Benefit-Cost Analysis
Seismic Retrofit of Portland URMs

Presentation to the URM Policy Committee

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Portland's URM Buildings

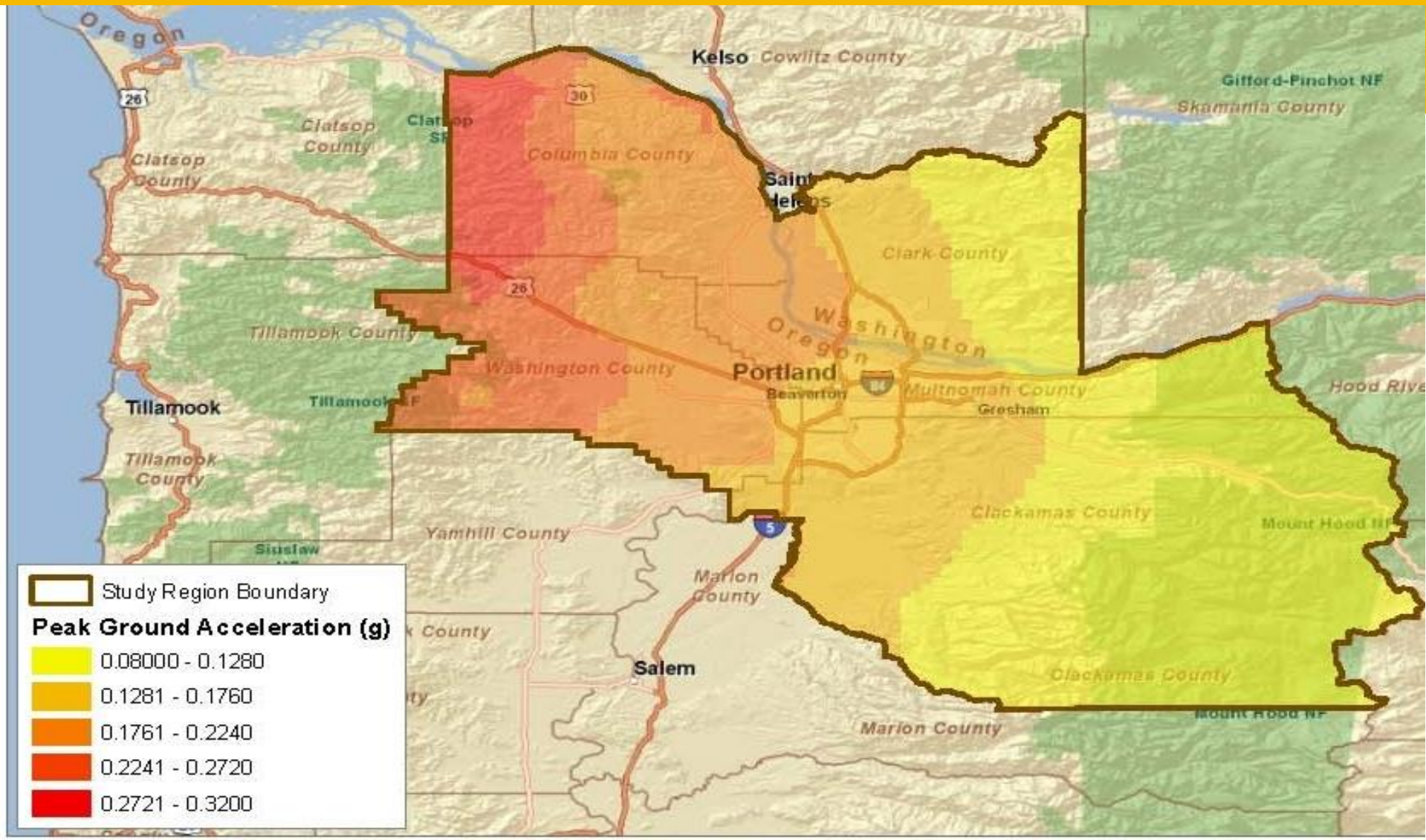
1,661 URM buildings excluding 1- and 2-family homes

- Built from 1870 – 1966, with more than 60% before 1930.
- 575, about 35%, listed as historic buildings.
- 80% are 1- or 2-story.
- 63% less than 10,000 SF, ~4% greater than 50,000 SF, average size is 12,451 SF.

