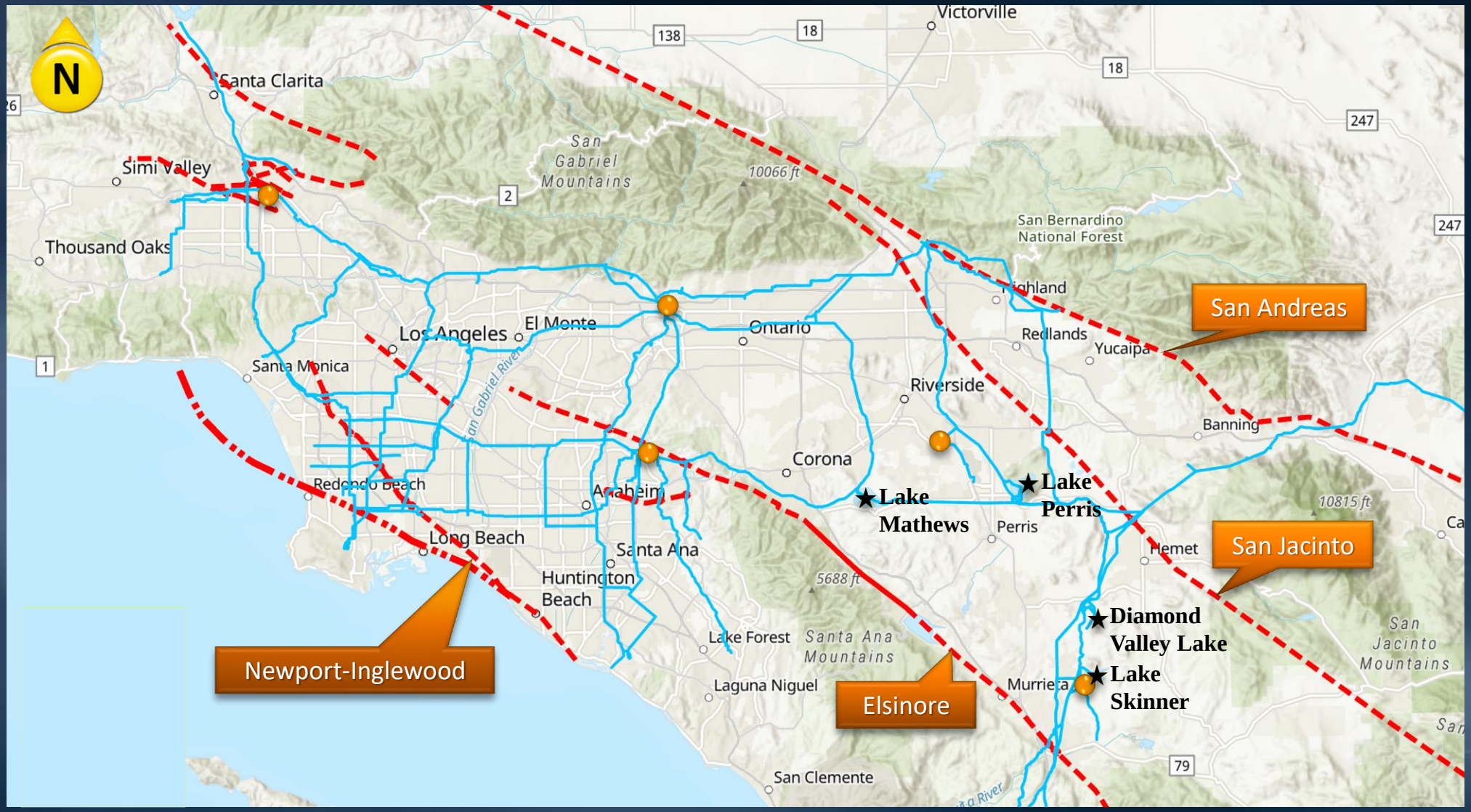
Innovative Approaches to Seismic Resilience for Metropolitan's Pipelines and Tunnels

