Willamette Water Supply
Our Reliable Water

A RIVER RUNS THROUGH IT
2019 PNWS-AWWA CONFERENCE
VANCOUVER, WASHINGTON

Seismic Facility Updates and Operational Planning

May 2, 2019

Outline

- Safety Moment
- Introduction and Update
- Raw Water Facilities
- Water Treatment Plant
- Operational Considerations
- Cost of Resiliency
- Where Does the Industry Need to Go?

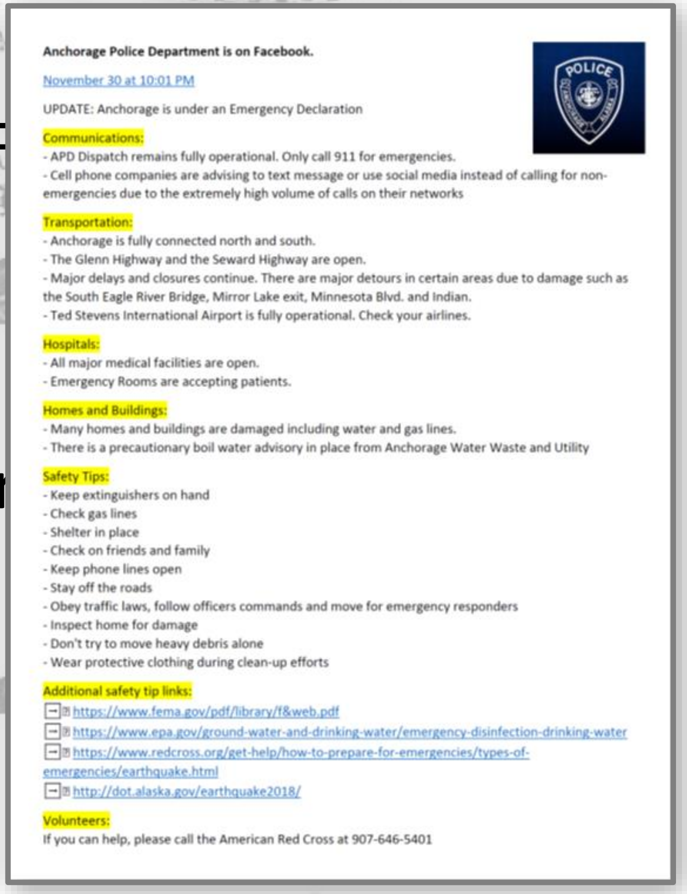
M 7.0 Earthquake Anchorage, Alaska

November 30, 2018

Post Event Communications

- Agency recovery & response communications
  - *“Communications is one of the most types of failures during disasters”* – F
- Personal communications
  - Power impacts
  - Communication service provider dis
  - Texting
  - Social media

Have a contact out of the area



Anchorage Police Department is on Facebook.

November 30 at 10:01 PM

UPDATE: Anchorage is under an Emergency Declaration

Communications:
- APD Dispatch remains fully operational. Only call 911 for emergencies.
- Cell phone companies are advising to text message or use social media instead of calling for non-emergencies due to the extremely high volume of calls on their networks

Transportation:
- Anchorage is fully connected north and south.
- The Glenn Highway and the Seward Highway are open.
- Major delays and closures continue. There are major detours in certain areas due to damage such as the South Eagle River Bridge, Mirror Lake exit, Minnesota Blvd. and Indian.
- Ted Stevens International Airport is fully operational. Check your airlines.

Hospitals:
- All major medical facilities are open.
- Emergency Rooms are accepting patients.

Homes and Buildings:
- Many homes and buildings are damaged including water and gas lines.
- There is a precautionary boil water advisory in place from Anchorage Water Waste and Utility

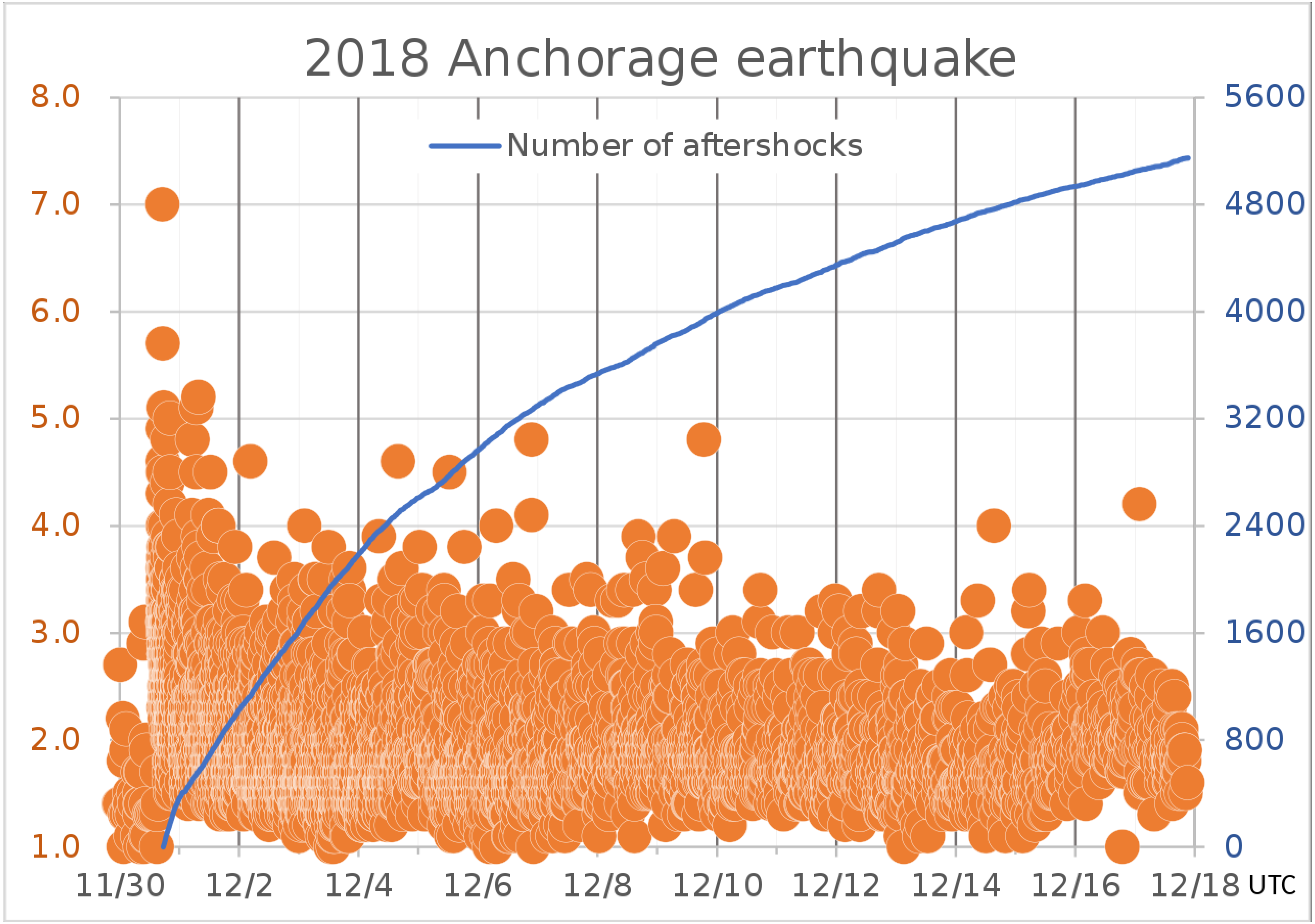
Safety Tips:
- Keep extinguishers on hand
- Check gas lines
- Shelter in place
- Check on friends and family
- Keep phone lines open
- Stay off the roads
- Obey traffic laws, follow officers commands and move for emergency responders
- Inspect home for damage
- Don't try to move heavy debris alone
- Wear protective clothing during clean-up efforts

Additional safety tip links:
https://www.fema.gov/pdf/library/f&web.pdf
https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water
https://www.redcross.org/get-help/how-to-prepare-for-emergencies/types-of-emergencies/earthquake.html
http://dot.alaska.gov/earthquake2018/

Volunteers:
If you can help, please call the American Red Cross at 907-646-5401

Vine Rd near Wasilla

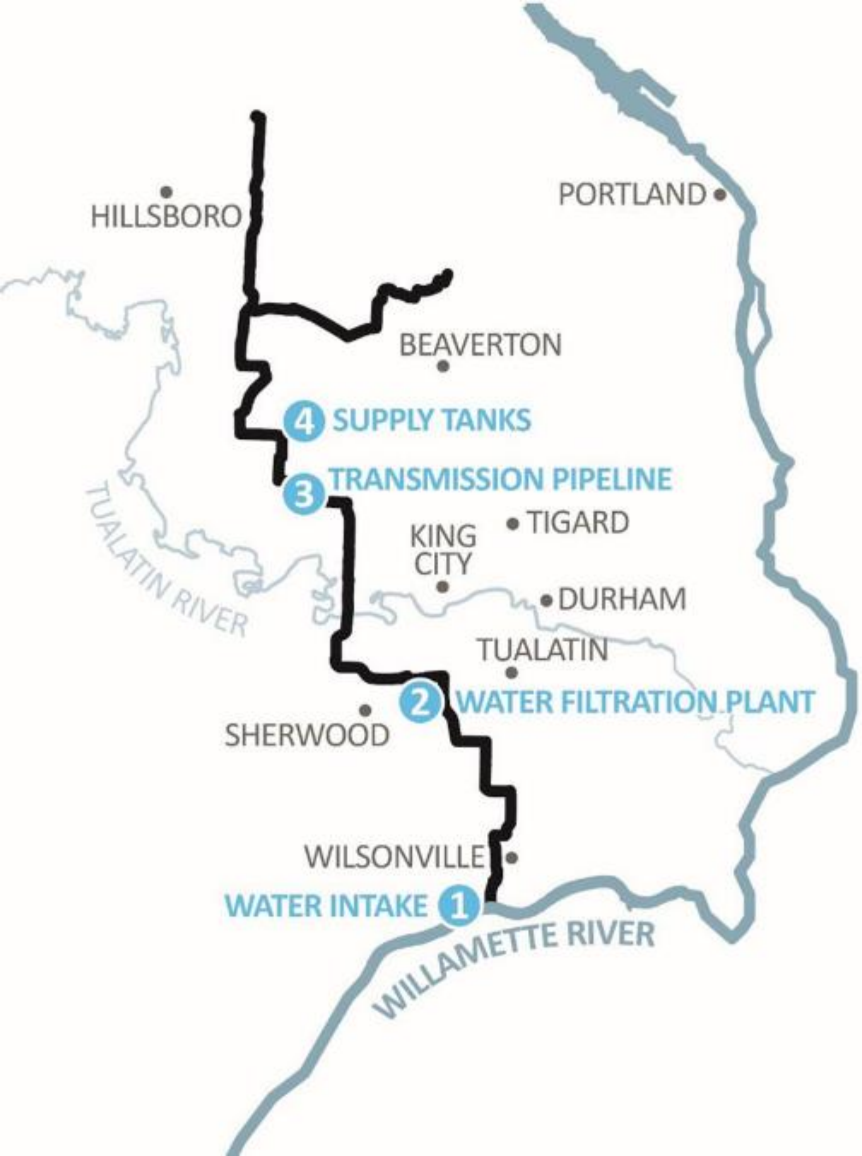
Source: nystm.com



Source: Wikipedia (Phoenix7777)

INTRODUCTION AND UPDATE

Willamette Water Supply Program



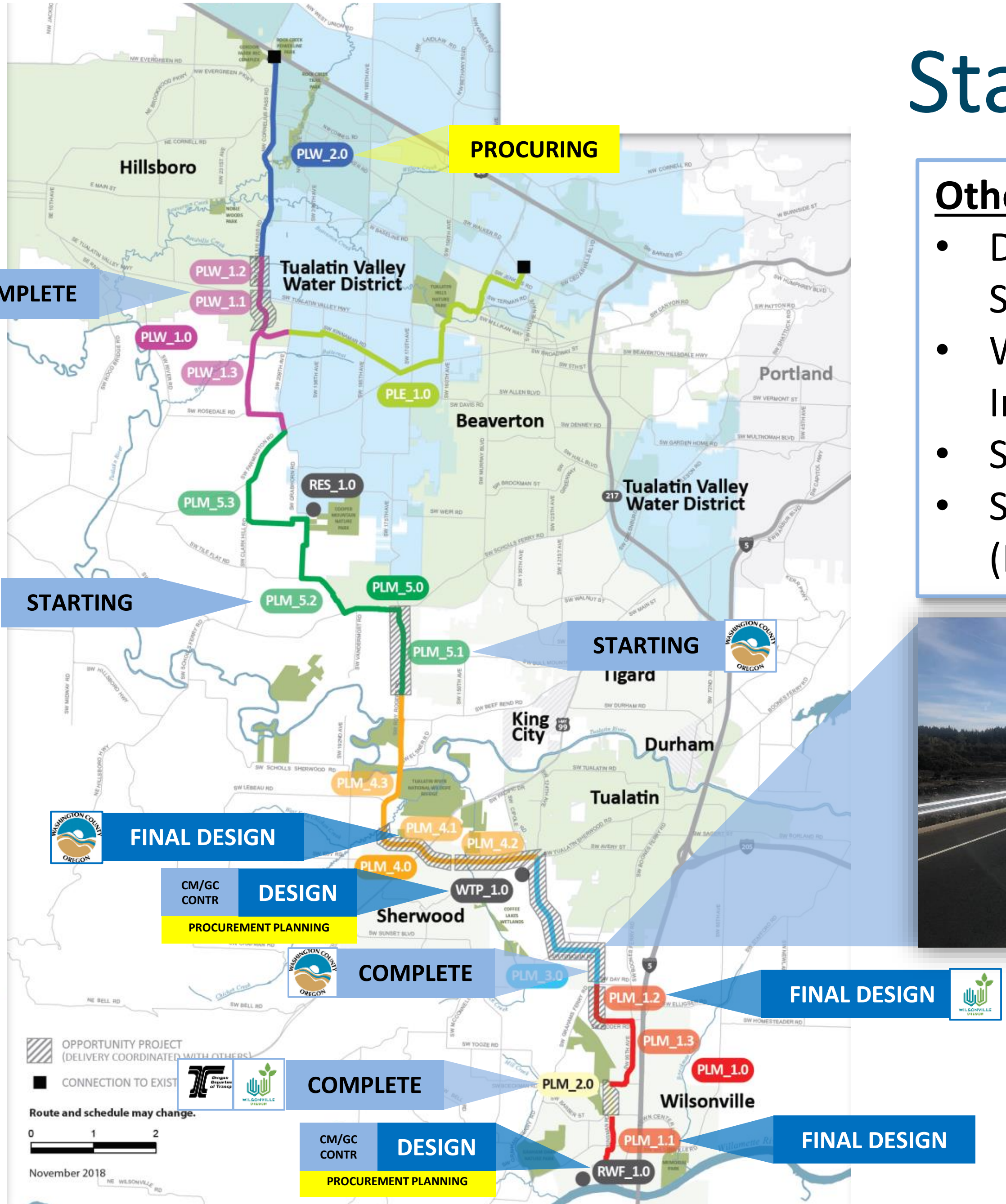
Mission Statement: Provide a cost-effective, reliable and resilient water supply system *by July 2026, that benefits current and future generations of the communities we serve and supports a vibrant local economy.*

