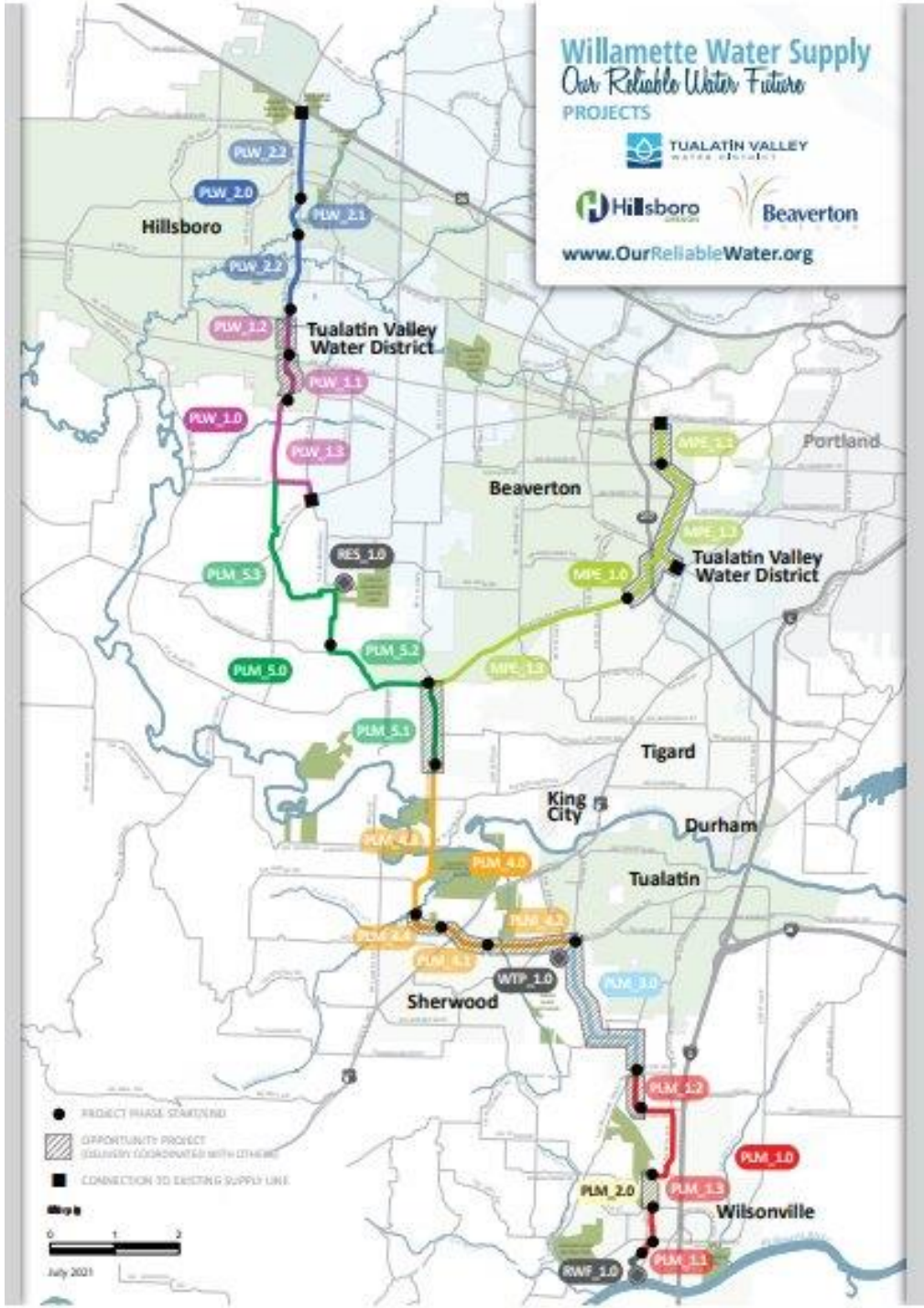


Willamette Water Supply Raw Water Facility Seismic Improvements

Scott Schlechter, PE, GE, D.PE

Project Background & Team

- Project part of larger WWSP
  - Challenging segment of program
- GRI subcontracted to Black & Veatch



Presentation Outline

01 PROJECT OVERVIEW & MITIGATION AREA FOCUS

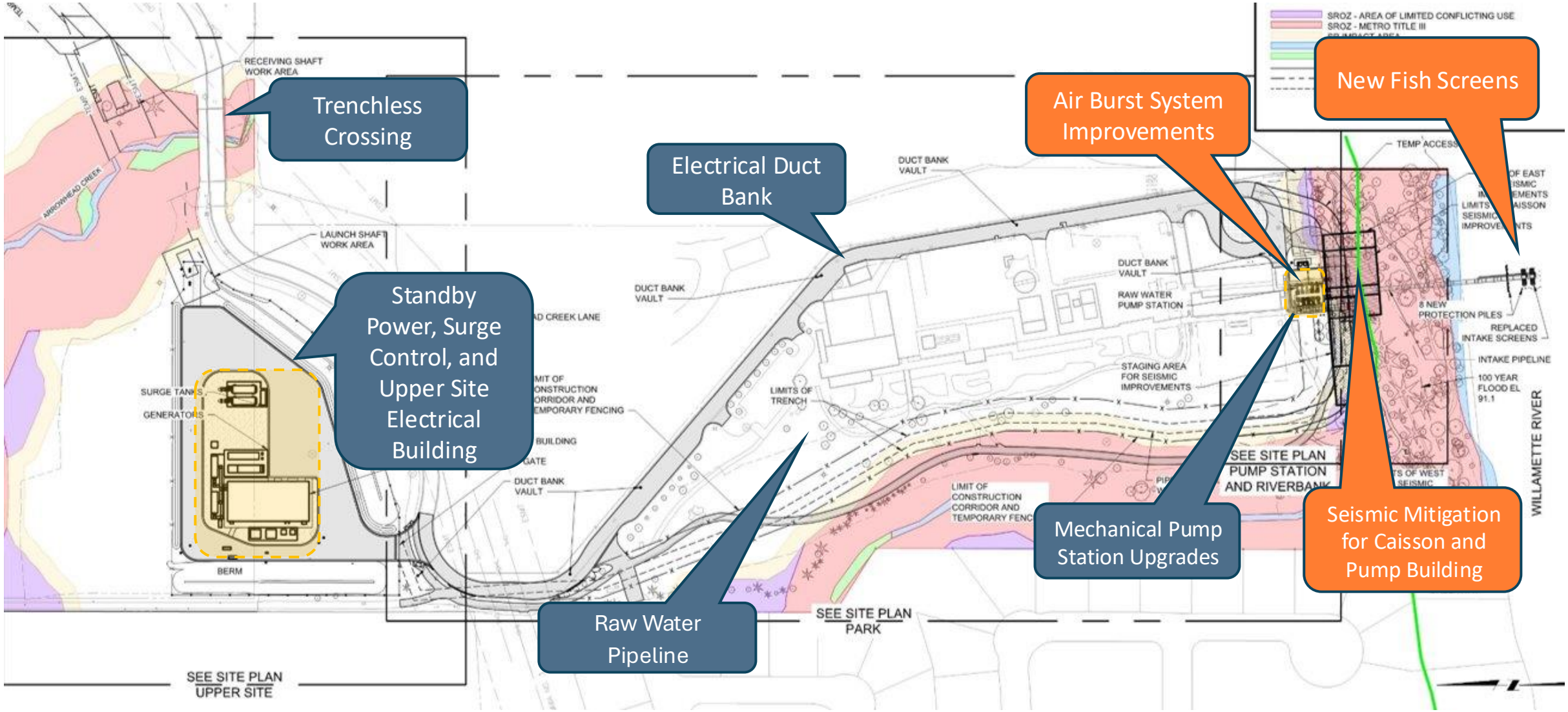
02 SEISMIC HAZARD OVERVIEW

03 DESIGN PROCESS – MULTIPLE CODE CONSIDERATIONS

04 SUMMARY

PROJECT OVERVIEW

PROJECT OVERVIEW





SITE OVERVIEW – LOWER SITE

SITE OVERVIEW – UPPER SITE



PERFORMANCE CRITERIA & EVALUATION OF STRUCTURES

WWSP Seismic Design Guidelines

- System to achieve 50% capacity within 48 hours following a full 2,475-year event
- The program had already completed a lot of upfront work regarding pipeline performance
- Information not yet developed for structures at beginning of project



CODE CONSIDERATIONS

- New pipelines (WWSP, ALA)
- New Buildings (ASCE 7)
- Existing Buildings (ASCE 41)
- WWSP Performance Criteria and Hazard Level



EERI 2017 Session Summary

Summary and Recommendations for Practice

- The Pacific Northwest is unique in the range of contributing seismic sources and implications to seismic design. Evolution of seismic design and built environment also create unique challenges.
- The seismic hazard variability within and between codes and design criteria can make communicating the risks to owners, design team, and the public challenging.
  - Meeting one code is generally easy.
  - Reconciling multiple codes on one project is more difficult.
- Design team is responsible for helping owner develop performance criteria. Owner must be involved in the process early and the entire design team must understand and scope the process as each site is unique!

