other Sector Lifelines and **interdependency** will slow restoration of services and rebuilding of the economy.



Key Finding – Liquid Fuel Dependency

- Liquid Fuel vulnerability is

a key issue for transportation

ODOT Resiliency Planning
10-Step Process

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9. *Develop triage approach for reduced level of mobility*
10. *Coordinate investment plan statewide with other modes/sectors through DHS/TSA Regional Resiliency Assessment Program (RRAP)*

Thanks for your attention.

Bruce Johnson, Former State Bridge Engineer, ODOT

Acknowledgement:
Albert Nako, ODOT Seismic Stnds Engr