- Modified water intake
- New water filtration plant
- 30+ miles of large diameter pipeline
- Water reservoirs
- Tualatin Valley Water District: 60%
  City of Hillsboro: 40%
- Scheduled completion: 2026

Tualatin Valley Water District

Hillsboro OREGON

Construction and Design Status

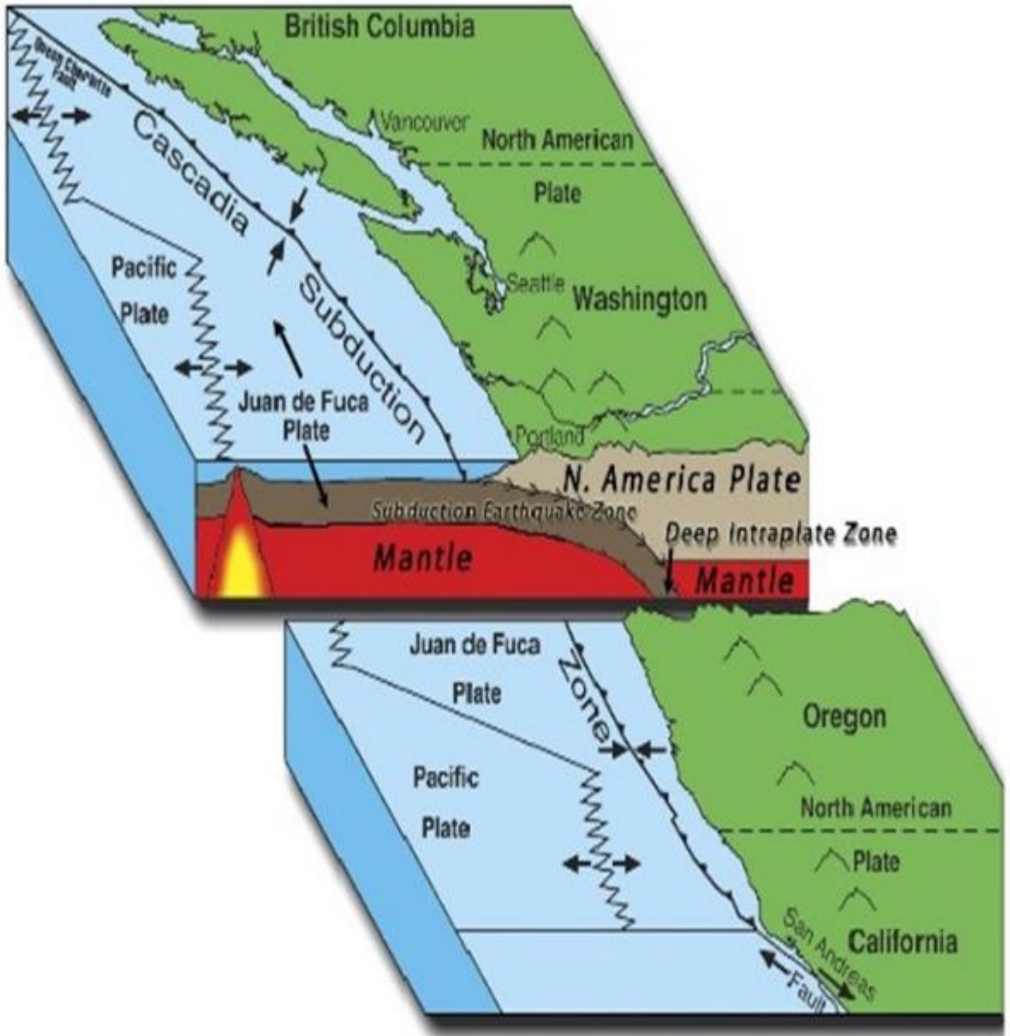


Other Activities:

- Distributed Control System (DCS)
- Water System Integrator
- Security Standards
- Seismic Guidelines (Facilities)

Seismic hazards are one of the greatest risks to water systems in the NW Region

- For the last 25 years, scientists have been aware of the possibility that a great earthquake caused by the Cascadia Subduction Zone could strike the Pacific Northwest in the next 50 years
- Great Subduction Zone Earthquakes are the largest earthquakes in the world and can produce magnitude 9.0 or greater earthquakes

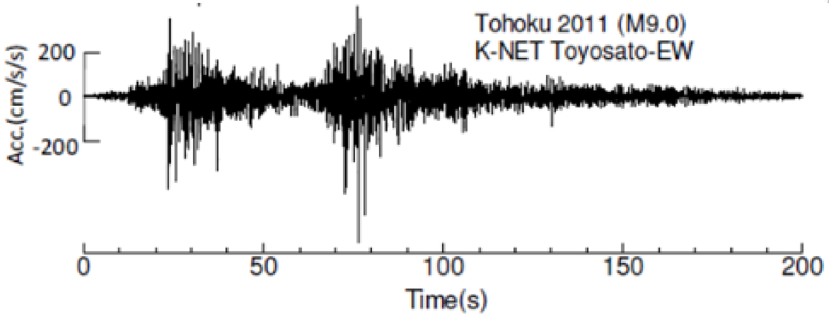


Subduction zone earthquakes

Tohoku, Japan (2011)

9.0 M Earthquake

- 16,447 Deaths
- 4,787 Missing
- 5,888 Injured
- 430,000 Homeless
- 111,944 Buildings destroyed
- 637,277 Buildings damaged
- Honshu Island moved 7.8 feet West
- Nuclear power meltdown
- Cost could exceed $300 billion

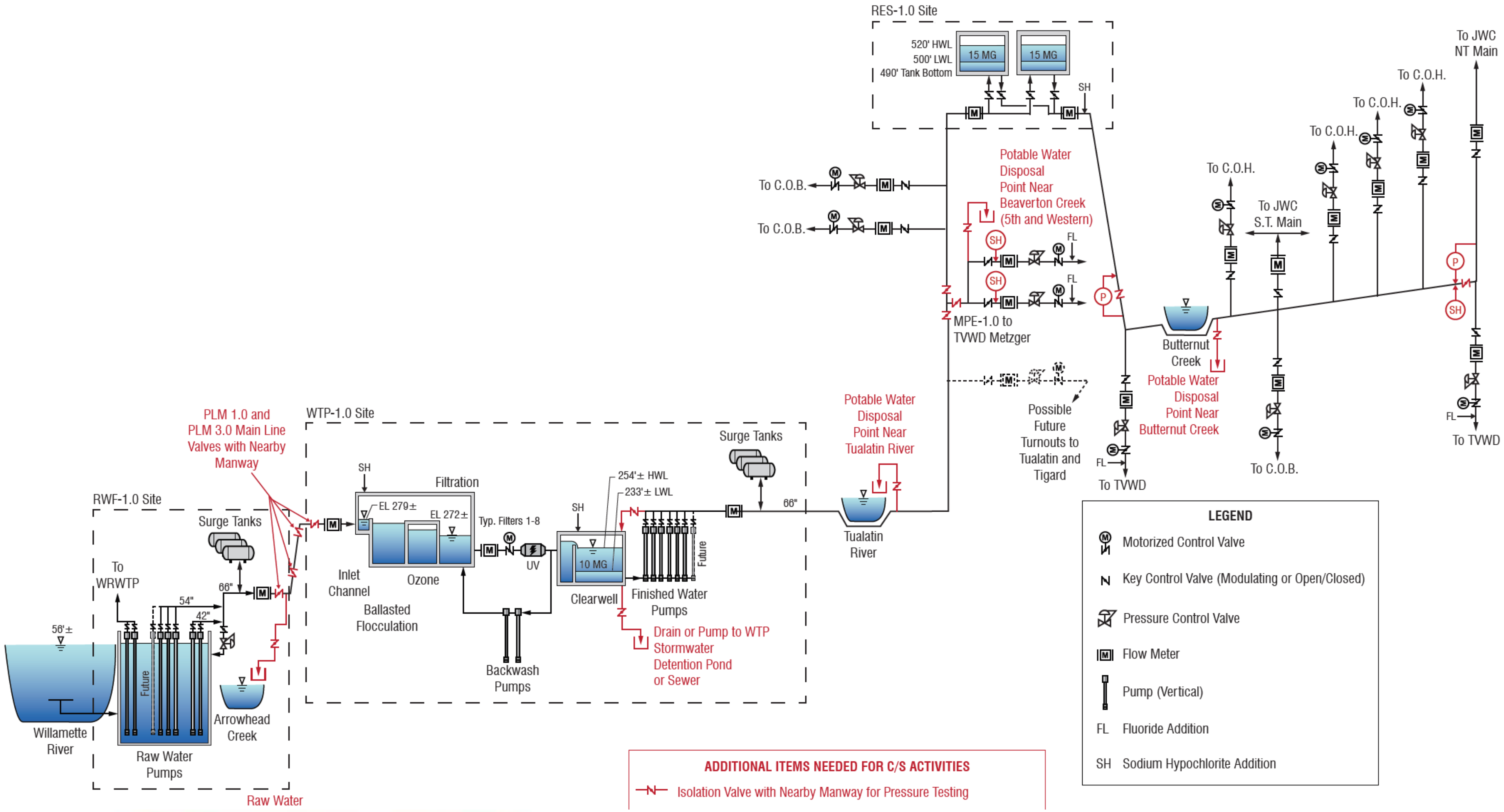


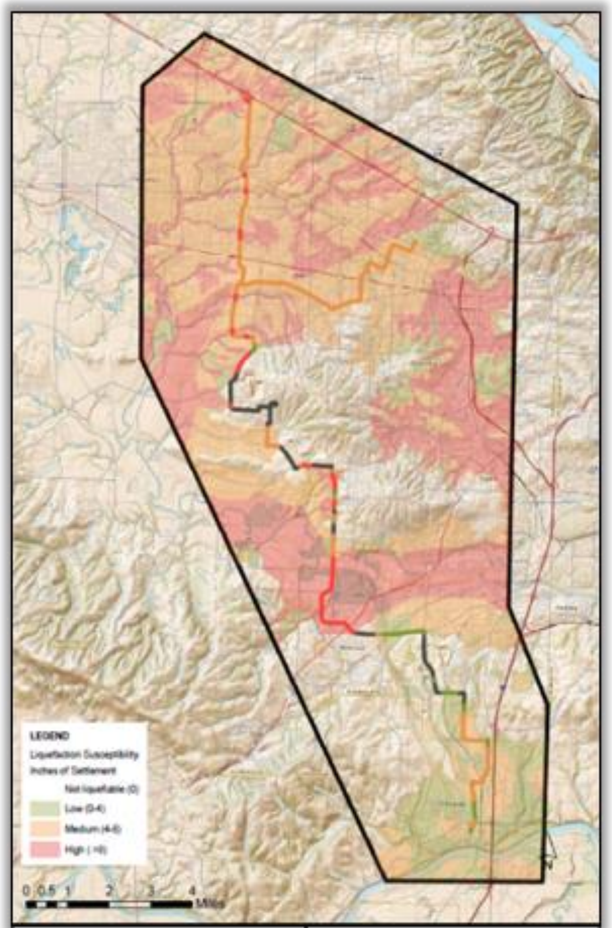
Alaska (1964)

9.2 M Earthquake
March 27, 1964, at 5:36 p.m.

"AlaskaQuake-FourthAve" by U.S. Army - http://libraryphoto.cr.usgs.gov/

Water supply system is complex

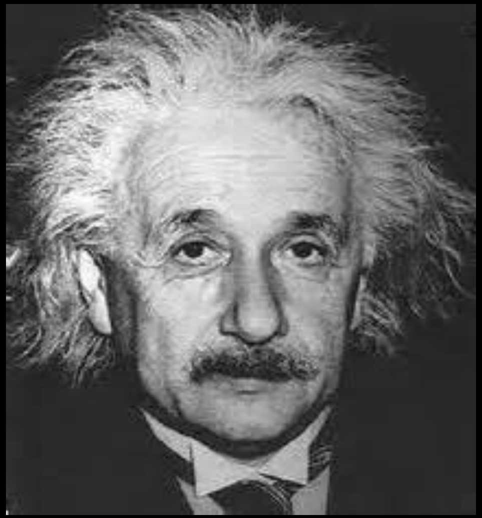




% of Alignment	Hazard
100%	Ground shaking
~60%	Settlement
~10%	Lateral movement

How do you solve the problem?

It's complicated



"Everything should be made as simple as possible, but not simpler"

Albert Einstein

Seismic design framework


www.OurReliableWater.org

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Willamette Water Supply Program

Seismic Guidelines and Minimum Design Requirements

June 08, 2018

AWWA M41 Chapter 14. Seismic Design Guidelines for Ductile Iron Pipe [release with next manual]


AWWA M41 – DRAFT SEISMIC DESIGN CHAPTER

Chapter 14. Seismic Design Guidelines for Ductile Iron Pipe

"Everything should be made as simple as possible, but not simpler"
- Albert Einstein

14.1 INTRODUCTION

One of the most critical resources we have is water. Water is crucial to public health, firefighting, and societal development. People can only survive for a few days without water. A reliable and resilient water supply is necessary to sustain the economy and support responsible growth within a region. A resilient water supply will benefit both current and future generations.