GRI

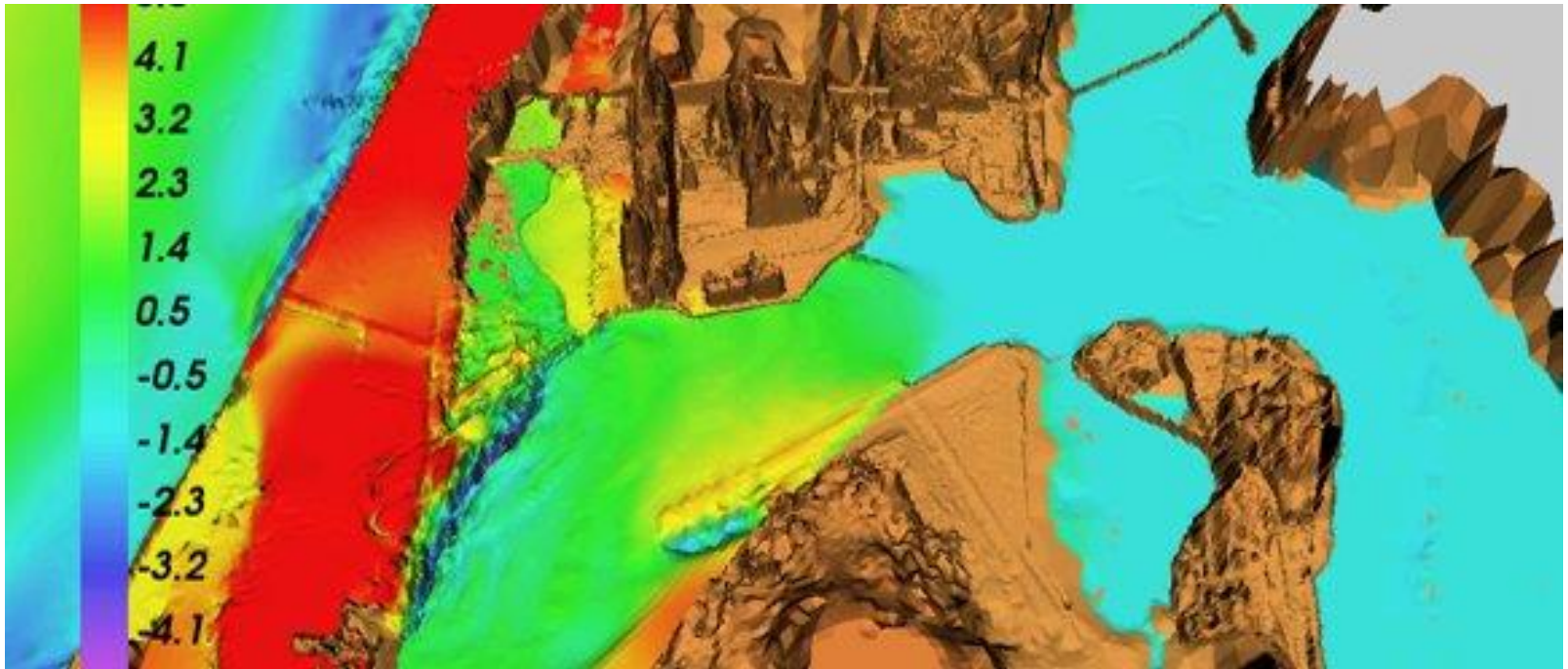
Hazard Evaluation

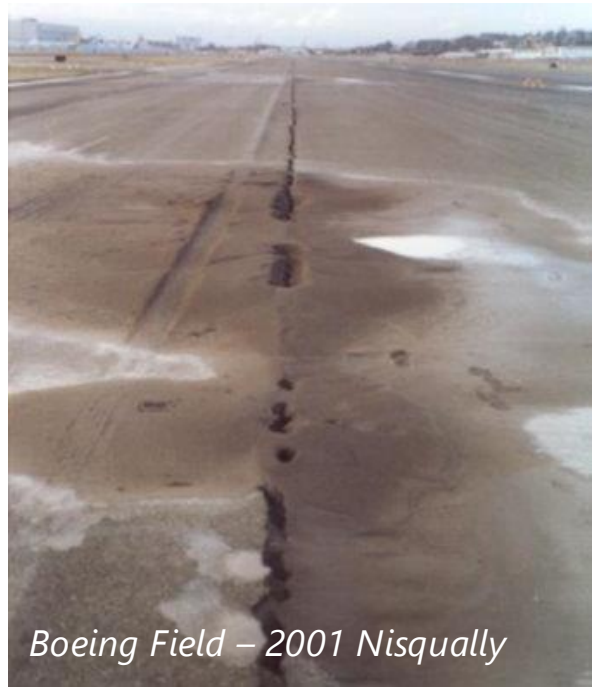
SEISMIC HAZARD OVERVIEW

- Ground Shaking
- Liquefaction
- Lateral Spreading
- Fault Rupture
- Landslides
- Tsunamis