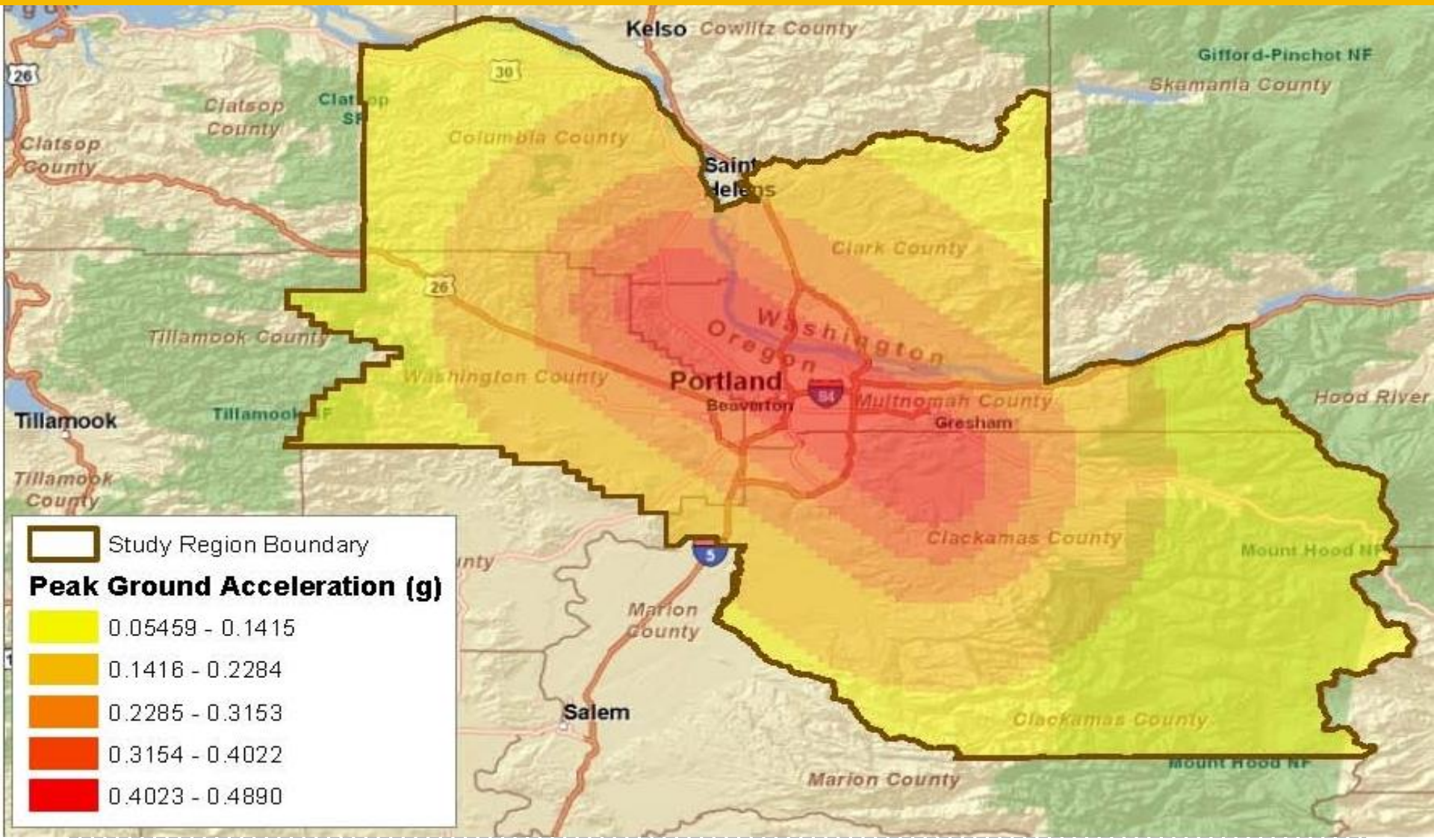
Seismic Hazards

- Most likely major earthquake to impact Portland is a large magnitude earthquake on the CSZ.
- Probability of a M9.0 on the CSZ in the next 50 years is about 12% to 18%.
- Worst-case scenario is a M7.0 on the Portland Hills Fault – much higher levels of ground shaking than a Cascadia M9.0, albeit with a very low probability of occurring.