Presidential Policy Directive (PPD) 21 defines the term "resilience" as "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents" (PPD-21, 2013). Today, approximately 91 percent of Americans live in areas subject to natural disasters or terrorism (Ripley, 2009). There are many kinds of disasters, both natural and manmade, which can impact a water supply. Water infrastructure is one of the top four most important types of critical infrastructure following disasters (FEMA, 2014). Of all types of natural disasters or other events that can impact water systems, perhaps the most significant are earthquakes. The impact from large earthquakes on water systems and the related communities they serve can be significant. The United States Geological Survey (USGS) estimates that over 50 percent of the land mass in the contiguous United States would be affected by at least strong shaking (MMI VI level of shaking) from relatively infrequent ground motions from earthquakes as shown in Figure 14.1 (Jaiswal et. al., 2015)[1]. It is estimated that 12 percent of fire stations, 12 percent of hospitals, and 15 percent of all schools are located in regions of the contiguous 48 states where there is a 2 percent chance that severe shaking (MMI VIII level of shaking) or higher could occur in the next 50 years. "At such levels of shaking, even well-designed earthquake-resistant construction could experience some damage, while unreinforced masonry or nonductile concrete constructions are expected to perform extremely poorly, that is, experiencing partial or complete collapses" (Jaiswal et al, 2015).

[1] Table 14-3 later in the document describes the different levels of ground shaking associated with the modified Mercalli intensity (MMI) index which is a measure of ground shaking based on observed impacts. Developed in 1931 by American seismologists Harry Wood and Frank Neumann, this scale is "composed of increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, [and] is designated by Roman numerals" (USGS, n.d.).

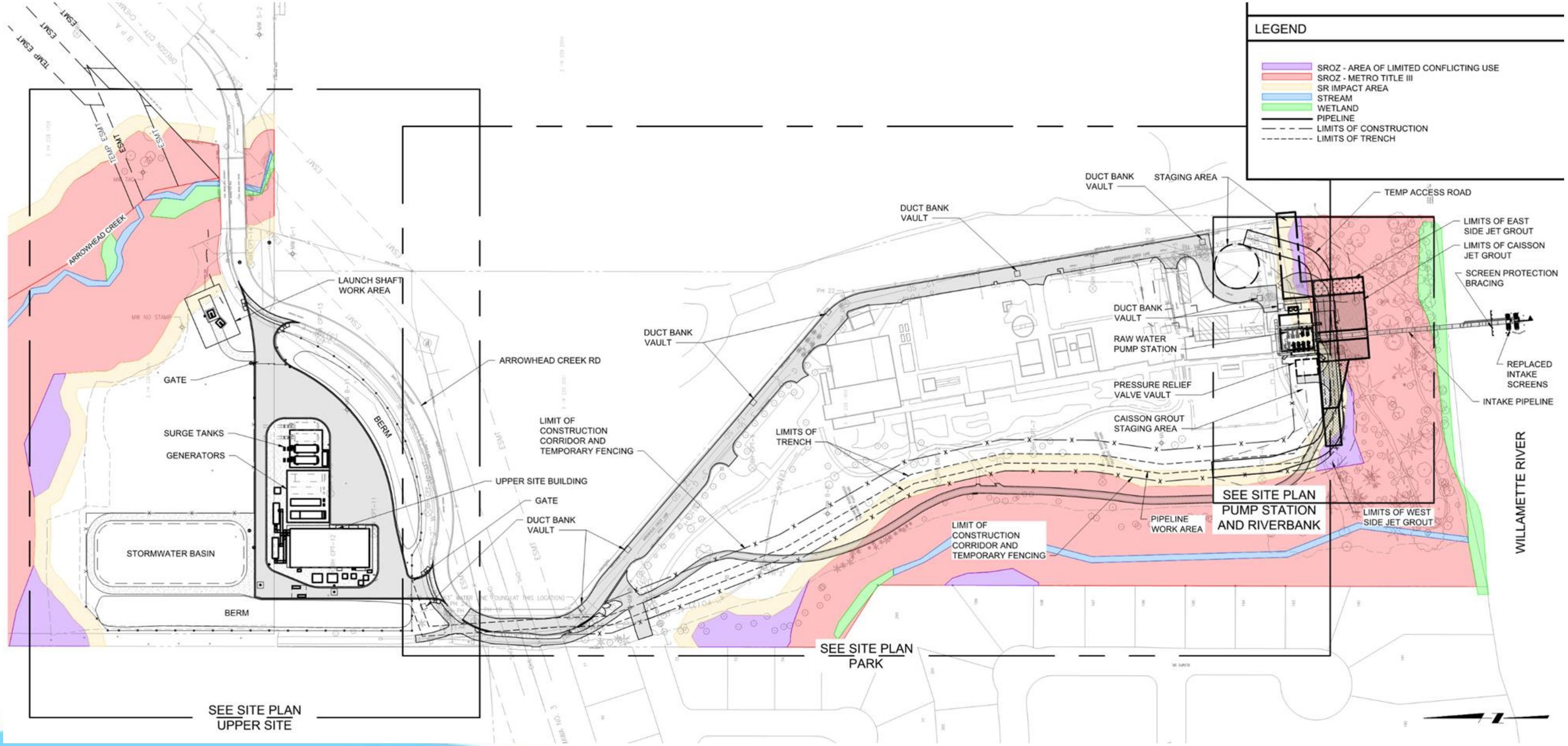
May 2018 1
Committee_Draft M41 Seismic Design Chapter_rev6_5-7-18

Framework Steps:

1. Identify Service Priorities
2. Establish Level of Service Goals
3. Establish Design Earthquake
4. Evaluate Project Specific Seismic Hazards
5. Establish Design Standards and Methods
6. Design for Seismic Risk Mitigation