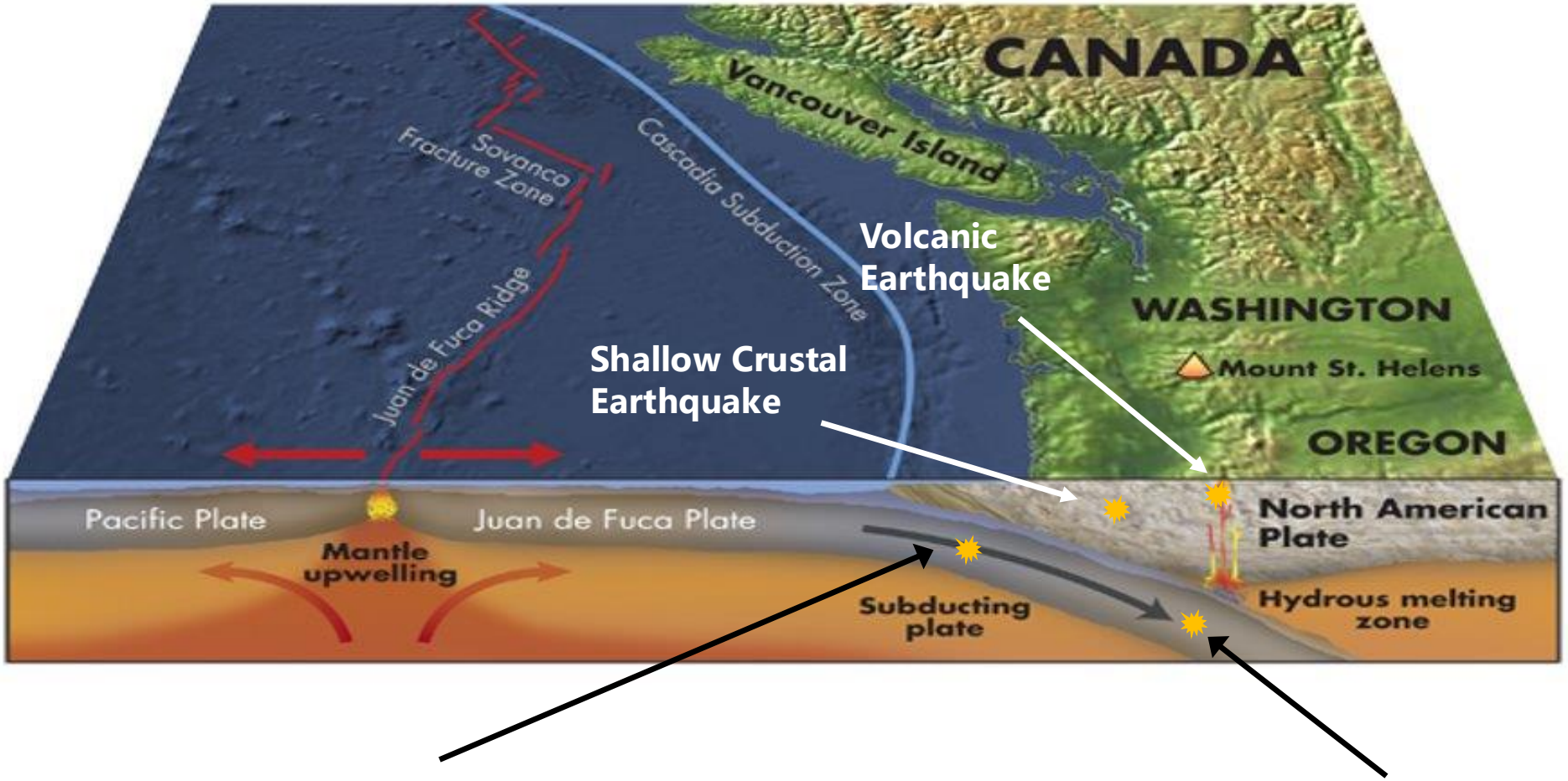
EERI 2010 Haiti Recon



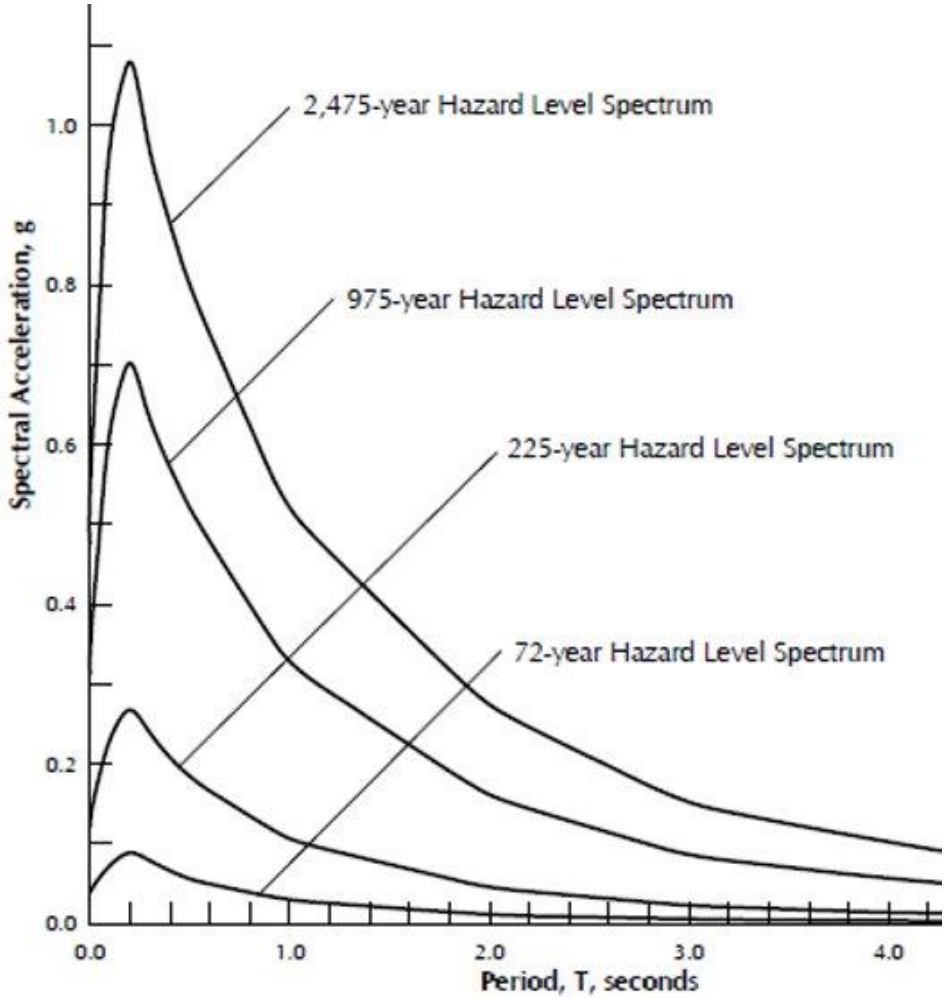


Boeing Field – 2001 Nisqually

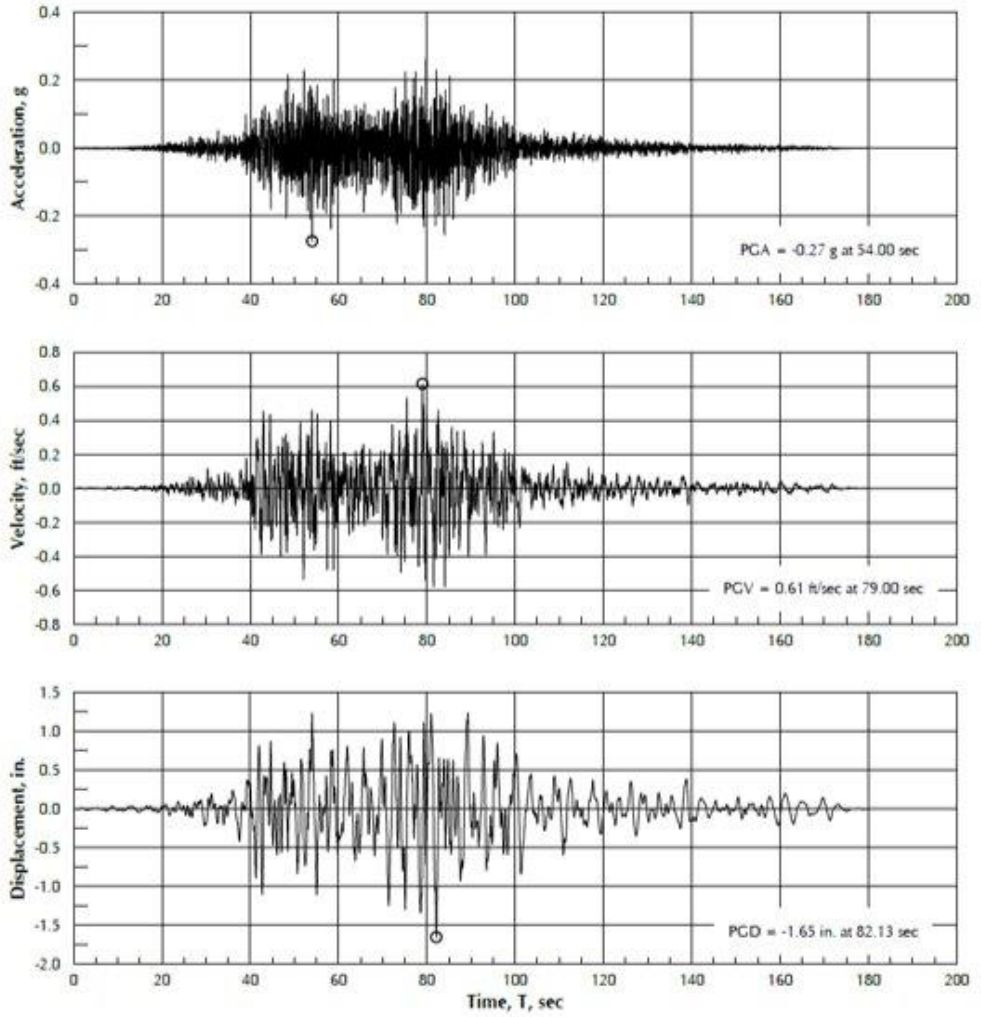
Ground Shaking



Ground Shaking

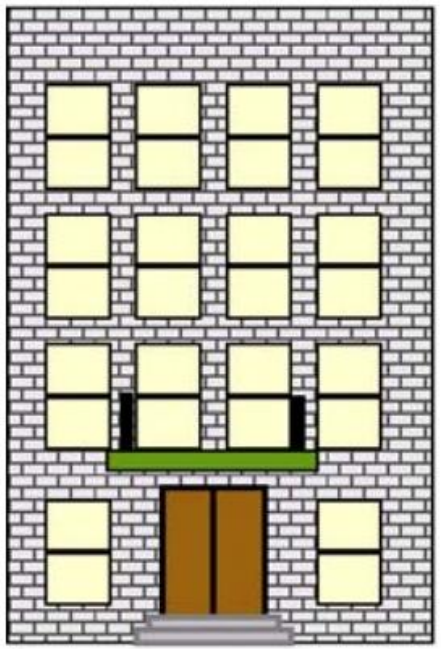


- *UHS incorporates multiple sources*

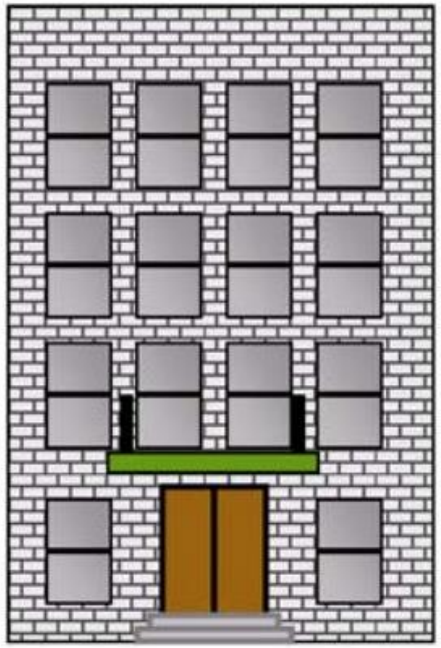


- *Ground motion selection requires judgement*

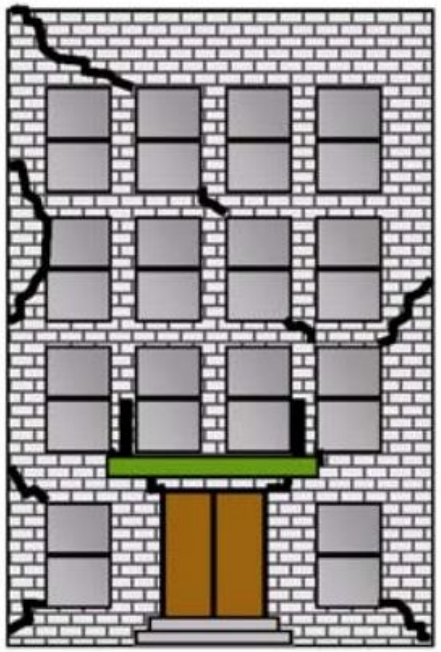
Ground Shaking



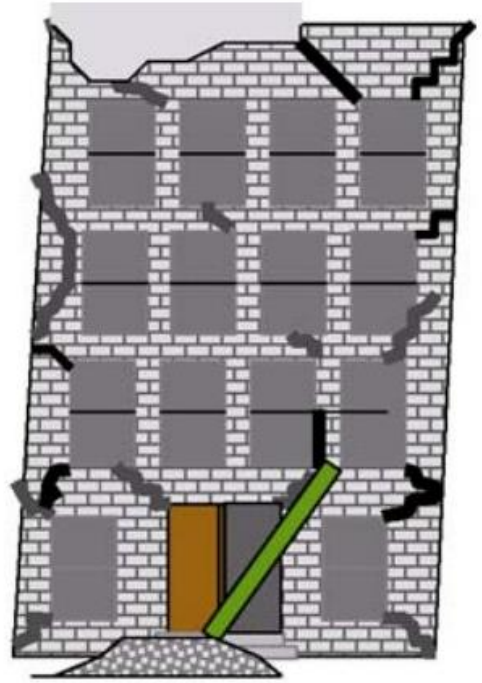
Operational



Immediate Occupancy



Life Safety

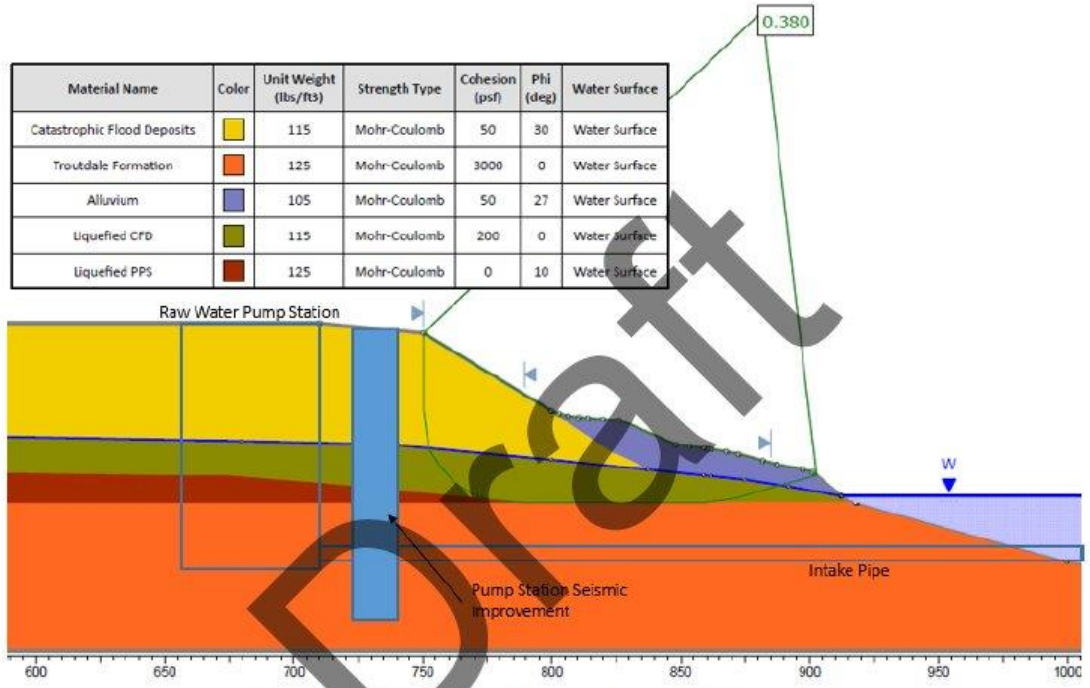


Collapse Prevention

- ***Bonus Question***

Building Code Requirement for New Structures

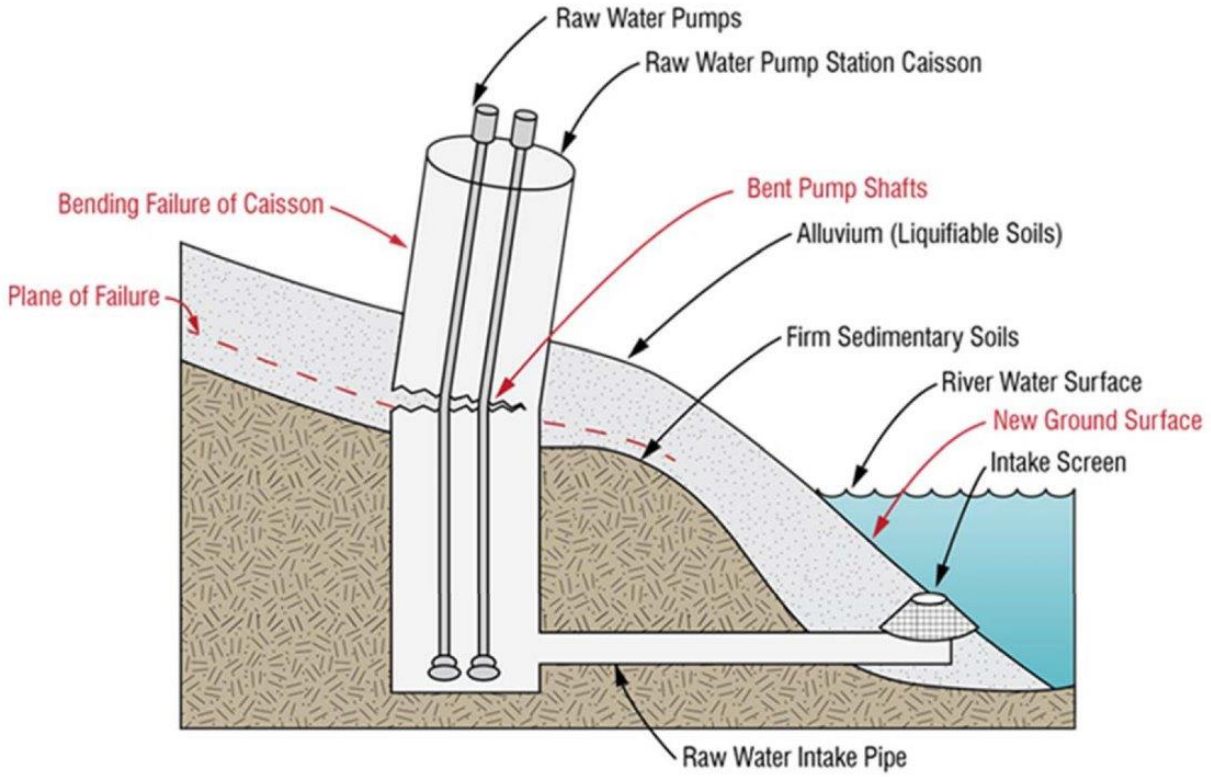
Liquefaction & Lateral Spreading Hazard



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Catastrophic Flood Deposits		115	Mohr-Coulomb	50	30	Water Surface
Troutdale Formation		125	Mohr-Coulomb	3000	0	Water Surface
Alluvium		105	Mohr-Coulomb	50	27	Water Surface
Liquefied CFD		115	Mohr-Coulomb	200	0	Water Surface
Liquefied PPS		125	Mohr-Coulomb	0	10	Water Surface