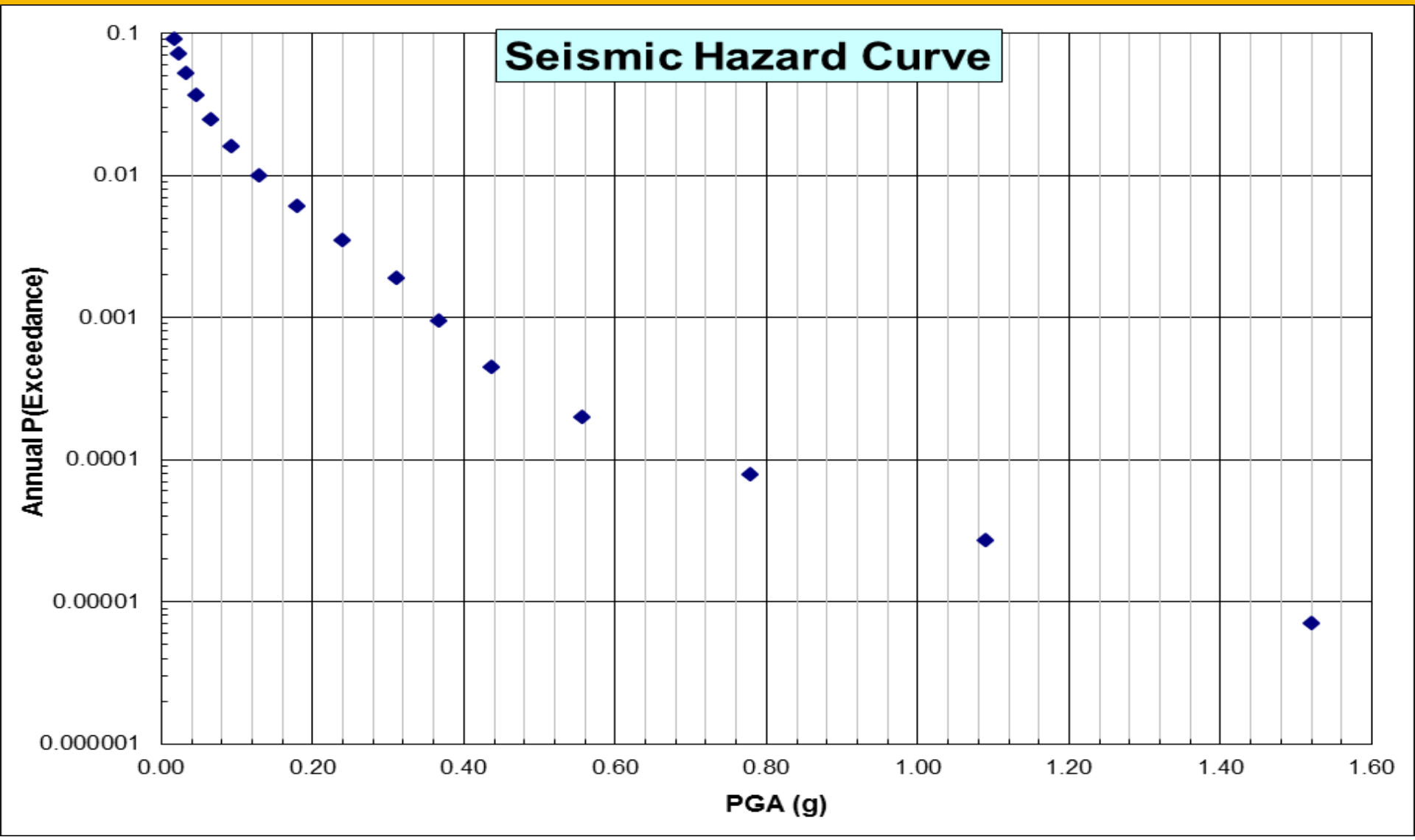
USGS Shake Map: Cascadia M9.0



USGS Shake Map: Portland Hills M7.05



Probabilities of Earthquake Ground Motions



BCA Consulting Project

- The perspective of the BCA study is holistic – the primary focus is on the overall benefits and costs for the City and its residents.
- Neither the costs nor the benefits of seismic retrofits are distributed homogenously to all stakeholders.
- However, for the City and its residents, the benefit-cost ratios do not depend on who pays for the retrofits.

BCA for *Typical* Building

- The BCA results will likely vary for each Portland URM.
- Data to complete meaningful BCAs on a building by building basis does not exist.
- BCAs are completed for a *typical* URM building as the starting point.
- The sensitivity BCA results to a range of input parameters has been evaluated.

What is the *Typical* URM Building?

- Location: approximate centroid of URM inventory.
- Site Class: D – Stiff (Firm) soil.
- 10,000 SF.
- Low-rise building.
- Building replacement value $200/SF.
- Contents replacement value: $100% of building value.
- Displacement costs: $2.00/SF one time and $2.00/SF per month.
- Average occupancy: 1 person per 1,000 SF.