RAW WATER FACILITIES

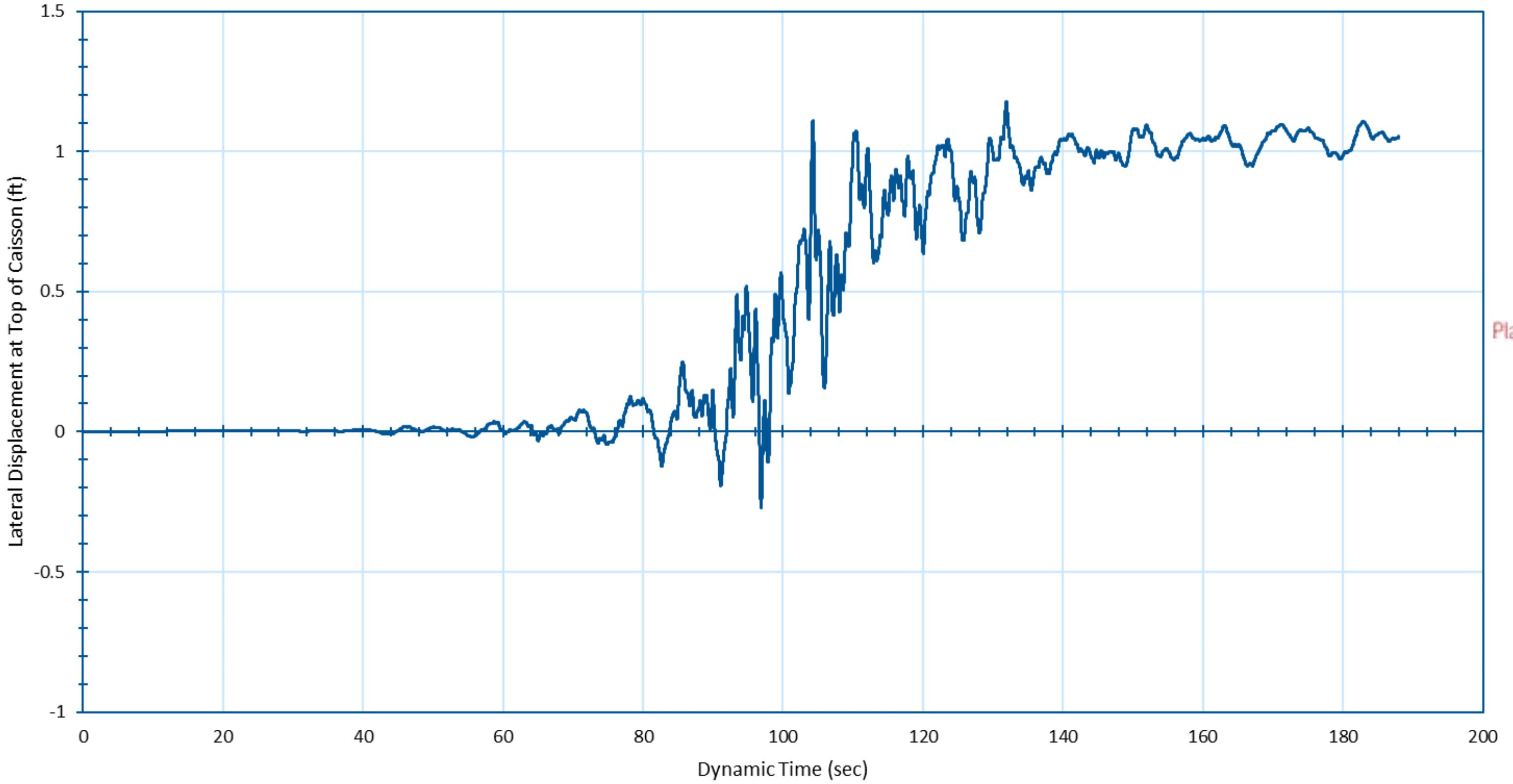
Raw Water Facilities

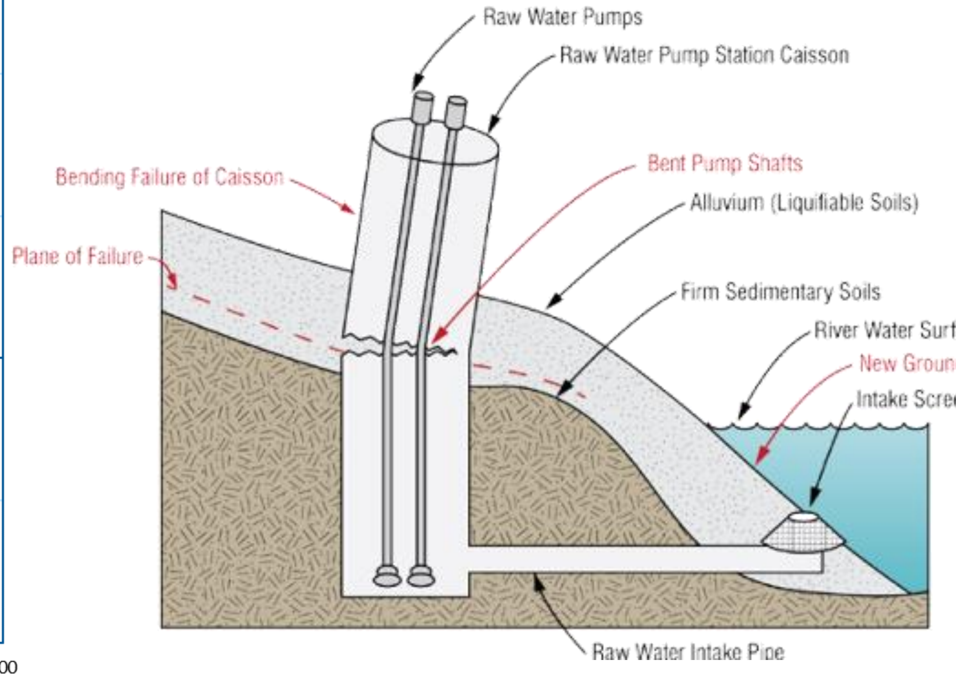


Raw Water Facilities

Subduction earthquake (long-duration ground shaking): existing conditions

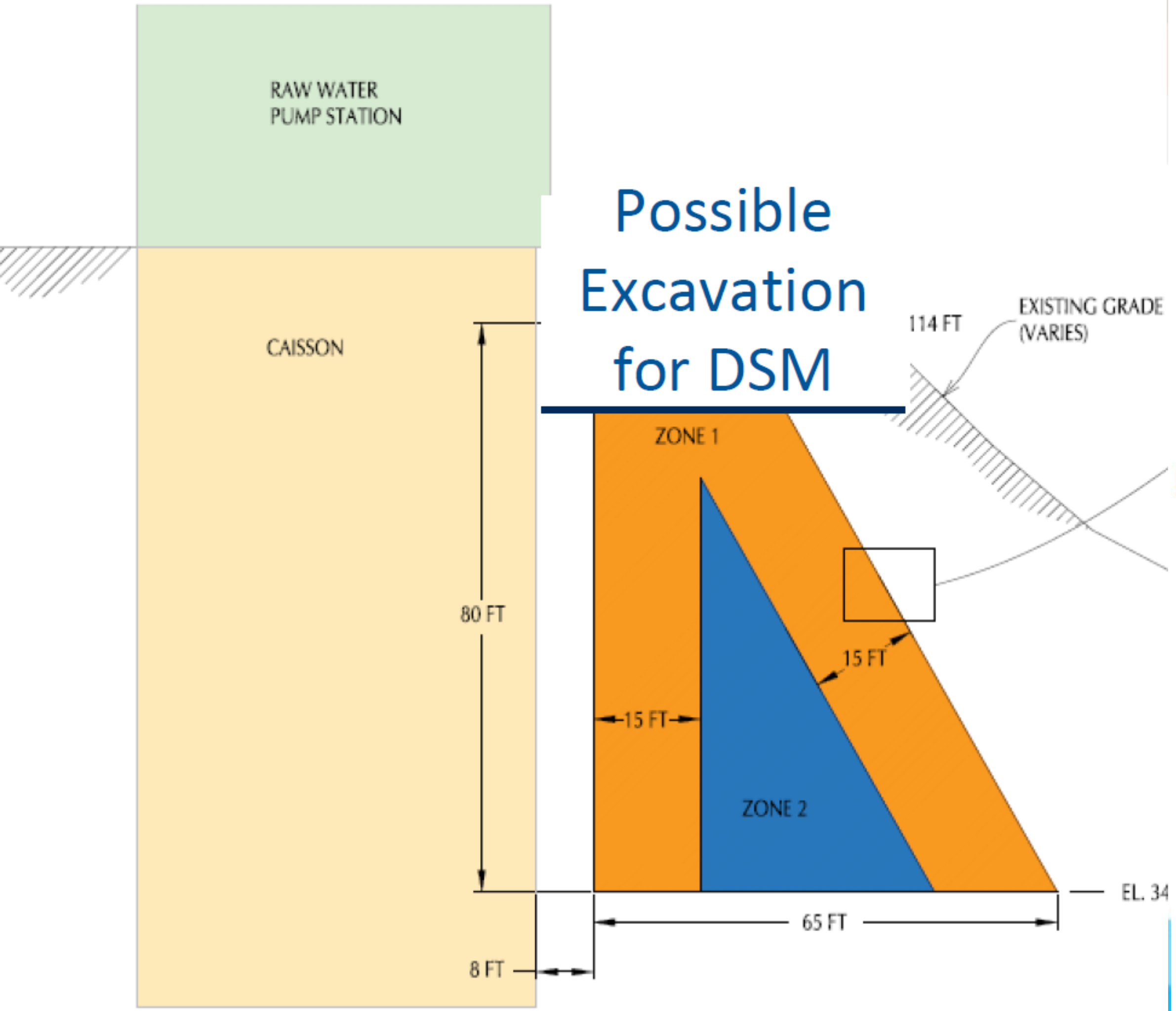
Lateral displacement of caisson





Raw Water Facilities

Caisson Mitigation



Jet Grout

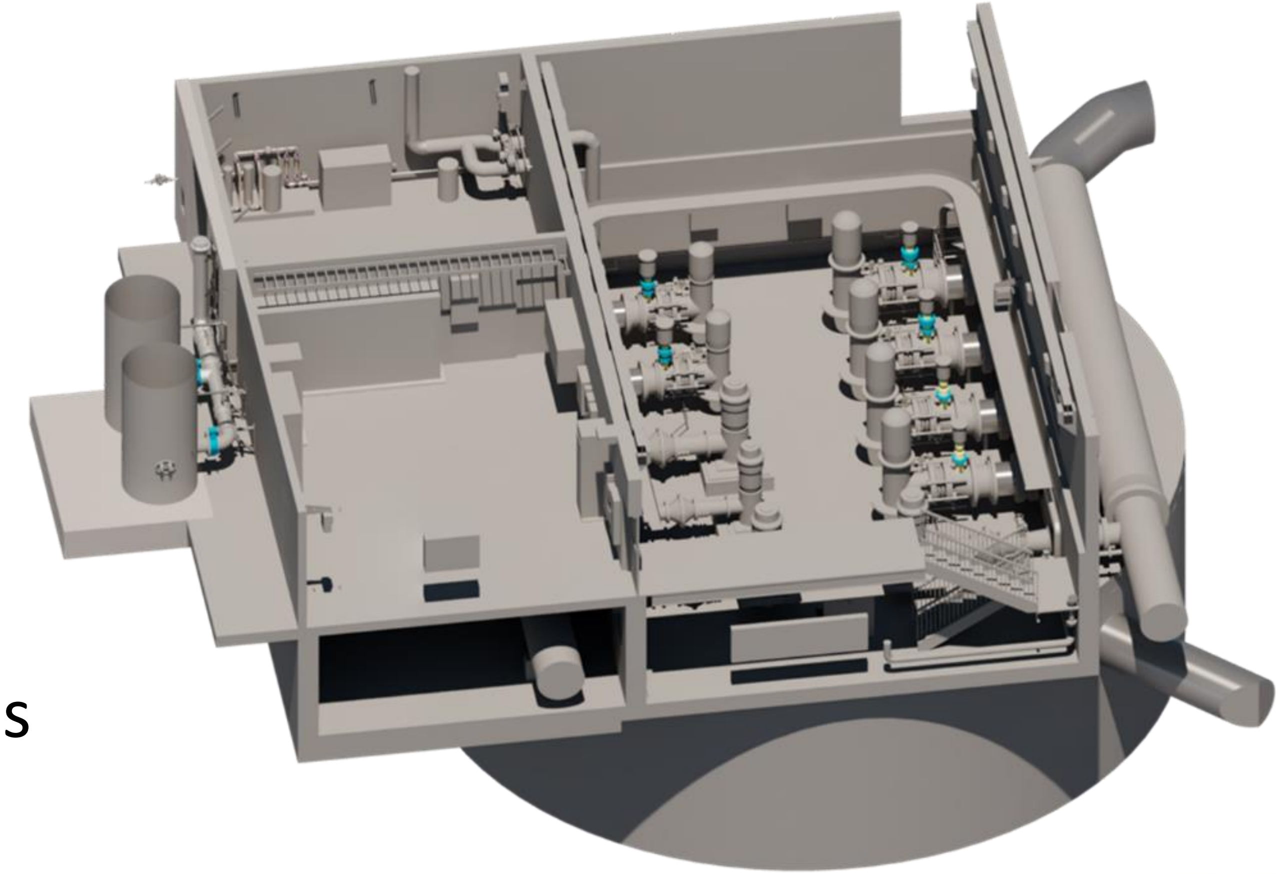


Deep Soil Mixing - DSM



Raw Water Facilities

- Single point of failure considerations:
  - Screens
  - Intake pipe
  - Caisson movement
  - Pump tolerance
  - Emergency operations
  - Emergency access
  - Evaluation of other site hazards

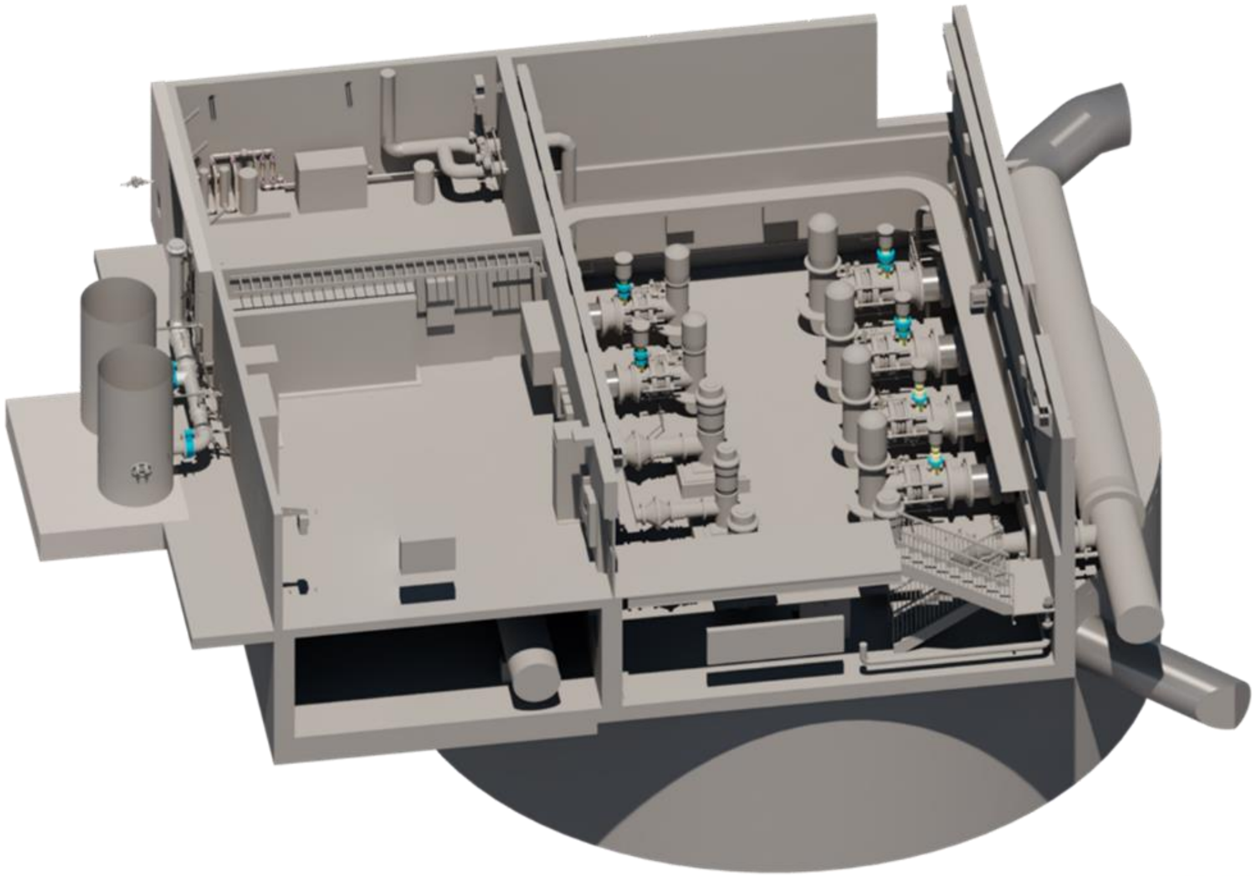


Raw Water Facilities

- Building code considerations:

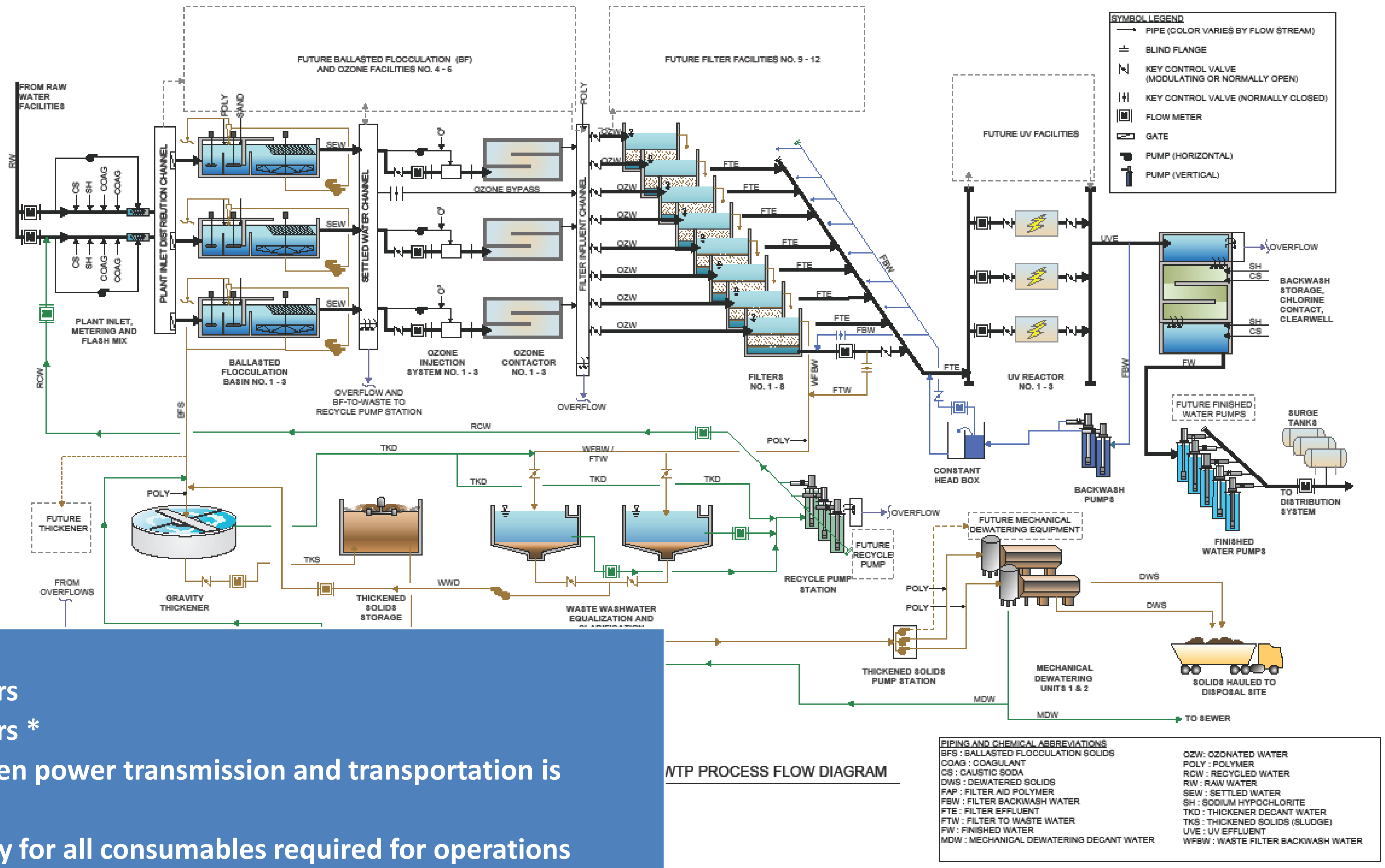
New Buildings: ASCE 7-16 Minimum Design Loads and Associated Criteria for Building and Other Structures (Design Earthquake: Full MCE_R, Risk Category: IV, Seismic Importance Factor: 1.5)

Retrofit of Existing Buildings: ASCE 41-17 (Structural Performance Level: S-1, Nonstructural Performance Level: N-A, Tier 3 Systematic Evaluation & Retrofit Process and Related Reporting)



WATER TREATMENT PLANT

New seismic guidelines for facilities



Level of Service (LOS)

25% capacity w/in 24 hrs

50% capacity w/in 48 hrs *

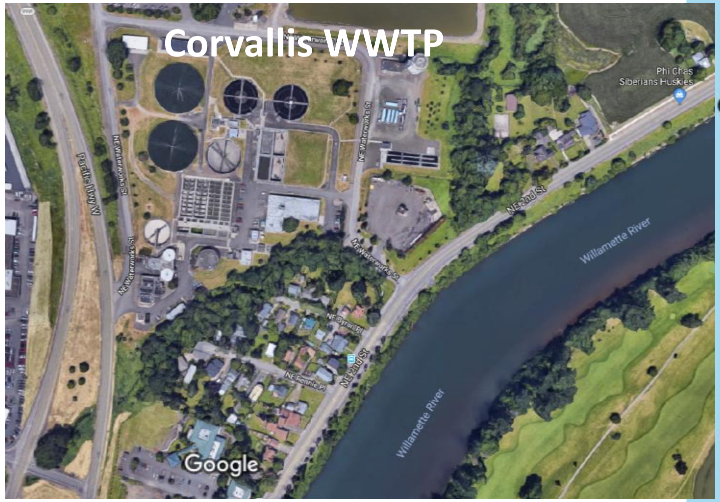
90% to full capacity when power transmission and transportation is restored