Figure 2. River Bank Post Liquefaction Stability Analysis

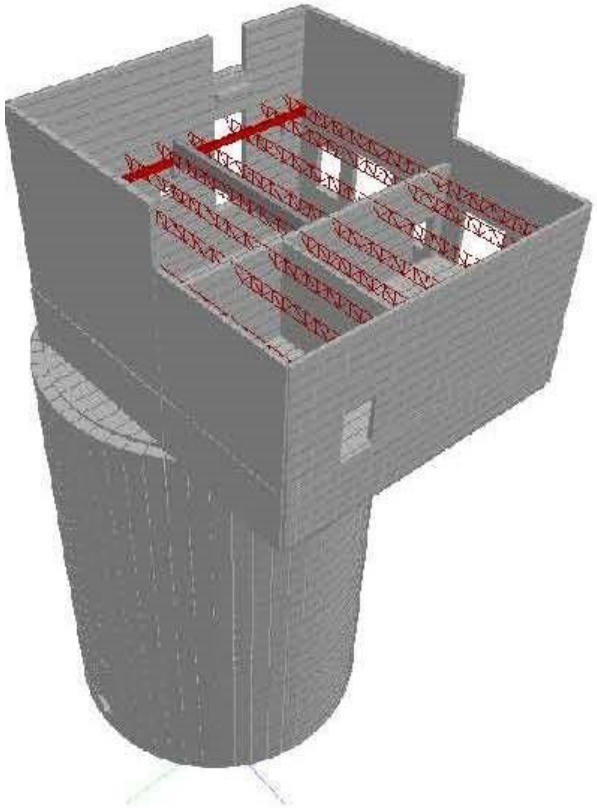
Draft



Design Process

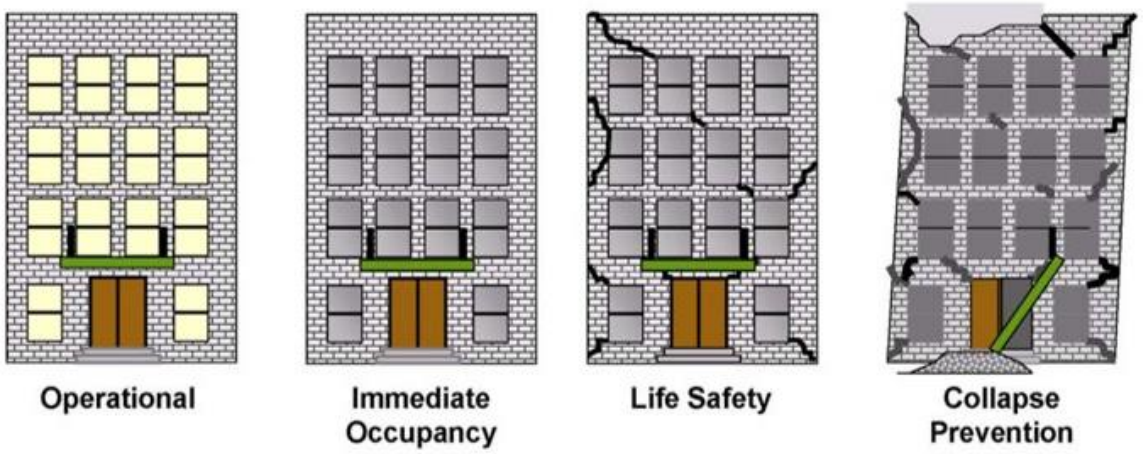
HOW TO BEGIN DESIGN

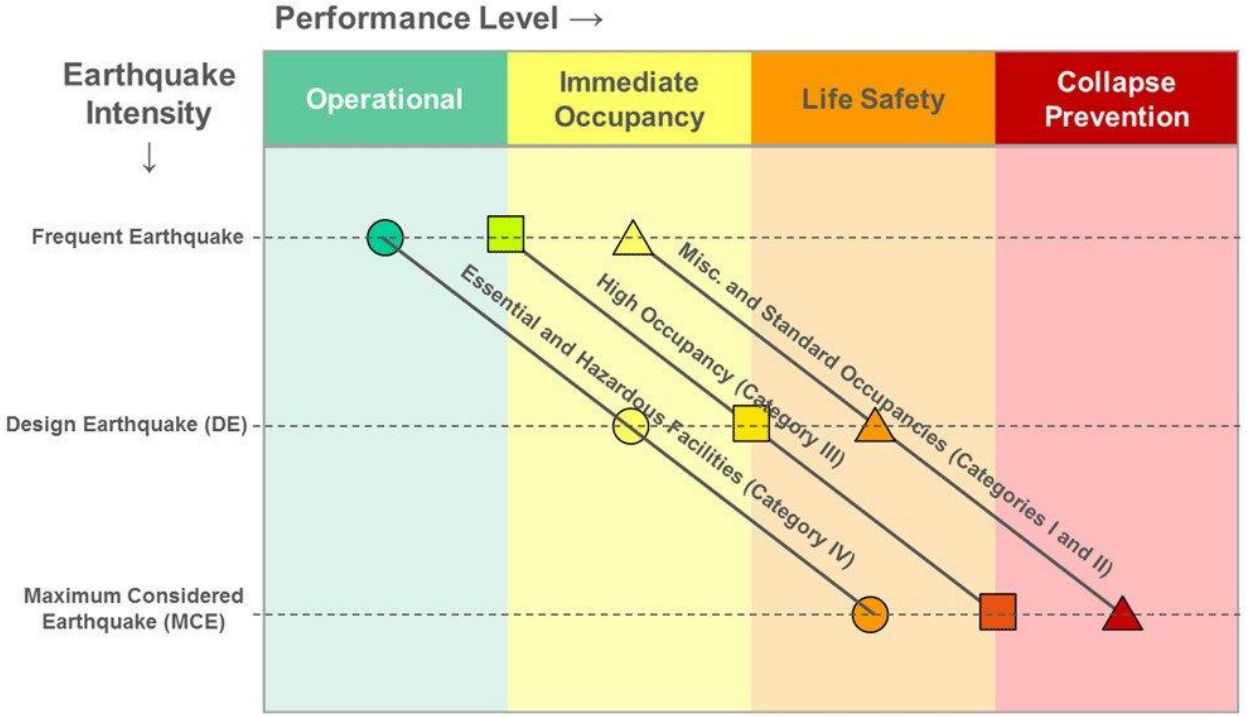
- New buildings
- Existing buildings
- Pipelines
- Buried caissons...



- Use of multiple design codes requires development of project specific design criteria.
- Design team is responsible for helping owner develop performance criteria. Owner must be involved in the process early and the entire design team must understand and scope the process as each site is unique!
- Key scope and time item!

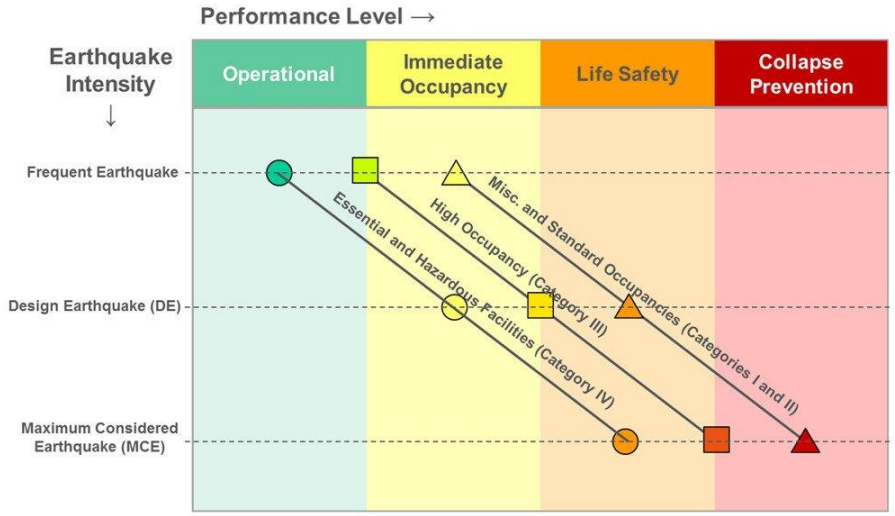
New Structures

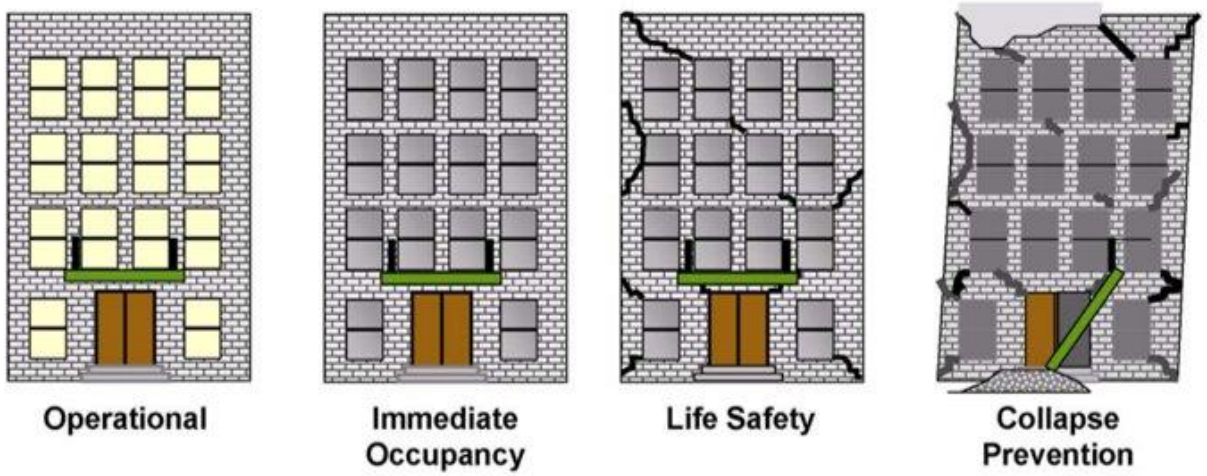




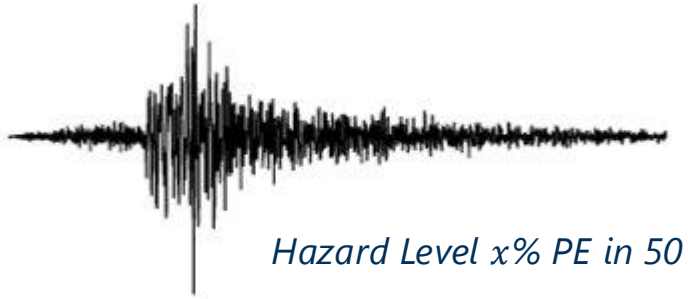
- IBC for new structures is based on ASCE 7.
- Structural analysis will be defined by the DE which is 2/3 of the MCER or approximately 2/3 of a 2,475 year hazard level with risk coefficients
- Geotechnical hazards are based on the full MCEg values which are approximately a 2,475 year hazard level (regardless of building risk category)