Benefit-Cost Analysis (BCA)

BCA Software (Excel):

- Software used for Oregon Seismic Rehabilitation Grant Program, with minor modifications.
- Very similar to software is used by Department of Administrative Services for BCAs of seismic retrofits of State buildings.
- Draws heavily on FEMA BCA software.
- Many input parameters are HAZUS based, either verbatim or with modifications to be more realistic for Portland and to correct omissions in HAZUS.

Portland's URM Classes 1 to 5

- Class 1: Critical Buildings.
- Class 2: Schools and Risk Category III buildings per the Oregon Structural Specialty Code.
- Class 3: Buildings $\geq$ 4 stories or $\geq$ 300 occupants or residential with $\geq$ 100 units.
- Class 4: Buildings not in Classes, 1, 2, 3 or 5.
- Class 5: 1 or 2 stories, with 0 to 10 occupants.

Estimated Retrofit Costs Per SF

- Class 1: $111.45
- Class 2: $82.62
- Class 3: $68.77
- Class 4: $51.00
- Class 5: $20.40
- Costs include construction, usual soft costs and relocation costs for construction, per Retrofit Standards Committee 2015,updated by 2%.

Technical Data Inputs

- Seismic fragility parameters that define the probability of each damage state (slight, moderate, extensive and complete) at every level of ground shaking:
  - Existing URMs: HAZUS with revisions including accounting for demolition of earthquake damaged URMs at less than the nominal “complete” damage state.
  - Post-retrofit URMs: Consulting team estimates that vary with URM Class because the seismic performance objectives vary with URM Class.

Technical Data Inputs

- Casualty rates for each damage state (slight, moderate, extensive or complete as defined by HAZUS)
- HAZUS-based with substantial modifications to reflect:
  - The unique characteristics of URMs that are not fully addressed by HAZUS, and
  - Correct the explicit omissions in HAZUS, including:
    - Heart attacks, car accidents, falls, power failure which causes failure of a respirator, incidents during post-earthquake search and rescue or post-earthquake clean-up and construction activities.

Technical Data Inputs

- Correct the explicit omissions in HAZUS, continued:
  - Electrocution, tsunami, *landslides, liquefaction, fault rupture, dam failures, fires or hazardous material releases.*
- Other omissions include:
  - Effects of *extremely long duration shaking and large magnitude aftershocks*
  - Casualties from falling interior hollow clay tile partition walls.
  - Undercounting of casualties for people adjacent to URMs on streets or sidewalks or in shorter adjacent buildings (especially from multi-story URMs).

Benefit-Cost Ratios: *Typical* URM Buildings

- Class 1: N/A[1]
- Class 2: 1.474
- Class 3: 1.661
- Class 4-A: Same as Class 3
- Class 4-B: 1.967
- Class 5: 1.94[2]

[1] Class 1 has only 10 buildings: 6 very small utility buildings, 1 industrial hazmat building, and 3 emergency response buildings – no typical building.

[2] Class 5 URMs don't meet the criteria for *typical* URM buildings. Benefit-cost ratio adjusted downwards.

Benefit-Cost Results: Caveats

- Results are for the *typical* building and will vary with variations in all of the data inputs documented in the BCA Report.
- Key parameters that affect the benefit-cost ratios include:
  - Combination of discount rate and post-retrofit building useful lifetime.
  - Retrofit costs.
  - Building values, contents values and building occupancy.
  - Casualty rate estimates for each HAZUS building damage state (slight, moderate, extensive and complete).
  - Site Class.

Discount Rate and Useful Lifetime

Present Value Coefficient

Useful Lifetime (years)	Present Value Coefficient vs. Discount Rate and Useful Lifetime						
	1%	2%	3%	4%	5%	6%	7%
30	25.81	22.40	19.60	17.29	15.37	13.76	12.41
50	39.20	**31.42**	25.73	21.48	18.26	15.76	13.80
100	63.03	43.10	31.60	24.50	19.85	16.62	14.27

Multipliers to Adjust Benefit-Cost Ratios

Useful Lifetime (years)	Benefit-Cost Ratio Relative to 2% Discount Rate and 50 Year Lifetime						
	1%	2%	3%	4%	5%	6%	7%
30	0.82	0.71	0.62	0.55	0.49	0.44	0.39
50	1.25	**1.00**	0.82	0.68	0.58	0.50	0.44
100	2.01	1.37	1.01	0.78	0.63	0.53	0.45

Benefit-Cost Ratios (BCRs) are Inversely Proportional to Retrofit Costs

- For example, if retrofit costs are $1,000,000 and the benefits are $2,000,000, then the benefit-cost ratio is 2.00.
- If the same retrofit cost $2,500,000 then the benefit-cost ratio would be 0.80.
- If the same retrofit cost only $500,000, then the benefit-cost ratio would be 4.00.