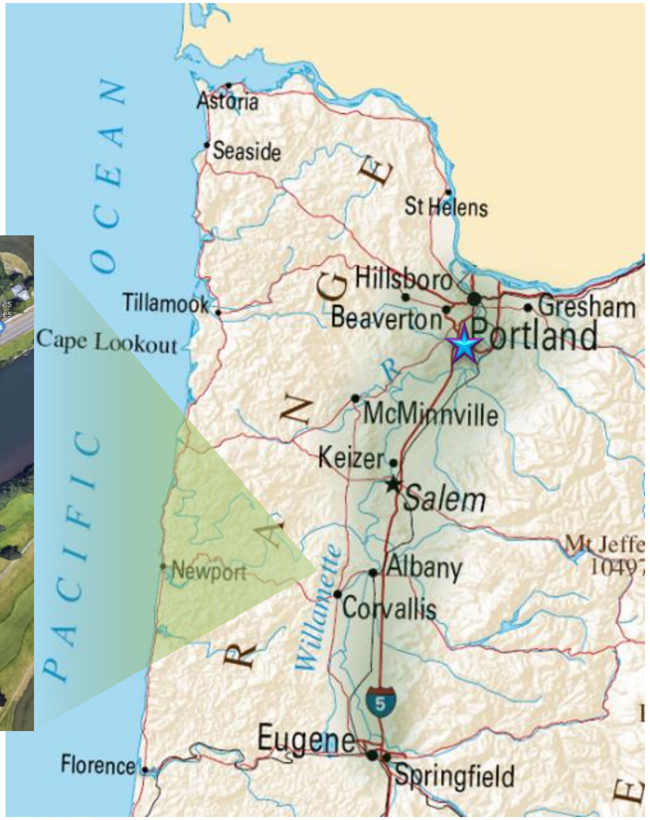
5 days of self-sufficiency for all consumables required for operations

* *Provide full treatment at 50% capacity*

Source water assessment

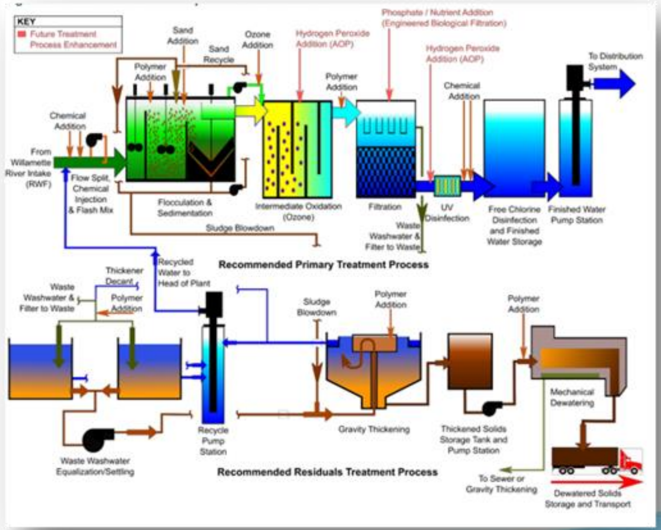
Various point & non-point sources identified





Influences selection and sizing of treatment processes for physical, biological, and chemical constituents including:

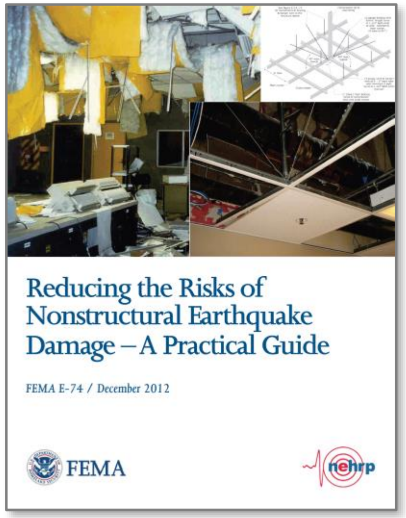
- Turbidity
- Organic materials
- Hydrocarbons
- Agricultural materials
- Emerging contaminants



Need to have the right tools in the toolbox

Both structural and non-structural components must be considered

- To achieve post-seismic event operational goals, both structural and non-structural components must be considered



Severe damage to the Olive View Hospital in San Fernando, California due to the 1971 San Fernando Earthquake
(Source: USGS)

WTP seismic considerations

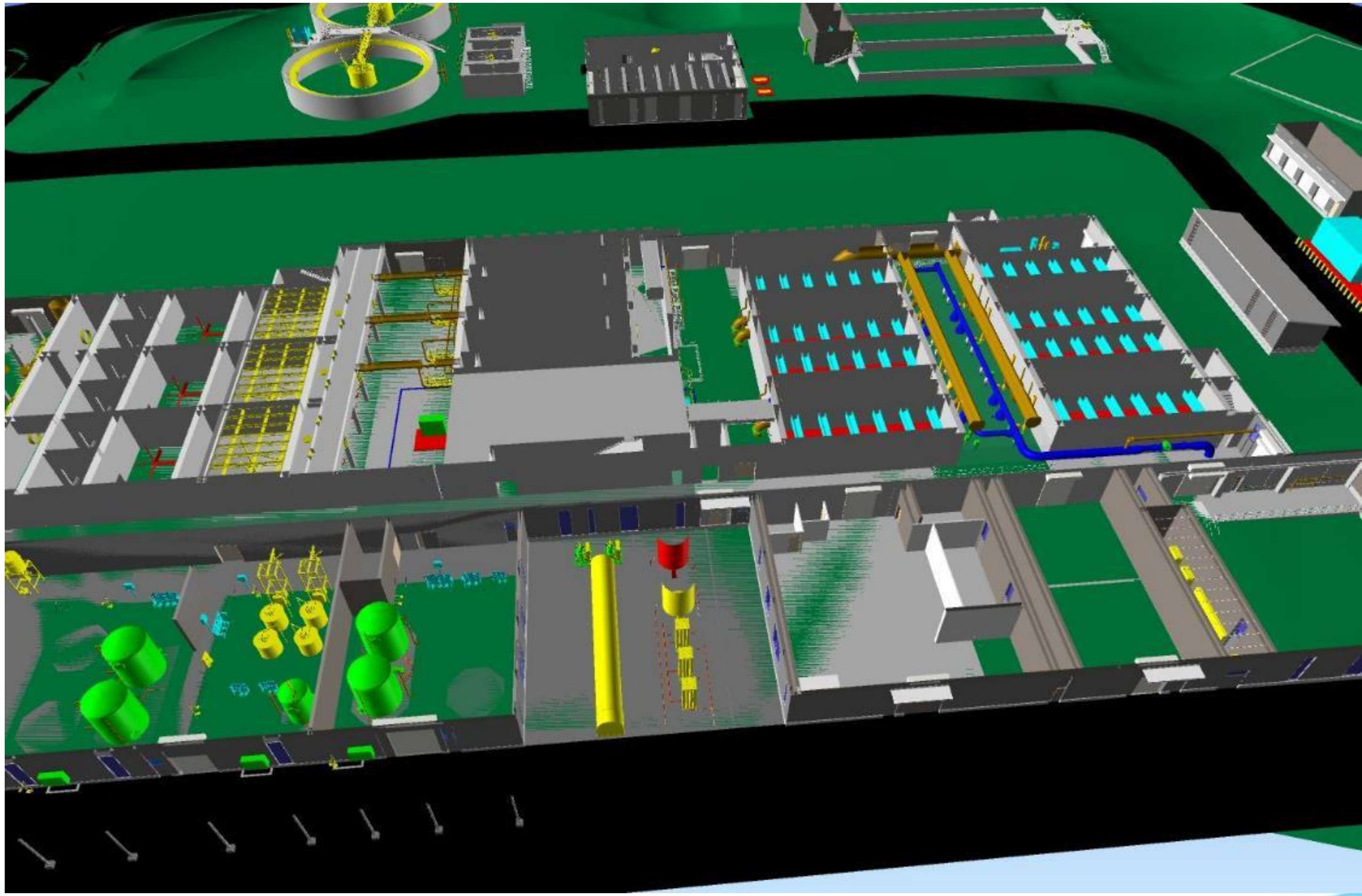
Structural components

Facility layout shall minimize structural horizontal and vertical irregularities as defined in ASCE 7-16.

WTP seismic considerations

Nonstructural components important including:

- Architectural components
- Mechanical, electrical, and plumbing (MEP) Components
- Furniture, fixtures & equipment (FF&E), and contents



Cost split between structural and non-structural

The "structural components of a commercial building account for approximately 15-25% of the original construction cost, while the nonstructural (mechanical, electrical, plumbing, and architectural) components account for the remaining 75-85% of the cost"

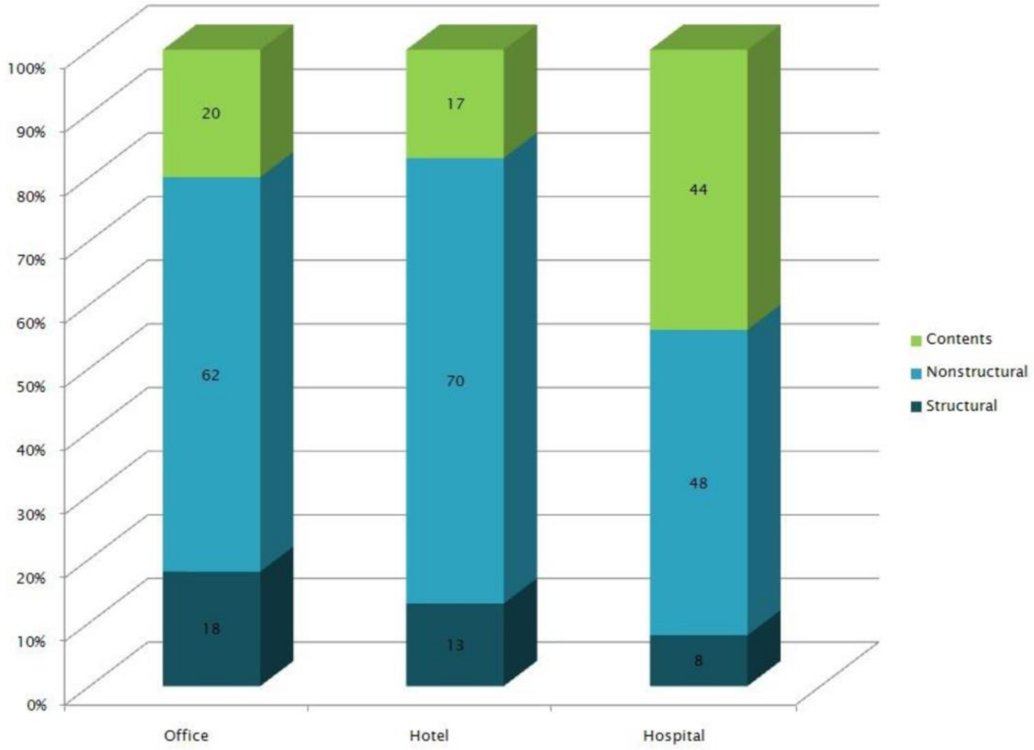


Figure 2.1.3-1 Typical investments in building construction.

"Non-structural failures have accounted for the majority of earthquake damage in several recent U.S. earthquakes"

(Source: FEMA E-74)

Causes of nonstructural damage

- Inertial forces “or shaking effects cause sliding, rocking, or overturning”

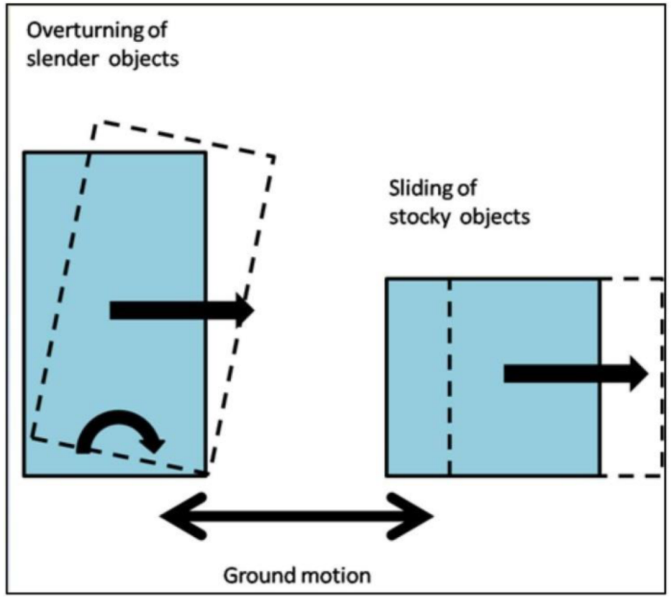
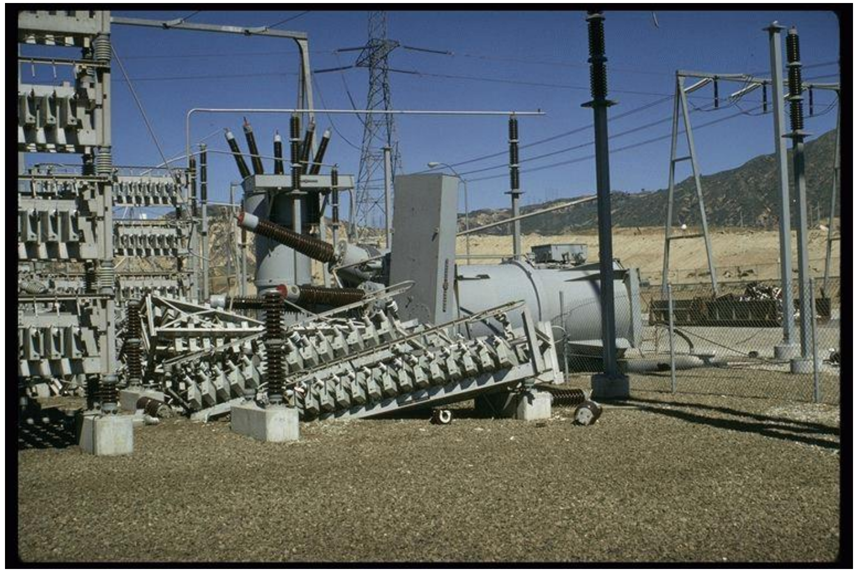


Figure 2.2.1-1 Sliding and overturning due to inertial forces.