Existing Structure Code Overview





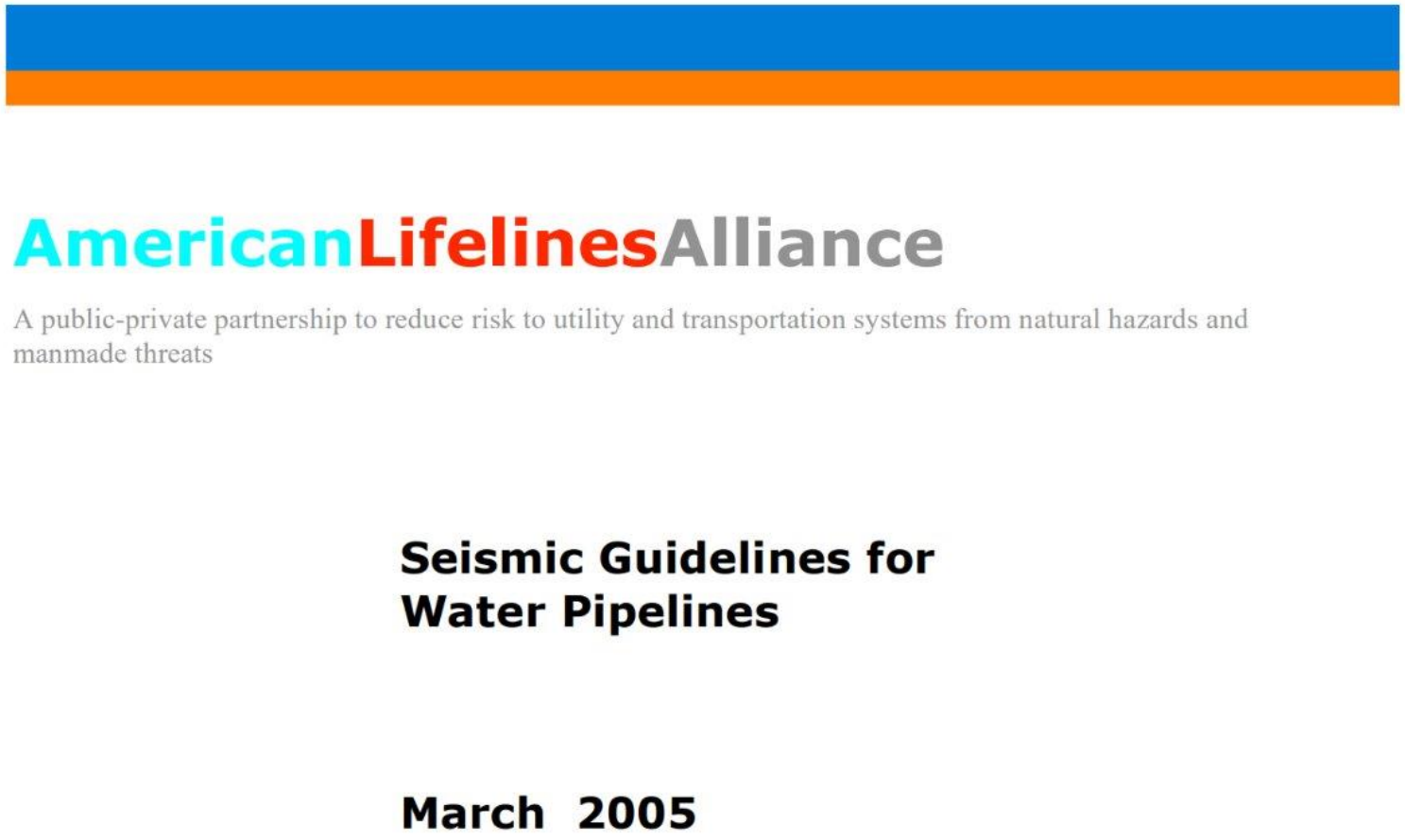
- **ASCE 41:-ASCE Retrofit Code**
  - Defines different performance levels: Maximum acceptable damage, given that the ground motion occurs
  - Performance levels depends on Risk Category and Occupancy
  - Four seismic hazard levels
    - BSE-2N: MCER ground motion in ACE 7 [2% PE in 50-yr • 2475-yr]
    - BSE-1N: Design Earthquake in ASCE 7 [2/3*BSE-2N]
    - BSE-2E: 5% PE in 50-yr [975-yr]
    - BSE-1E: 20% PE in 50-yr [225-yr]



Hazard Level x% PE in 50

Performance Based Design

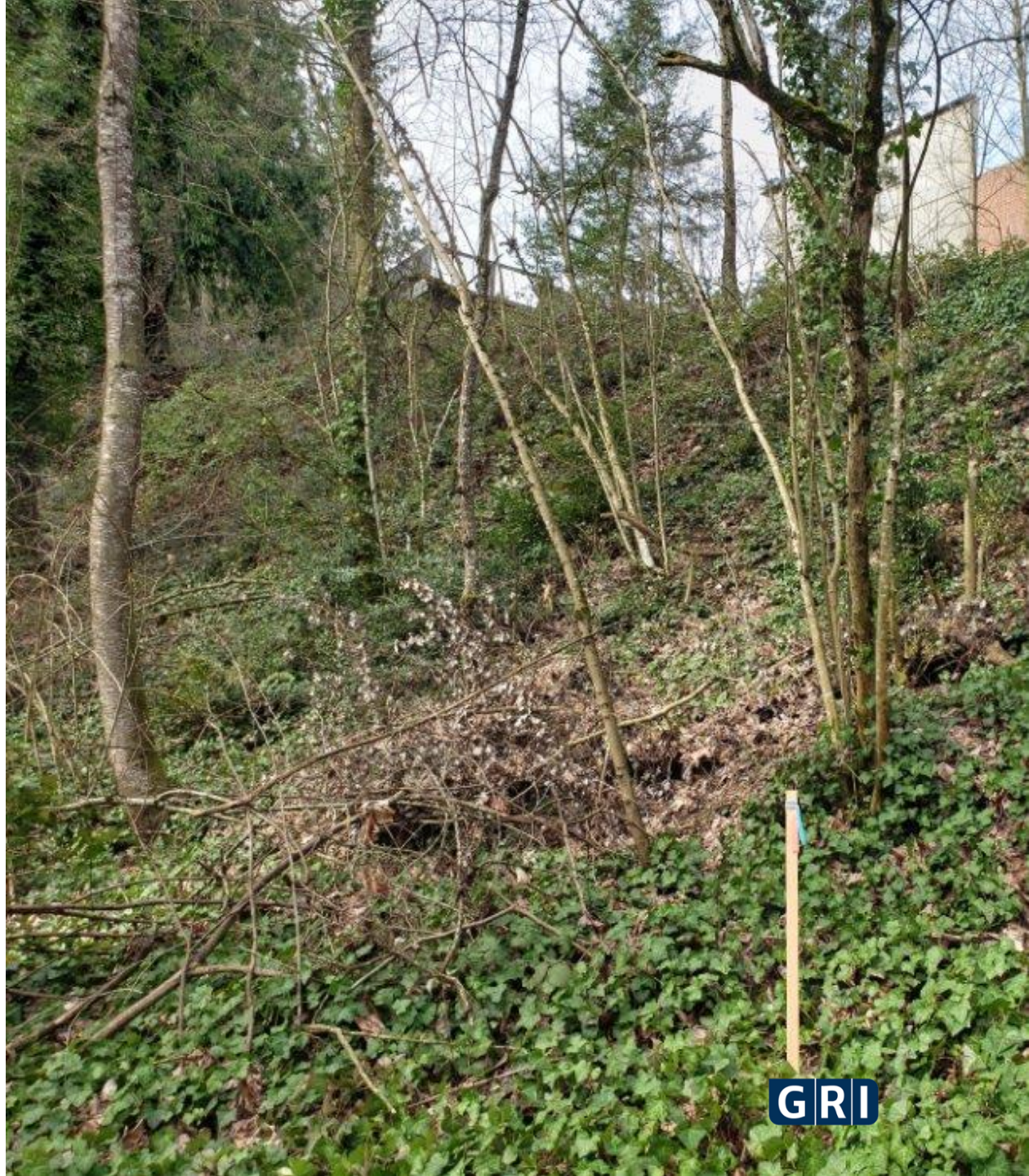
- **Non-Building Improvements**
  - Waterfront design codes also helped develop background for design approach
  - ALA, others…