Typical Benefits by Category

Benefits Category	Percent of Benefits	Percent of Benefits (Rounded)
Building Damage	22.74%	23%
Contents Damage	17.37%	17%
Displacement Costs	4.10%	4%
Casualties	55.79%	56%
Total Benefits	100.00%	100%

- If the building value were double the typical value, then the benefits and BCR would go up by 23%.
- If the contents value were 50% of the typical value, the benefits and the BCR would drop by 8.5% (50% of 17%).
- If the occupancy were double or one-half of the typical value, then benefits and BCR would increase by 56% or decrease by 28%, respectively.

Effects of Site Class

Site Class	Relative Benefit-Cost Ratios	Percent Change
Site Class E	2.258	68.26%
Site Class D	1.342	None
Site Class C	0.961	-28.39%

- Soil sites generally amplify earthquake ground motions compared to rock sites.
- For identical buildings and retrofits, the BCR for Site Class C (Very Dense Soil and Soft Rock) would be ~28% lower than if the building were on Site Class D (Firm Soil).
- For identical buildings and retrofits, the BCR for Site Class E (Soft soil) would be ~68% higher than if the building were on Site Class D (Firm Soil).

Benefits and Costs Not Quantified

- The BCA are necessarily incomplete: there are parameters for which meaningful data does not exist or could not be estimated quantitatively.
- The benefits of retrofits may be ***underestimated*** because:
  - Damages to existing buildings may be underestimated:
    - Possible effects of liquefaction, settlement and lateral spreading, landslides, fire following earthquake, flood damage from broken water pipes or failed dams or reservoirs may increase damages.
    - The prevalence of asbestos may *substantially* increase repair costs, including debris removal.
    - Building damages may trigger Portland's existing mandatory retrofit ordinance if repair costs exceed the 2016 thresholds of $57.57 for 1-story URMs and $42.18 for 2-story+ URMs.

Benefits and Costs Not Quantified

- Additional economic losses are likely, including:
  - Litigation costs and settlement costs for deaths and injuries in URMs.
  - Business income losses.
  - Higher insurance premiums.
  - Loss of tenants and/or lower rents from greater awareness of risks from URMs.

Benefits and Costs Not Quantified

- The benefits of retrofits may be ***underestimated***:
  - The extent to which completing a seismic retrofit to a defined performance objective may increase a building's market value and rental income was not evaluated.
  - The historic value of URMs designated as historically important was not included in the BCA for *typical* URMs. Multipliers on building value could be 1.5 or 2.0 for designated buildings or up to 5.0 for National Historical Landmarks. Using historical multipliers would yield higher BCRs for historically important buildings.
  - After a major earthquake with widespread damage to URMs, the building equivalent of "pariah" may substantially decrease the market value of most URMs, perhaps to little more than the land value less the cost of demolition for the URM building. This occurred in Christchurch.
  - In the Christchurch earthquake, more than 90% of URMs were demolished, including many with low or very low levels of damage.

Benefits and Costs Not Quantified

- The benefit-cost ratios of retrofits may be ***overestimated***:
  - The estimated seismic retrofit costs, including likely asbestos abatement in most URMs, are lower than the actual costs.
  - The time necessary to complete seismic retrofits is longer than estimated with higher relocation costs and greater loss of rental incomes.
  - Existing tenants don't return after retrofit and it proves difficult to find new tenants after the retrofit.

Benefits and Costs Not Quantified

- The BCRs of retrofits may also be ***overestimated*** if some of the parameters for the defined *typical* building are not fully representative of typical values for Portland URMs:
  - The combination of discount rate and retrofitted building useful lifetime.
  - The typical values for building value, contents, value, displacement costs and occupancy.
  - The seismic vulnerability parameters for building damages, contents damages and casualty rates for each of the HAZUS building damage states (slight, moderate, extensive and complete).

Conclusions

- URMs unequivocally pose substantial risks to life safety, not only to occupants but also to persons adjacent to URMs during an earthquake.
- URMs also pose substantial risks of economic losses to both owners and tenants.
- Seismic retrofits have a well documented history of substantially reducing damages to URM buildings.

Key Issues

- Allocation of retrofit costs between building owners, tenants, the City of Portland and the State of Oregon?
- Timelines for completion of seismic retrofits?
- What are appropriate, achievable, and realistic seismic performance objectives for seismic retrofits for each of Portland's five defined URM Classes.

Questions ?