(Source: FEMA E-74)



Overturned electrical equipment at Sylmar Converter Station damaged after the 1971 San Fernando earthquake.

(Source: Pacific Engineering Research (PEER) Center, University of California, Berkeley)

Causes of nonstructural damage

- Building deformations "damage interconnected nonstructural components"

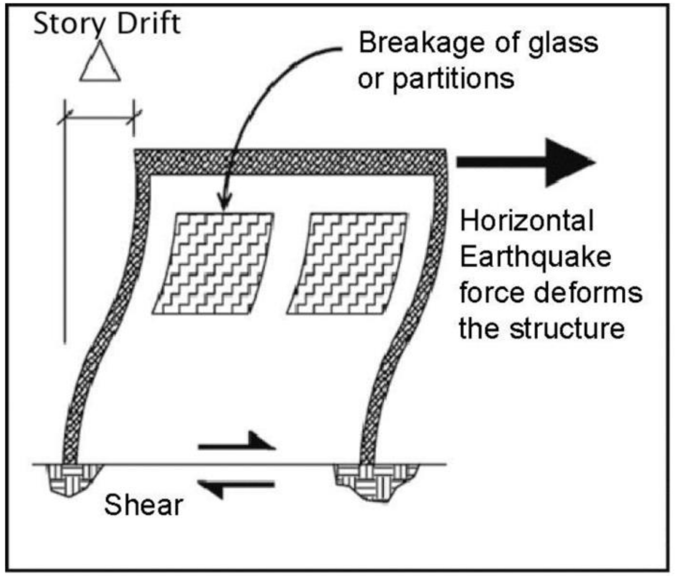


Figure 2.2.2-1 Nonstructural damage due to building deformation.

(Source: FEMA E-74)

Multi-story WWSP Administration Building

(Source: WWSP)

Causes of nonstructural damage

- Building separation “or pounding between separate structures damage nonstructural components crossing between them”

(Source: FEMA E-74)

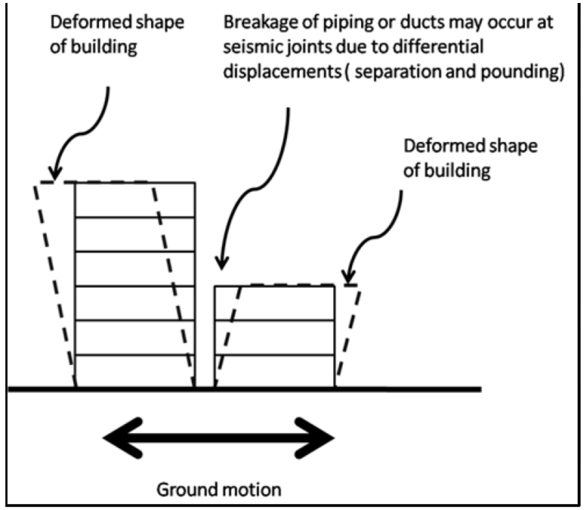
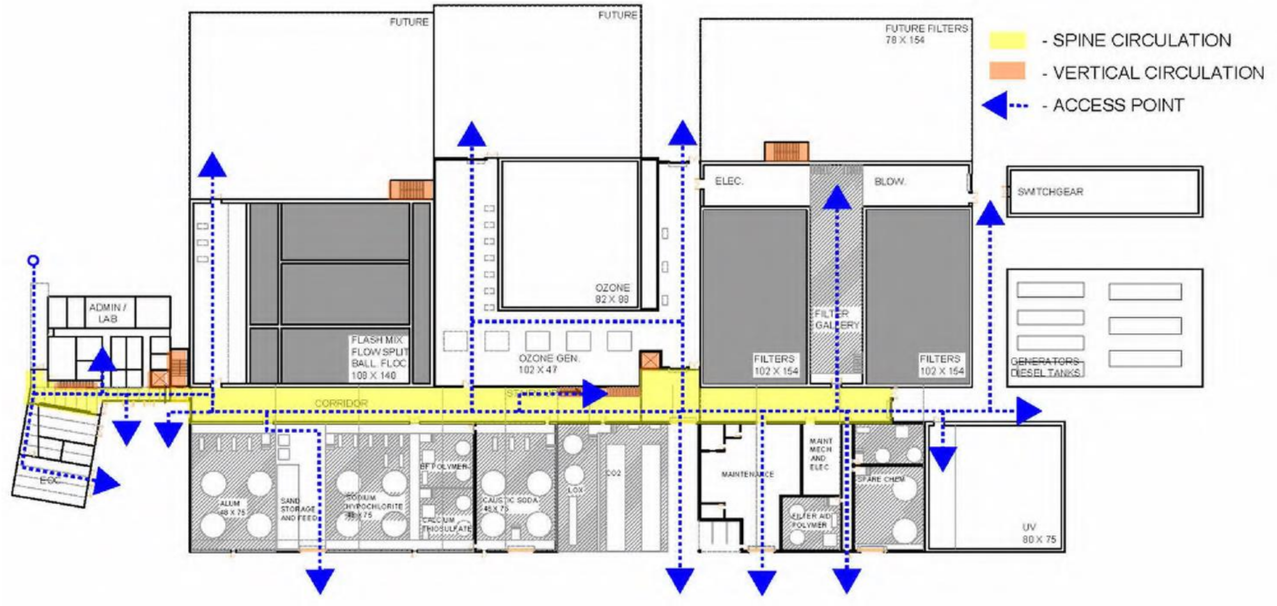


Figure 2.2.3-1 Nonstructural damage due to separation and pounding.



Circulation plan for interconnected building areas connected along central spine

(Source: WWSP)

Causes of Nonstructural Damage

- Interaction "between adjacent nonstructural components… cause damage"

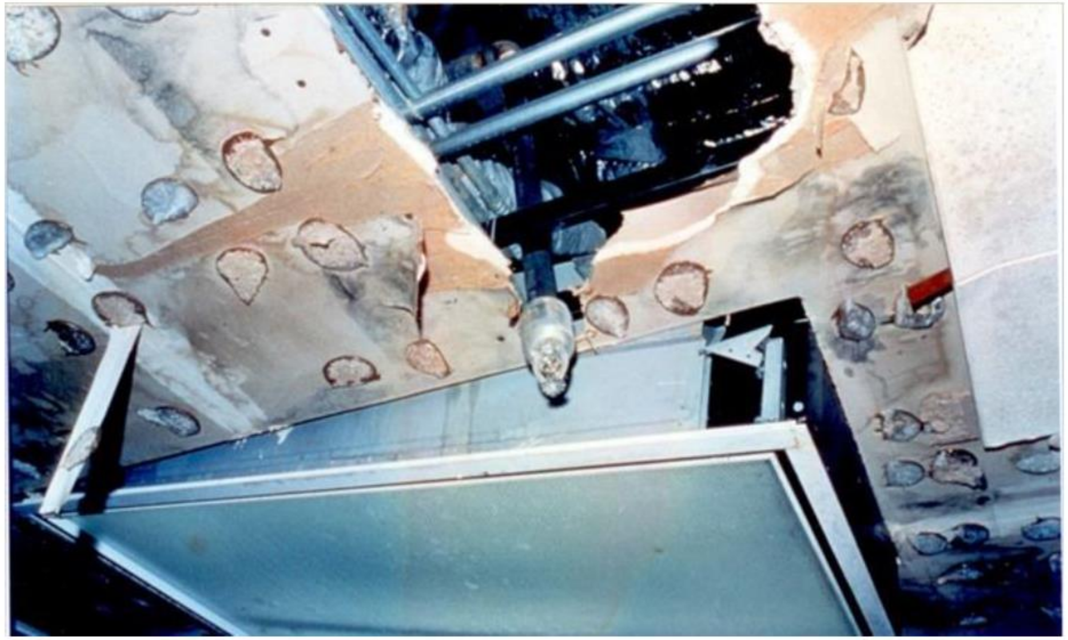


Figure 2.4.3-1 Broken sprinkler pipe at Olive View Hospital in Sylmar, California as a result of the 1994 Northridge, Earthquake. Pipe ruptured at the elbow joint due to differential motion of the pipe and ceiling (FEMA 74, 1994).

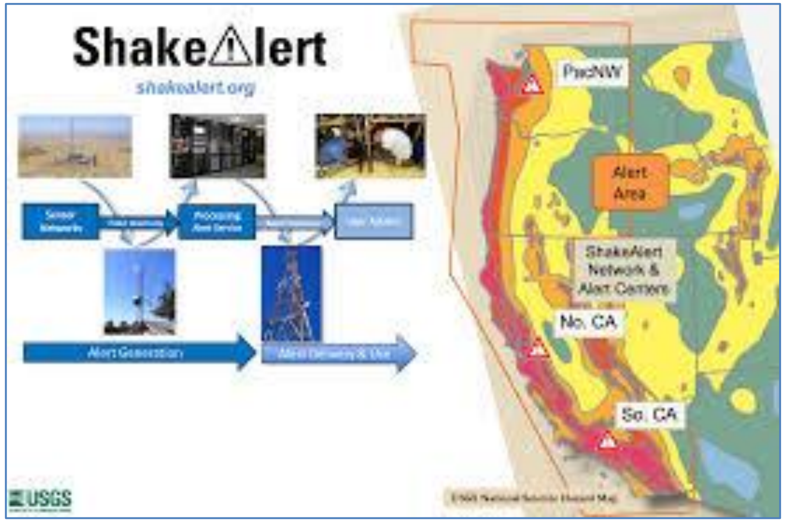
- Examples: sprinkler systems interact with ceiling, adjacent pipes unbraced collide with one another or adjacent objects, suspended mechanical equipment swings, or ceiling components or equipment falls

> "During the 1994 Northridge Earthquake, nonstructural damage caused temporary closure, evacuation, or patient transfer at ten essential hospital facilities. These hospitals generally had little or no structural damage were rendered temporarily inoperable, primarily because of water damage"

OPERATIONAL CONSIDERATIONS

System control considerations

- Early warning system under consideration



- Local accelerometers
  - Might be needed if communications is lost from early warning system
- Startup timing
  - Required facility inspections
  - Hydraulic transients
  - Aftershocks
- Resilient SCADA systems, communication networks, and uninterruptible power supply (UPS)

System turnouts

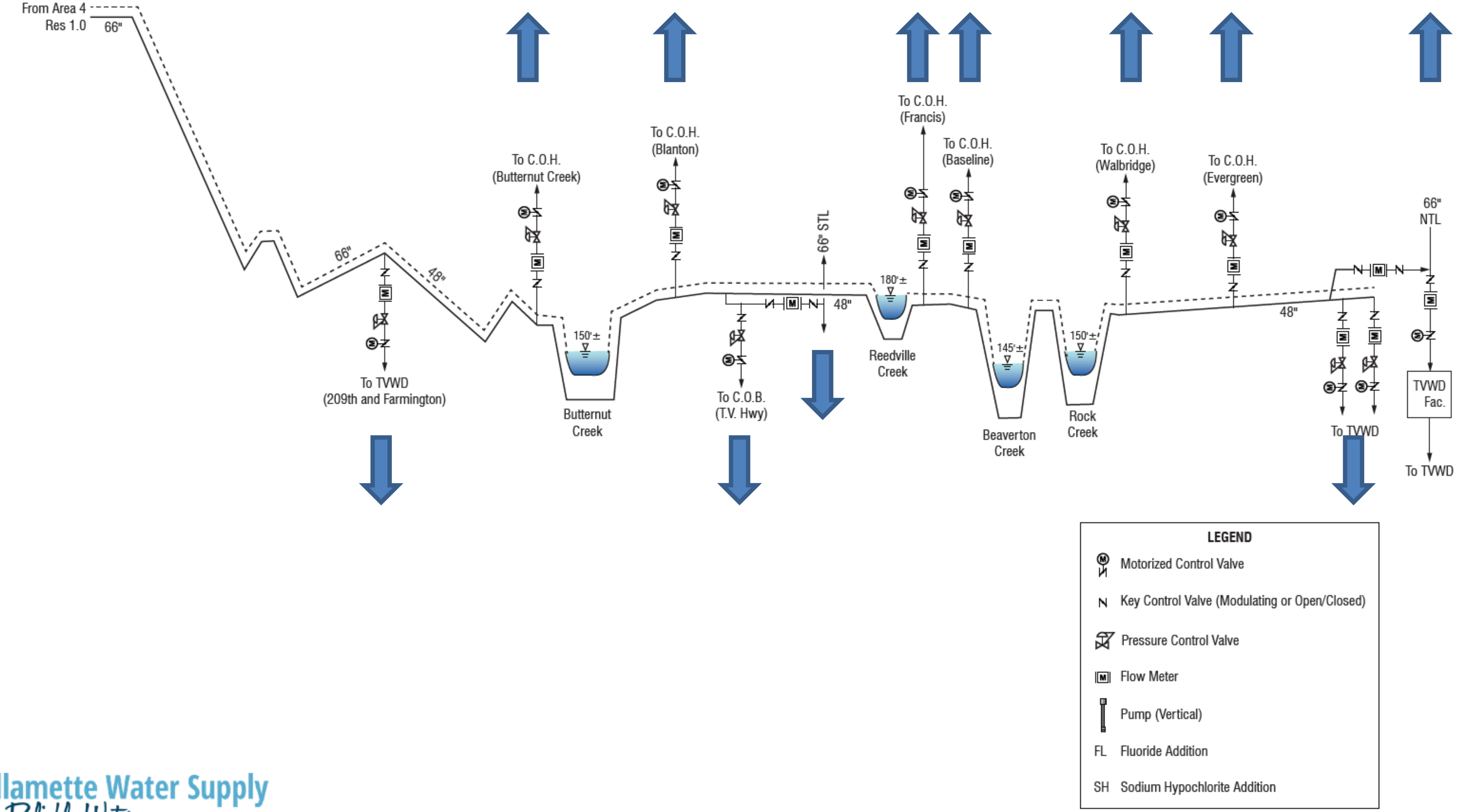


FIGURE 7. AREA 6 - GRAVITY LINE RES 1.0 TO NORTH TRANSMISSION LINE

Considerations:

- Valve control
- Metering flow
- Maintaining internal pressure in steel pipe beneficial