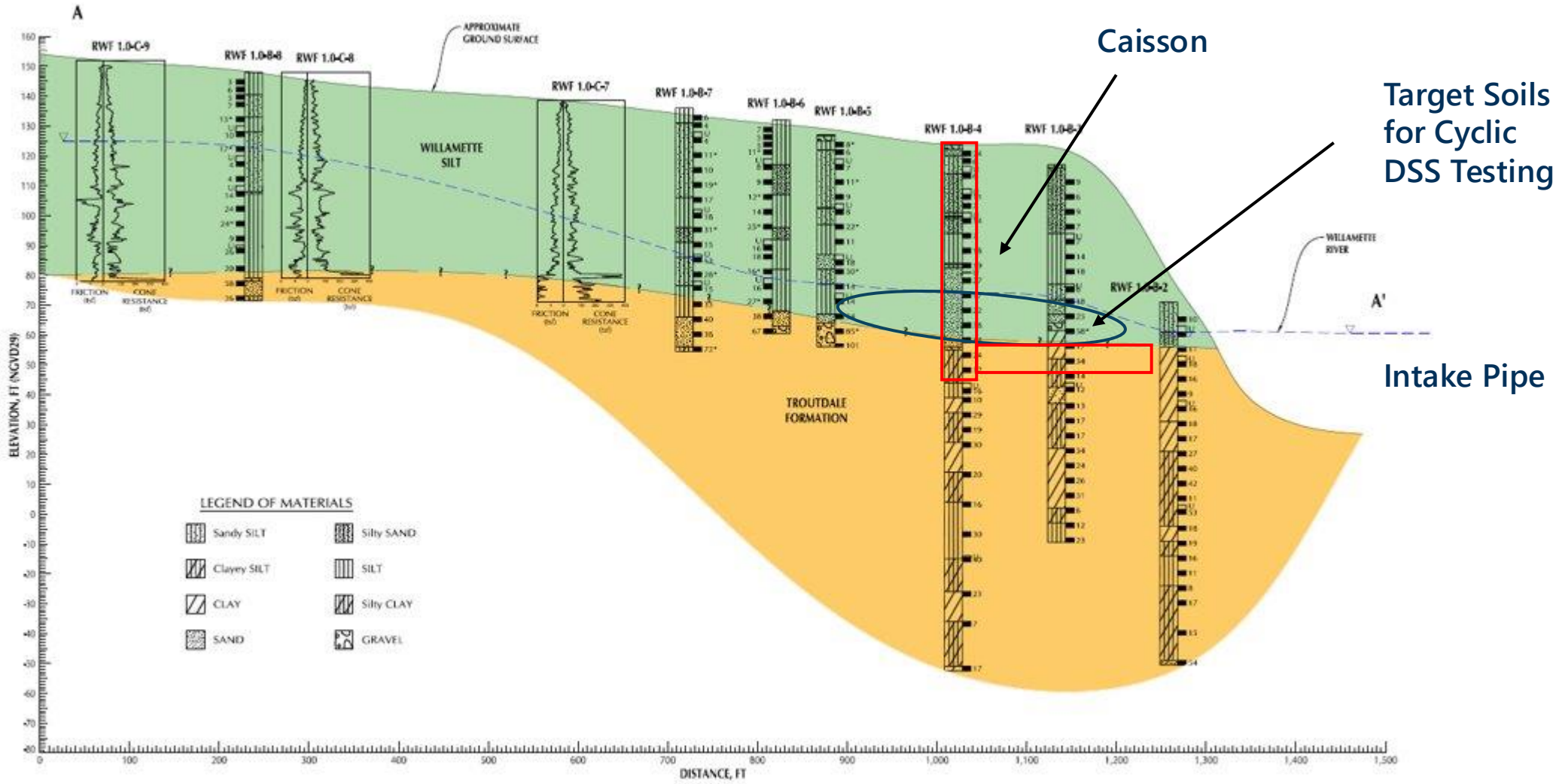
WWSP DESIGN PROCESS

Early design includes concurrent efforts to:

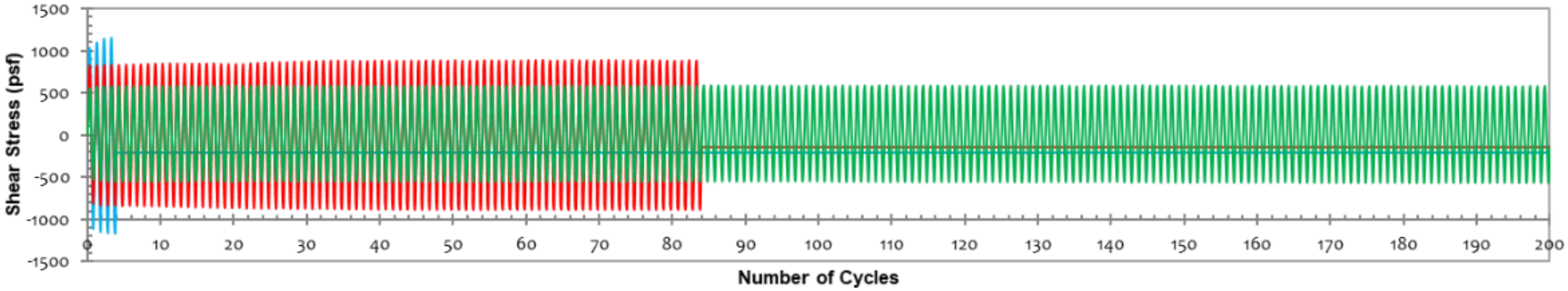
- Develop basis of design
- Begin to engage peer reviewers
- Complete exploration program and laboratory testing
- Develop and consider concept mitigation alternatives for coordination with environmental permitting constraints

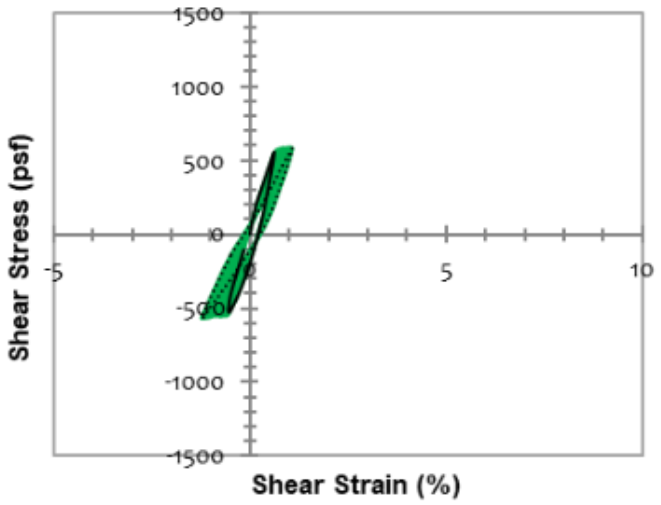


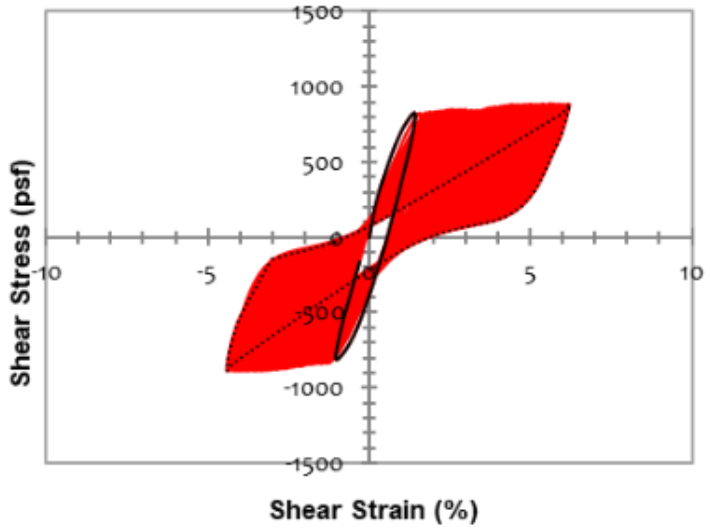
Investigation & Caisson Evaluation

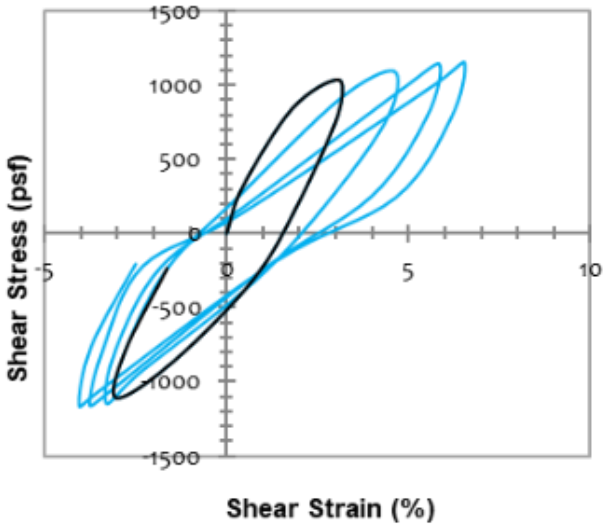


CYCLIC TESTING OF "TRANSITIONAL" SILT SOILS



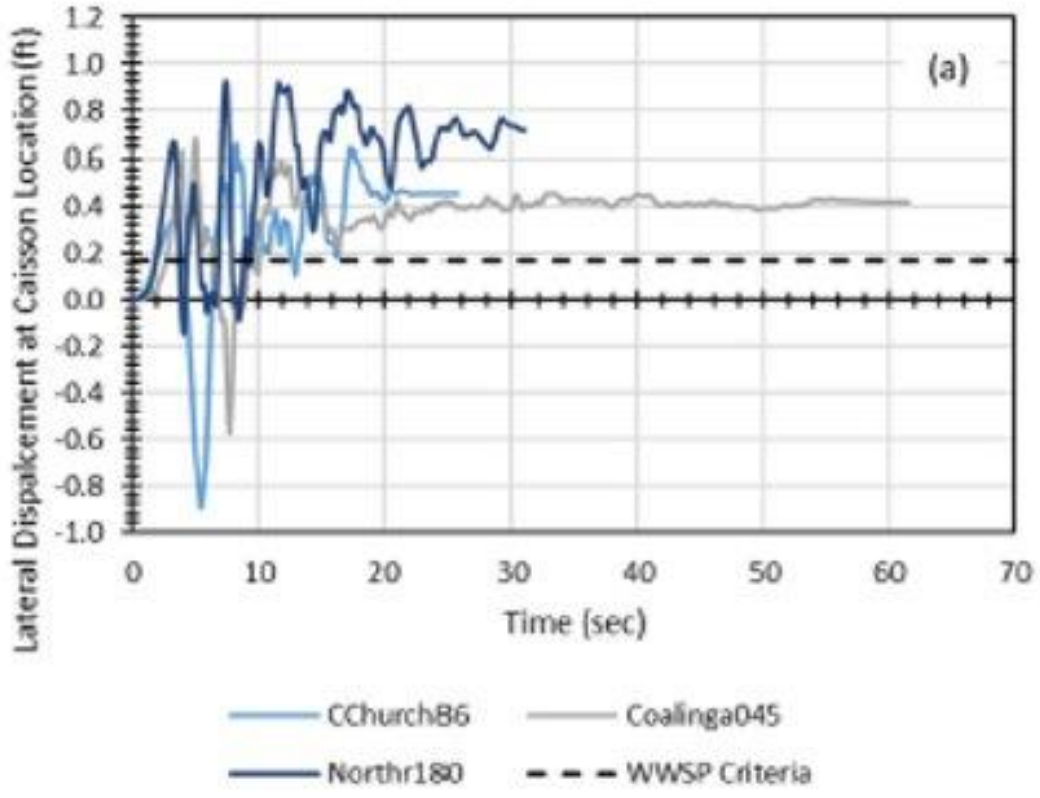


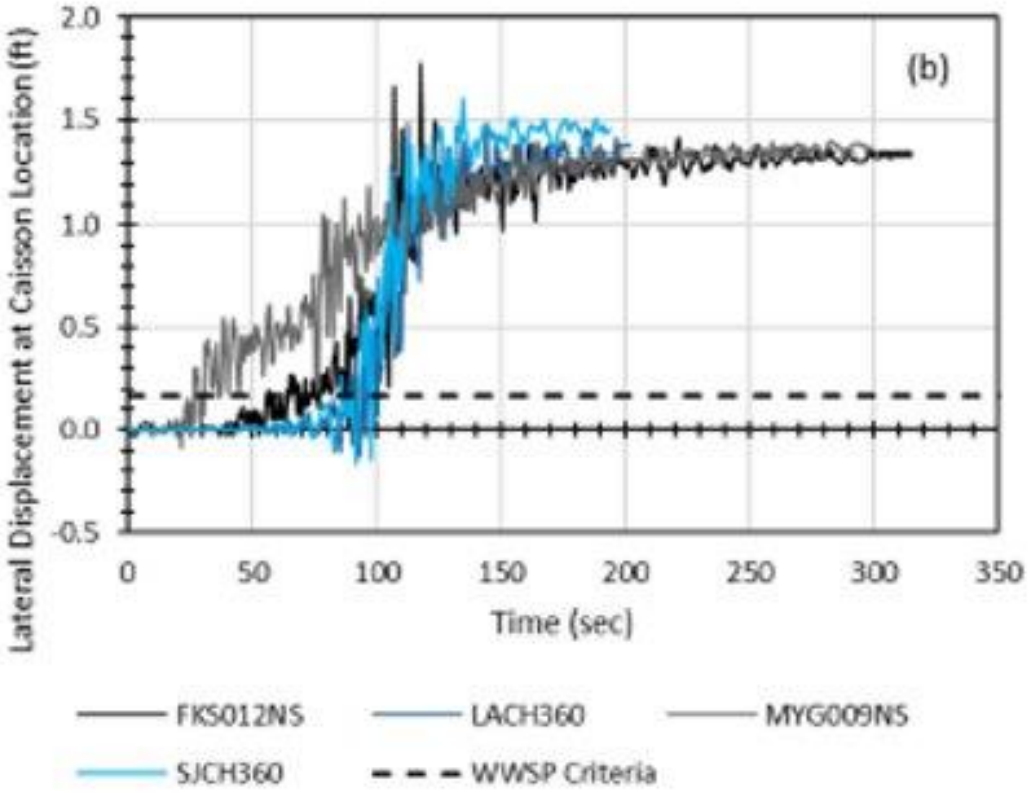




NUMERICAL MODELING

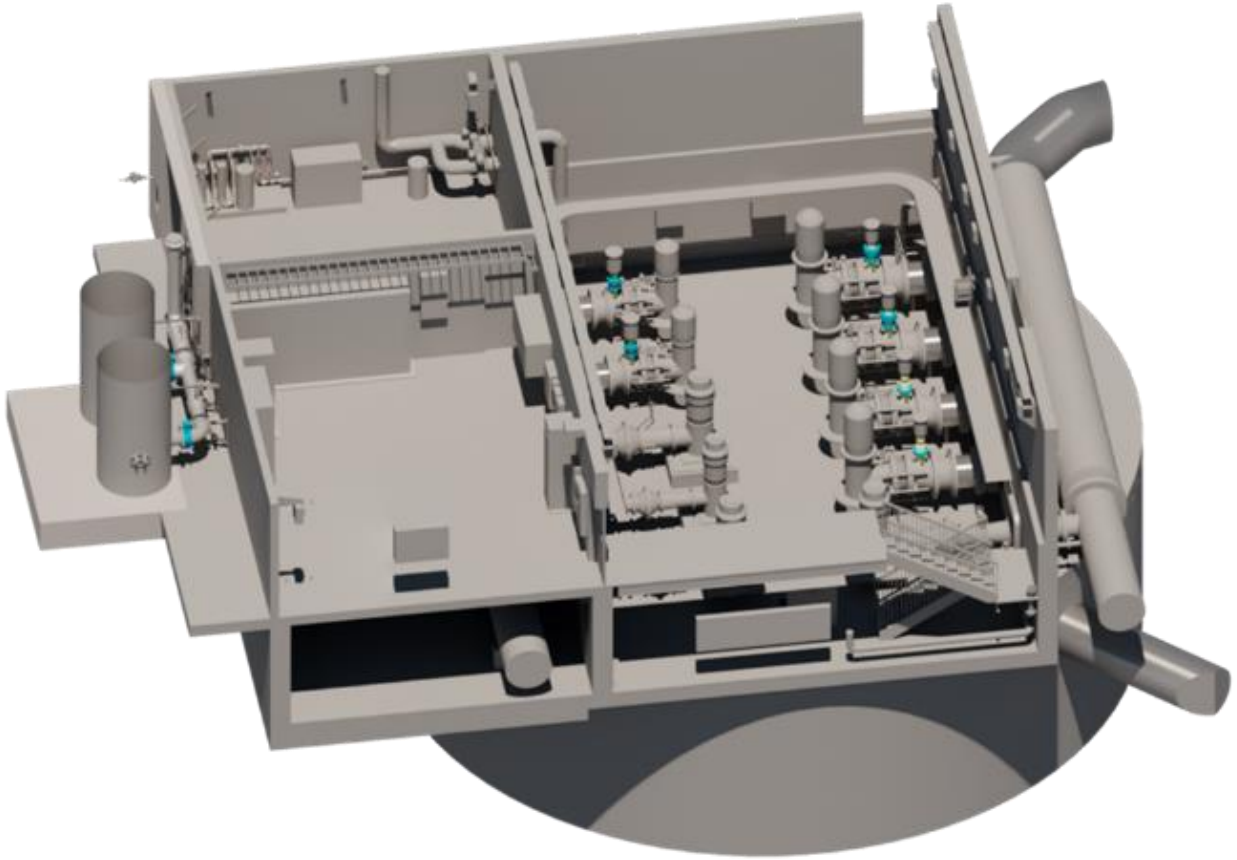
Unmitigated movements less than a couple of feet





CONTROLLING PERFORMANCE ITEMS

- Pump verticality - Less than 2-inch rotation. This criteria drove early mitigation concepts
- Need to evaluate seismic induced stresses and strains in caisson
- Pipeline – Allowable movements for pipeline types already defined in WWSP guidelines



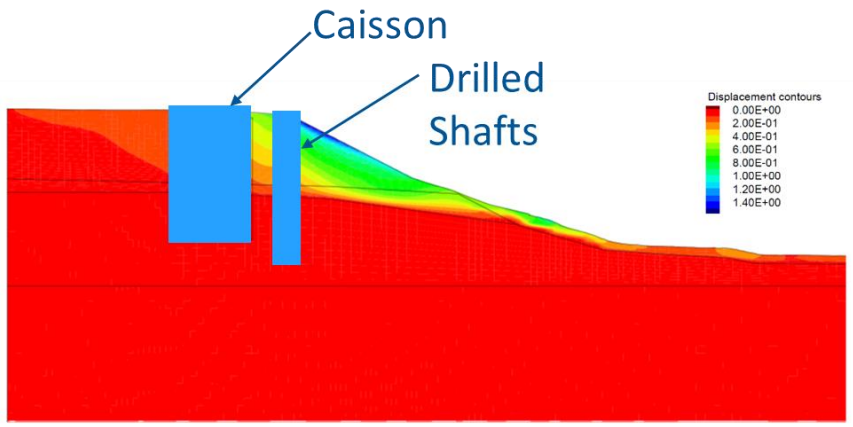
MITIGATION ALTERNATIVE EVALUATED

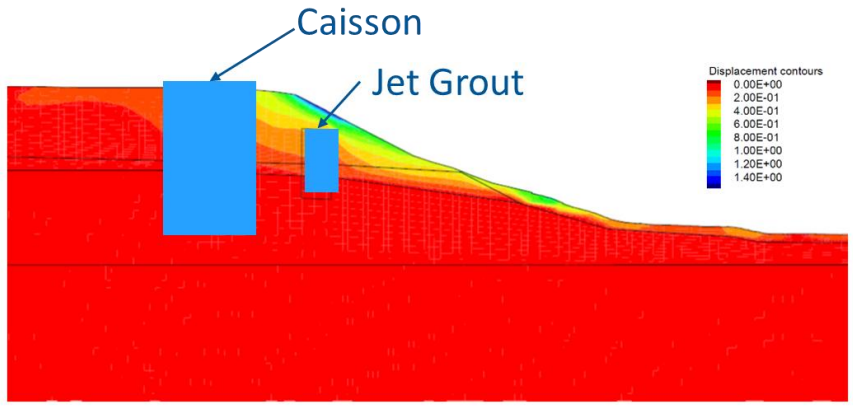
- Dewatering
- Stone Columns
- Compaction Grouting
- DSM
- Jet Grouting
- Structural Mitigation
- **Permitting and Site Constraints!**