Willamette Water Supply
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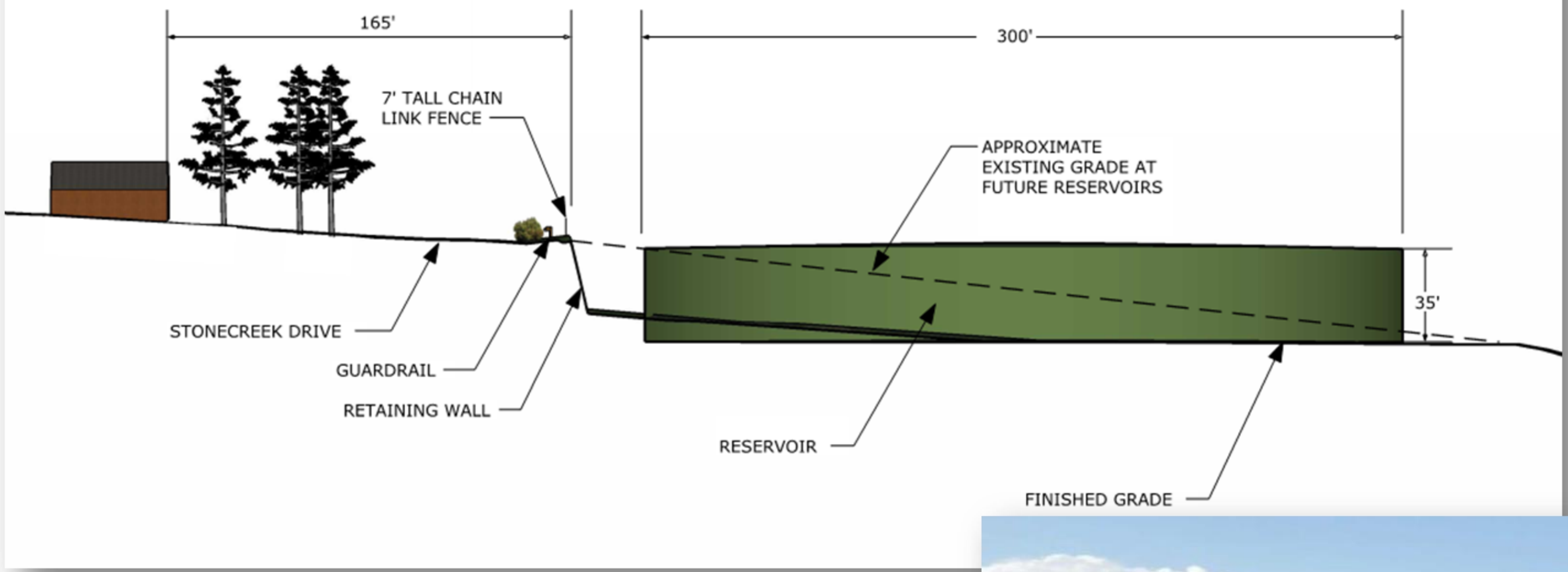
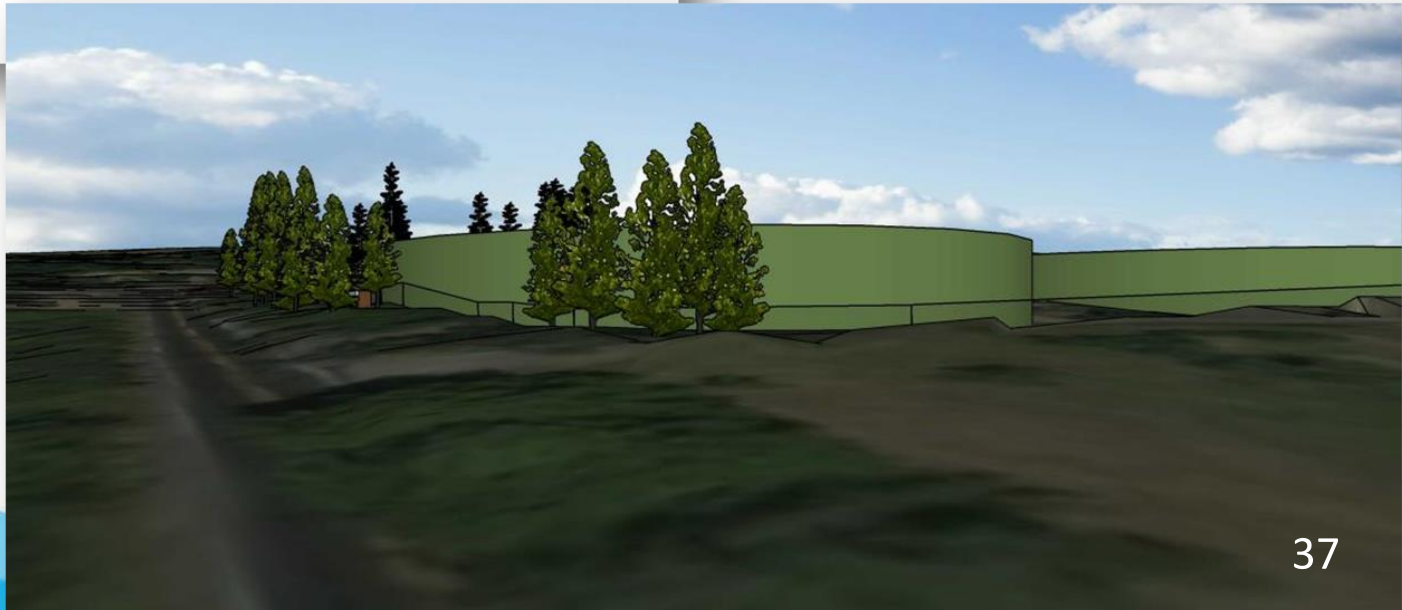
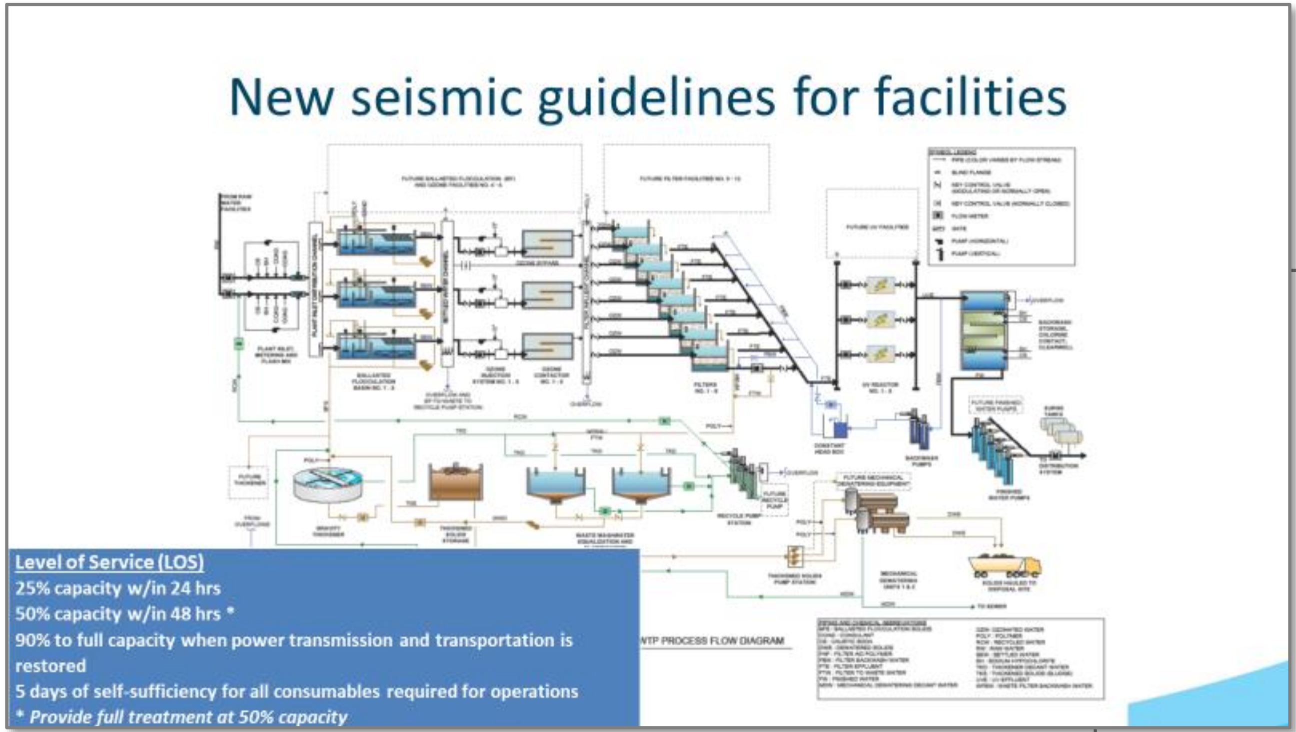
Seismic valves



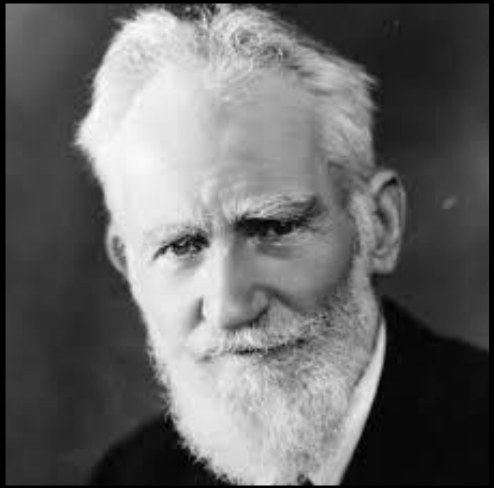


Consumables and spare parts



ADDITIONAL TECHNIQUES AND TOOLS

How do you solve the problem?



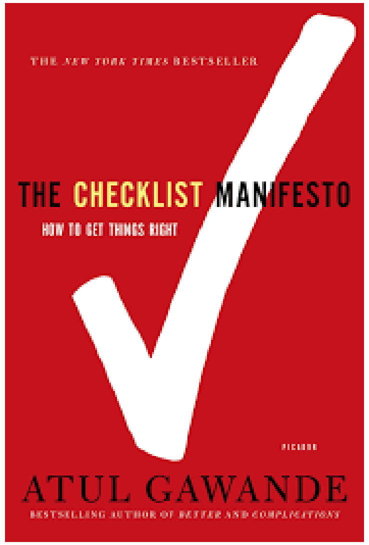
"Progress is impossible without change, and those who cannot change their minds cannot change anything."

George Bernard Shaw

Minimum design requirements (MDR) checklist

Willamette Water Supply *Our Reliable Water*

Guideline Section	MDR	Description	Seismic Design Minimum Requirements for Analysis and Reporting	Analyses Performed	Analyses Meet Requirements (Y/N)	Results
Section 6.2 Geotechnical Site Characterization for Seismic Hazards	MDR 6.2.1	Spatial Variability	Describe how the spatial variability of potentially liquefiable soils was considered and describe the classification of soil layers that are expected to be liquefiable.			
	MDR 6.2.2	Soil Property Variability	Describe how variations in soil properties were established.			
	MDR 6.2.3	Field Measurements and Lab Data	Describe how field measurements and laboratory testing have been incorporated into the seismic hazard analysis and site-specific site-response analysis.			
Section 6.5 Residual Strength Parameter	MDR 6.5.1	Liquefaction Hazard Assessment	Describe approach used as part of liquefaction hazard assessment and results including soil characterization. Also, describe liquefaction triggering procedures used, any discrepancies in results noted between methods, and how discrepancies were resolved.			
	MDR 6.5.2	Factors of Safety for Liquefaction and Residual Strengths	Describe results of factor of safety calculations for liquefaction. Include assumptions for undrained residual soil strengths.			
Section 6.6 Liquefaction Induced Settlement	MDR 6.6.1	Liquefaction-Induced Settlement	For design purposes use professional judgment regarding use of the empirical based results for predicted liquefaction-induced settlement except where cyclic direct shear tests are performed to establish more refined results. Describe procedures used to estimate liquefaction-induced settlement, the expected magnitude, any discrepancies noted, and how resolved.			
Section 6.7 Lateral Spreading	MDR 6.7.1	Lateral Spreading	Identify where lateral spreading is expected, procedures used to screen for lateral spreading, estimate of expected maximum movement, and how mitigated.			
Section 6.8 Soft or Weak Soils Below Pipe	MDR 6.8.1	Soft or Weak Soils Below Pipe	Identify where soft or weak soils are expected below the pipe or other infrastructure, procedures used to screen for soft or weak soils, estimate of expected maximum movement, distribution of lateral spreading ground displacements, and/or how mitigated.			



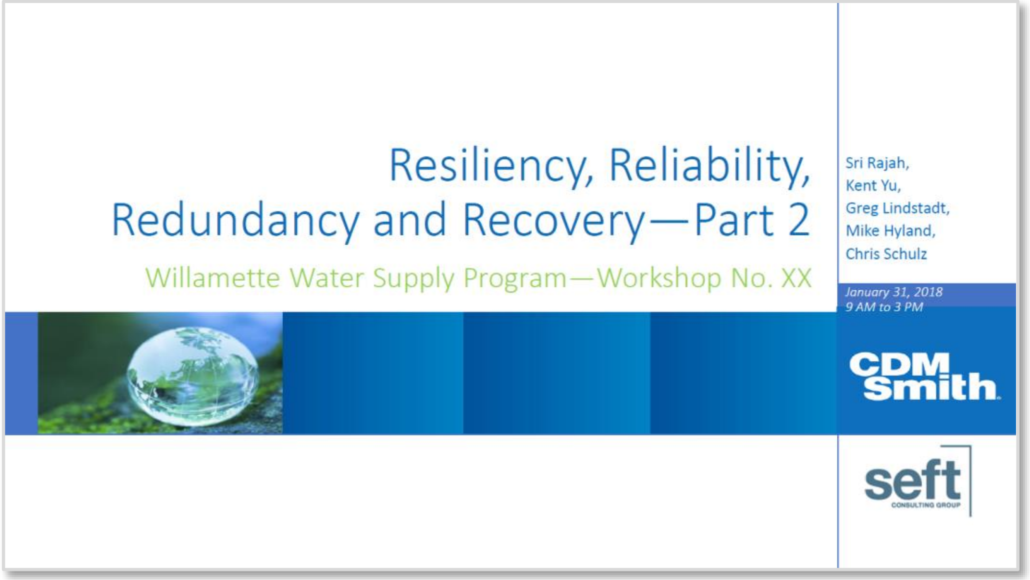
"I came away… with a kind of theory: under conditions of complexity, not only are checklists a help, they are *required* for success."