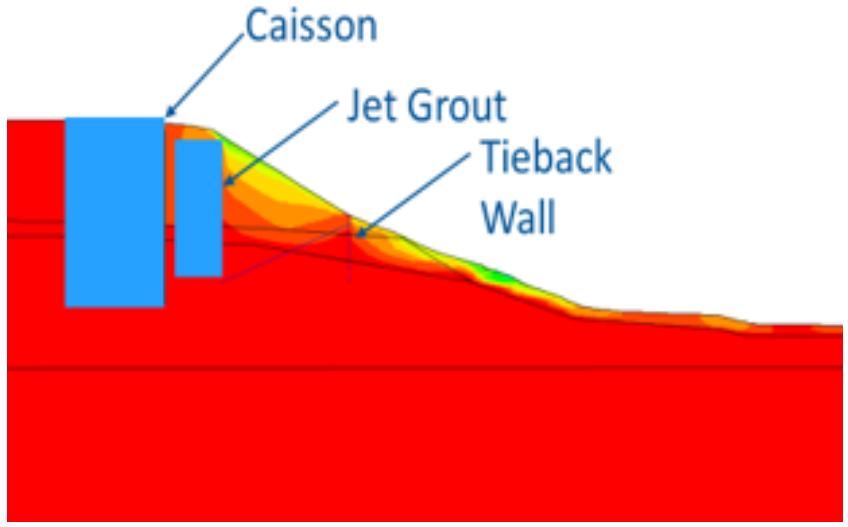
Table 5.1: ADVANTAGES AND DISADVANTAGES OF SEISMIC MITIGATION ALTERNATIVES

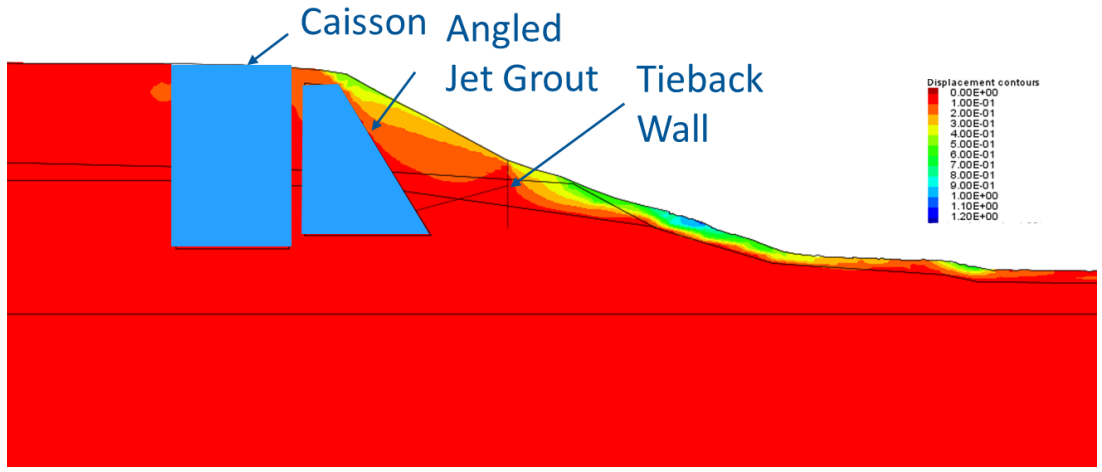
Mitigation Type	Advantages	Disadvantages
Dewatering	■ Relatively inexpensive.	■ Elevations do not work for passive systems. ■ Large footprint and maintenance considerations for active pumping system.
Vibro-Flotation and Stone Columns	■ Relatively inexpensive.	■ Will not meet performance guidelines in fine-grained soils. ■ Does not work with site constraints.
Compaction Grouting	■ Relatively inexpensive.	■ Not as effective in fine-grained soils. ■ Small diameter is typically less effective for lateral loading and not suitable for caisson deformation criteria.
DSM	■ Limited ground-surface deformations/vibrations. ■ Effective in most soil types.	■ Equipment requires relatively large, flat work surface. ■ Moderately expensive. ■ Spoils disposal.
Jet Grouting	■ Effective in these soils. ■ Limited footprint. ■ Can more easily be installed around existing utilities.	■ Most-expensive ground-improvement method. ■ Control of spoils can be challenging, and they require disposal.
Structural Mitigation	■ Deformations easier to estimate. ■ Effective in all soil types.	■ Equipment required to install large-diameter elements needs a relatively flat work surface. ■ May not meet some lateral/vertical displacement criteria without ground improvement.
Structural Mitigation with Ground Improvement	■ Most-robust alternative.	■ May require multiple contractors. ■ Relatively expensive. ■ Construction of structural elements may require temporary grading of the lower slope.

MITIGATION ALTERNATIVE EVALUATED

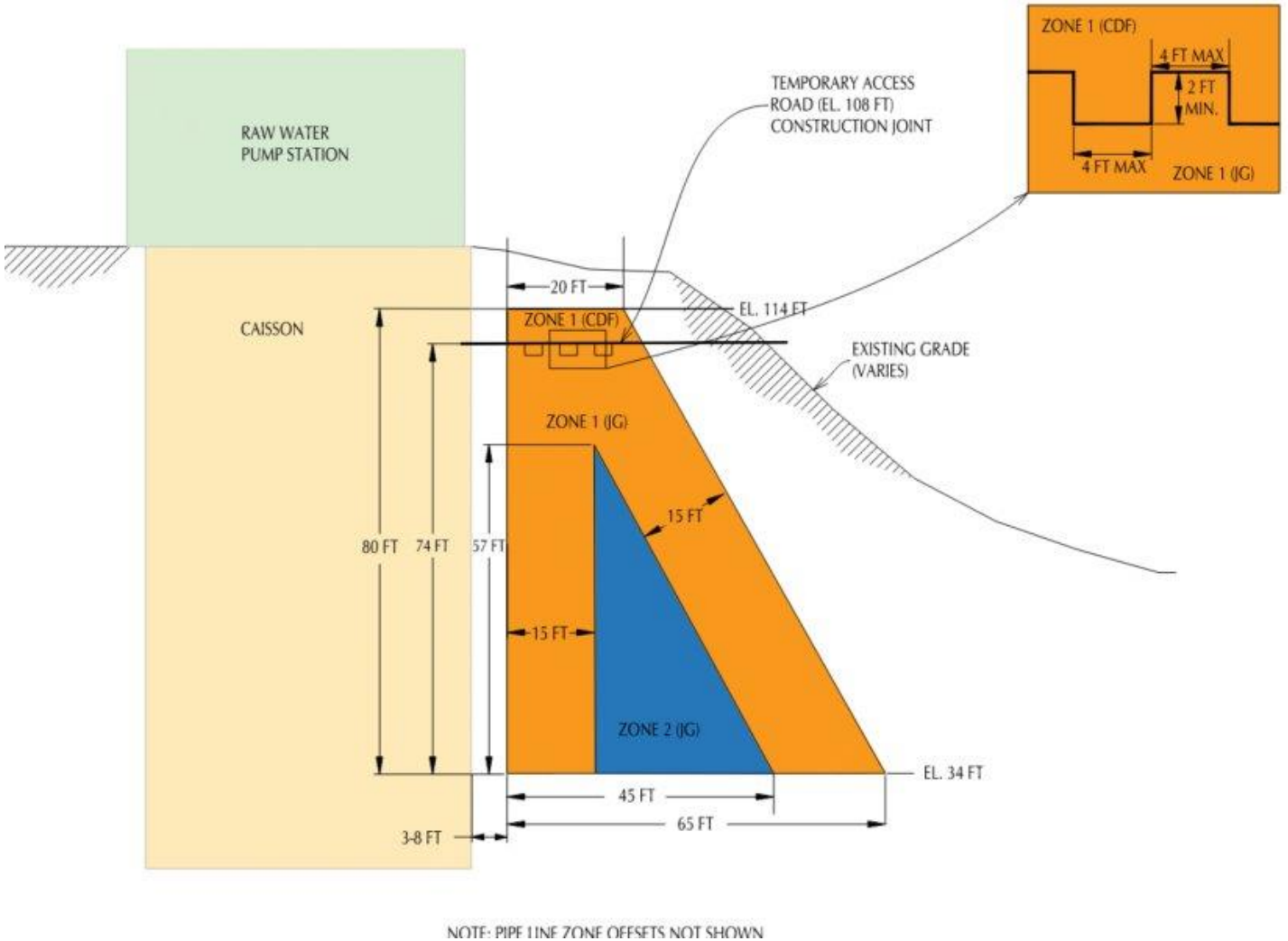






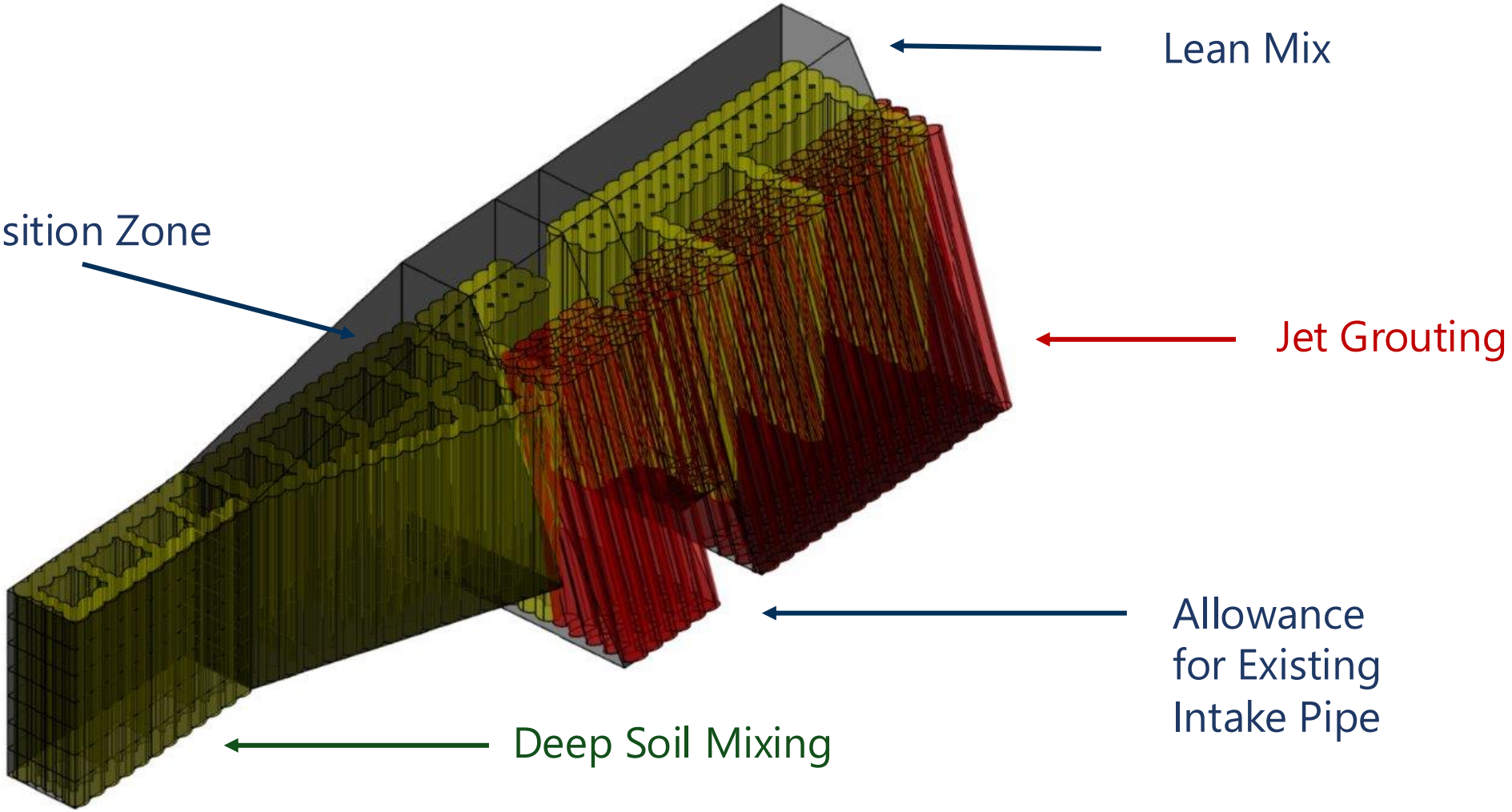


PREFERRED CAISSON ALTERNATIVE



- Flexibility in Road Elevation – CM/GC Contractor Considerations
- Specifications modified to allow flexibility in use/location of DSM and Jet Grouting

DRAFT CONTRACTOR LAYOUT



SUMMARY & LESSONS LEARNED

- **Hazard Overview**
  - Code can be confusing and complex for simple projects
  - Complex projects are even more challenging
- **Experienced Design Team**
  - Experience and lessons learned from **previous projects with overlapping code requirements**
  - These types of projects aren't the type you want your design team to learn as you go
- **Developing a Basis of Design is Key Early Step**
  - Multiple possible design codes, peer reviewers, site constraints, and potentially controlling equipment are still unknown at the beginning of a project and must be coordinated.
- **This project utilized extensive higher end analyses techniques to develop the best answer**
  - However, not all projects require this level of effort
  - Approach can be scaled and simplified for each project (and should be!)
- **Ask question about performance-based design options on your next project**

Contact information

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503-641-3478

Thank You and Questions