Atul Gawande

Focused reviews

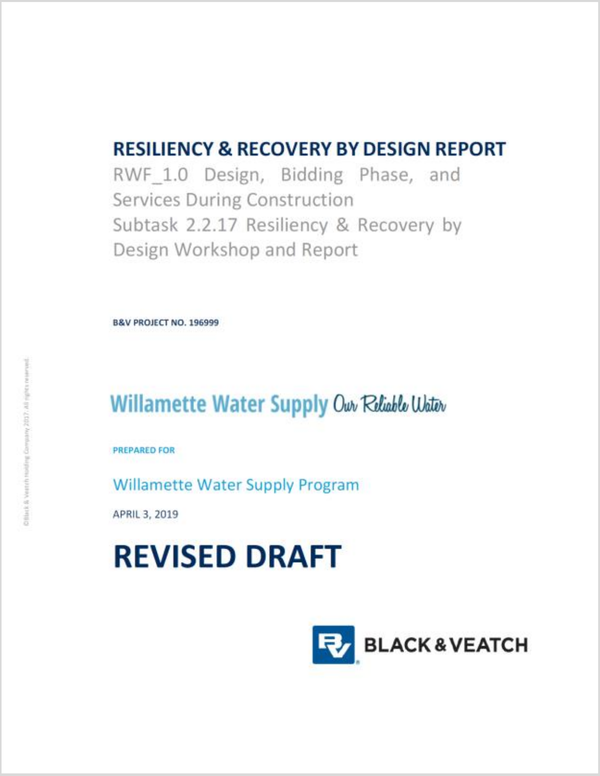
Water Treatment Plant

- Resiliency, Reliability, Redundancy, and Recovery Plan

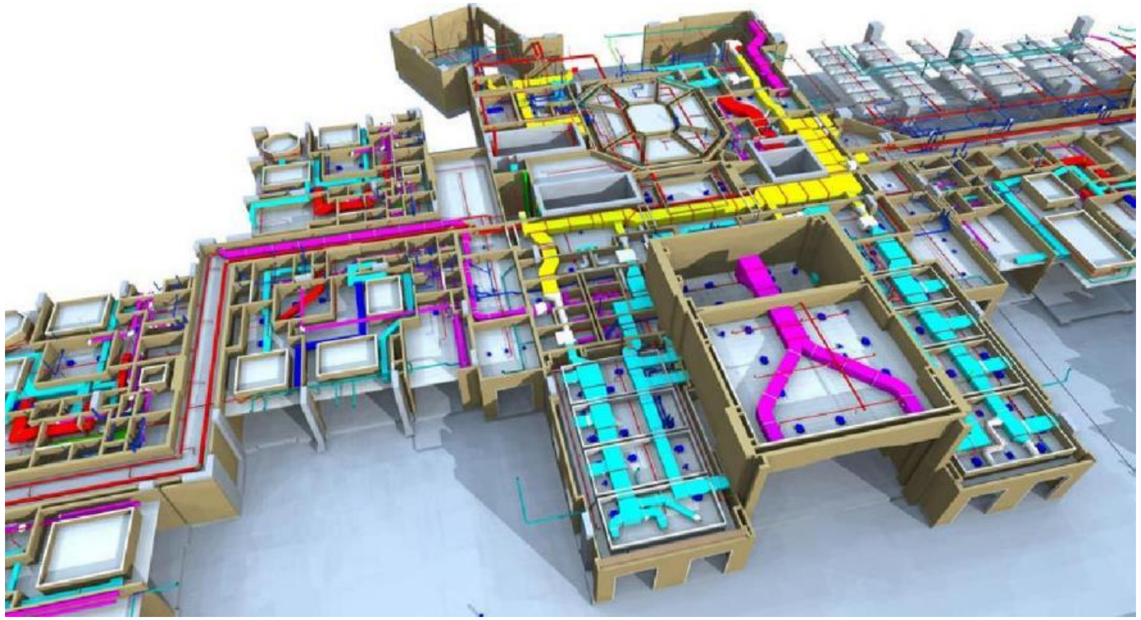


Raw Water Facilities

- Resiliency & Recovery by Design Report

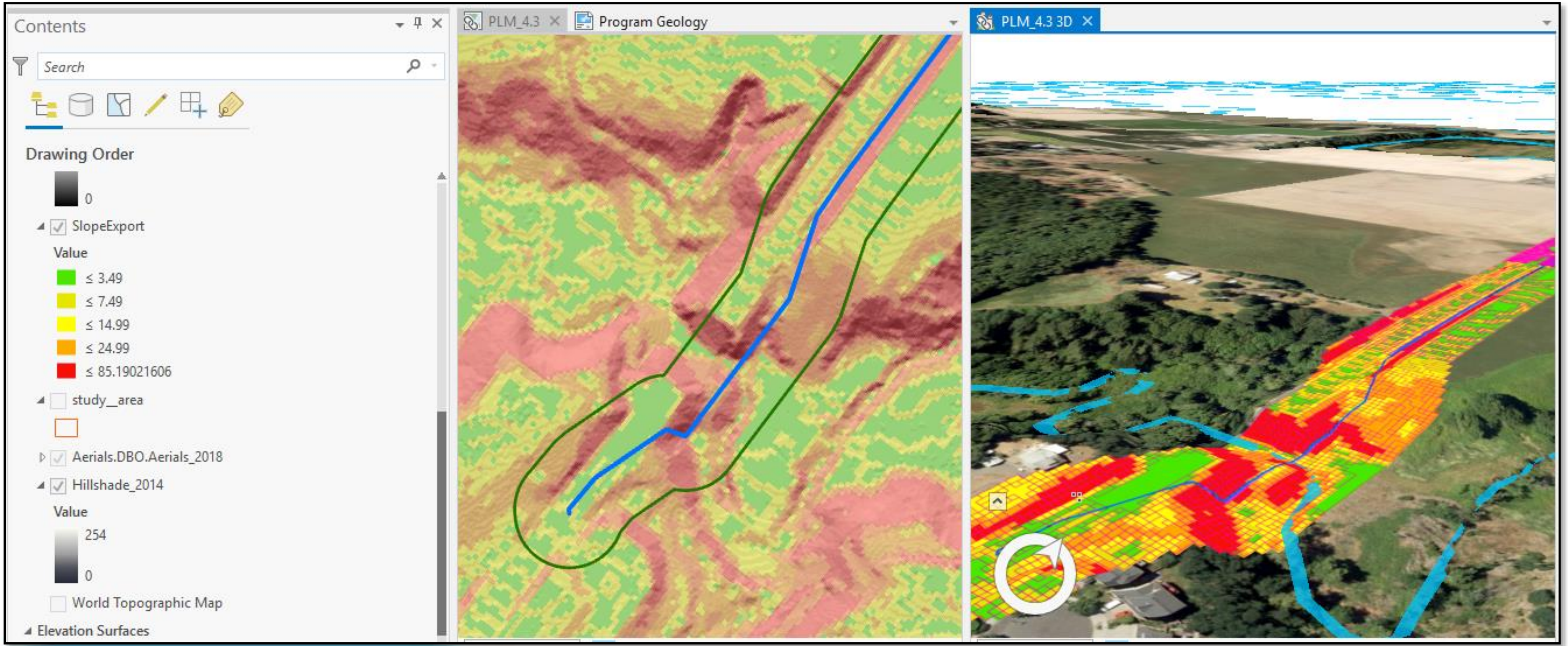


Use building information modeling (BIM) to avoid nonstructural conflicts



(Source: geospatialworld.net)

Use GIS as a tool identify potential hazards



COST OF RESILIENCY

Cost of not being resilient

Complex, multimodal, interdependent systems of infrastructure

Source:
NIST Special
Publication 1190

"Infrastructure is the backbone of the U.S. economy and a necessary input to every economic output. It is critical to the nation's prosperity and the public's health and welfare."

Source: ASCE 2017 Infrastructure Report Card

Cost of not being resilient

Most Critical Infrastructure

Energy
- Petroleum
- Electrical
- Natural Gas
- Nuclear
- Temp Power Gen
- Steam

Transportation

Linear:
- Roads
- Rail
- Waterways

Non-Linear:
- Airports
- Seaports

Public / Private Infrastructure
- Hospitals
- Police / Fire Stations
- Water
- Wastewater
- Dams / Locks / Levees
- EOCs
- Financial
- Manufacturing
- Agriculture
- Government Facilities / Monuments

Communications
- Telephones
- Cell Phones
- Internet
- High Frequency
- Microwave
- SATCOM
- Fiber Optic
- TELCO Hotels
- IXPs

FEMA

(FEMA, 2014)

"The water system is the utility [for the City of Los Angeles that is] most vulnerable to earthquake damage, and that damage could be the largest cause of economic disruption following an earthquake."

Lack of water could:

- Impede recovery
- Lead to business failure
- Lead to mass evacuation

Source: Resilience by Design

Cost premium examples

Building Systems

"1% for the Cooper Mountain High School"

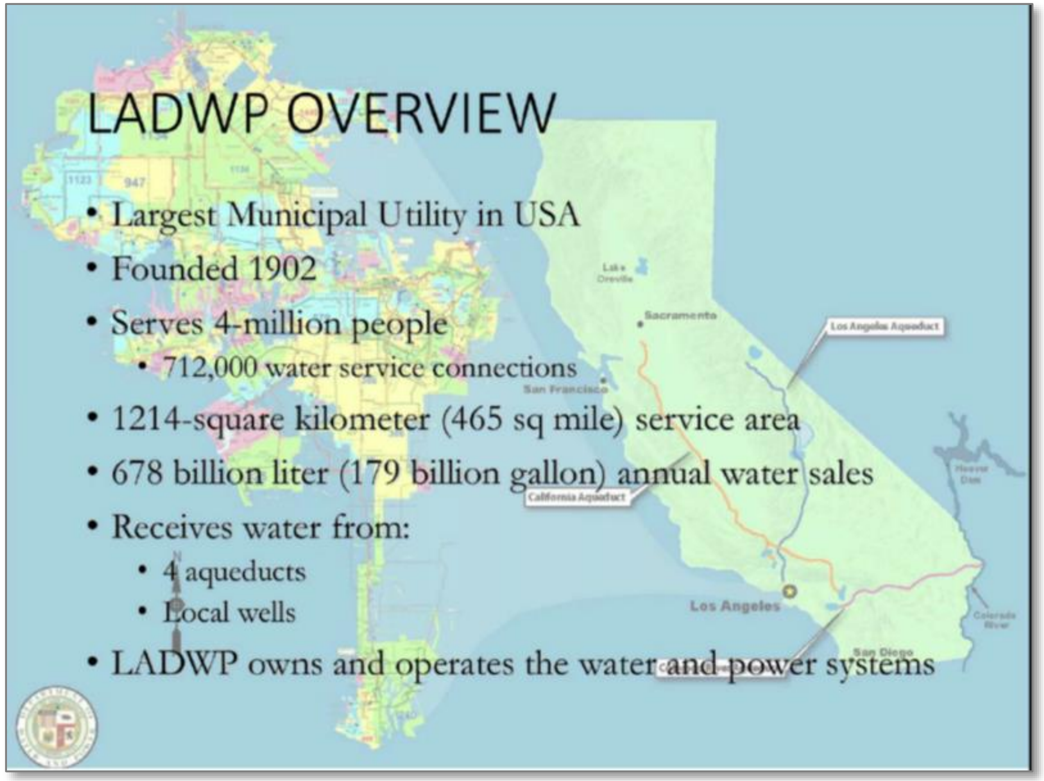
– *Kent Yu (SEFT, 2017)*

"[S]lightly over 1.5% for the Timberland Middle School"

– *Kent Yu (SEFT, 2017)*

Cost premium examples

Water Infrastructure Systems



Source: "Pipeline Rehabilitation for a Seismic Resilient System, Craig Davis, Ph.D., PE, GE, Water Research Foundation, Large Pressure Pipe Structural Rehabilitation Conference, 2016

According to Craig Davis* from LADWP, "the premium [for their pipe replacement project] was about 4% to 5%"

– Kent Yu (SEFT, 2017)

** Craig Davis, Ph.D., PE, GE is the Water System Resilience Program Manager for the Los Angeles Department of Water and Power, Water System.*

WWSS cost premium for resilience

RWF_1.0	• Jet grout wall, lower slope wall and catchment wall • Building structure retrofit • 5-day consumables storage • Pump bracing and enhanced bearings • Seismic certification
WTP_1.0	• Site relocation including property purchase • Treatment processes enhancements • 5-day consumables storage • Enhanced pump bearings and seismic certification • Possible EOC (Emergency Operations Center) and stand-alone lab
RES_1.0	• Standard design • Seismic valves
General Pipeline Design	• Added geotech and modeling to inform design (hazard avoidance) • Targeted application of butt welds • Seismic valves at turnouts • Seismic mitigation at vaults
PLM_1.0, PLM_2.0, PLW_1.0 & PLE_1.0	• Standard design
PLM_3.0	• Soil/rock interface design detail (wall and trench joint)
PLM_4.0	• Culvert crossings weld design • Chicken Creek crossing (pipe wall/butt welds/engineering analyses) • Tualatin River crossing slightly longer
PLM_5.0 & PLW_2.0	• Alignment refinements to avoid hazards

- Current Estimate of Cost Premium for Resilience*
  - Estimated cost of seismic mitigation ~$50M
  - Approximately 4% of total program cost

* Design development underway. Finalization of design may affect associated seismic mitigation costs.

WHERE DOES THE INDUSTRY NEED TO GO?

Areas to improve all across the industry

Responsibility Matrix

Categories	Owner	Policy	Engineer	Contr.	Bldg.
Design earthquake	X	x			
Level service goals	X	x			
System engineering			X		
Procurement:					
- Special procedures	X				
- Seismic certifications			X		
- Long-lead times				X	
Installation quality control			x	X	x
Code review/enforcement			X		X

Also, improvements in industry organizations and university system

Thank you!

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A RIVER RUNS THROUGH IT

2019 PNWS-AWWA CONFERENCE

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