Engineering and Operations Committee
Item 6c
July 12, 2021

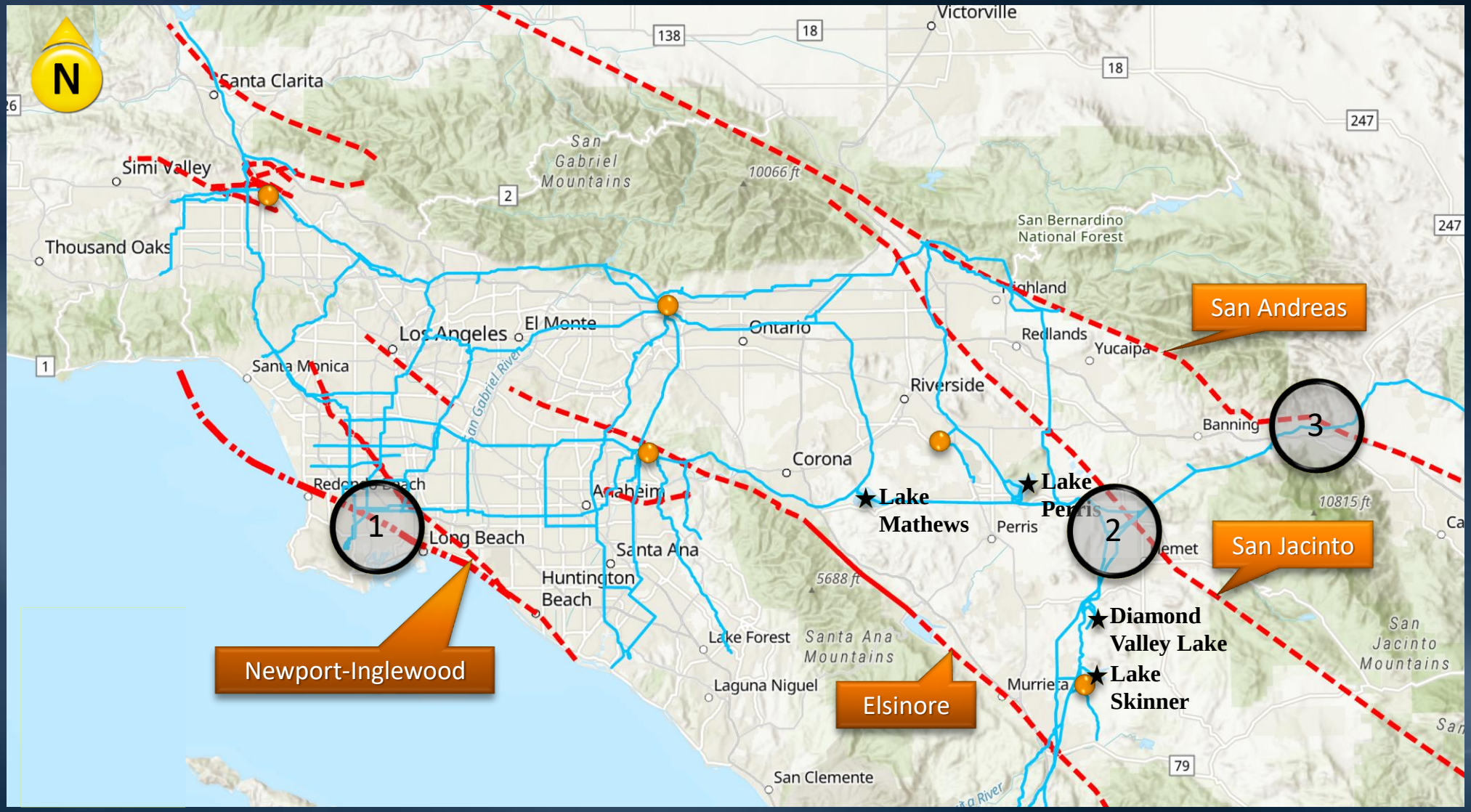
Overview

- Background
- Recent Advancements
- Seismic Risk Mitigation Approach
- Examples of Seismic Mitigation Design
- Conclusion/Next Steps

Regional Seismic Risk



Regional Seismic Risk



Steps Toward Overall Seismic Resilience

1930's
Construction of Colorado River Aqueduct

1971
San Fernando Earthquake

1994
Northridge Earthquake

2011
Christchurch Earthquake

Seismic Hazard for Buried Pipelines

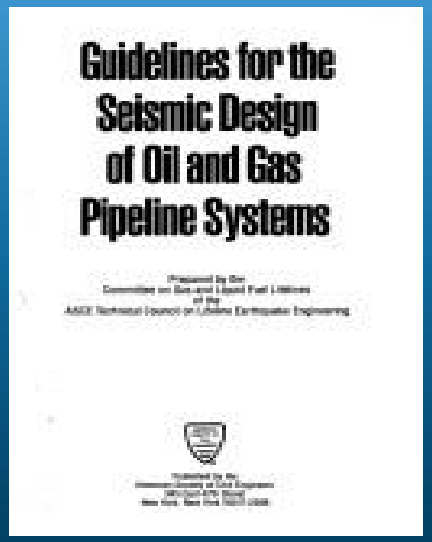
Risk	Type of Failure
1. Shaking	Pipe joint failure
2. Permanent Ground Displacement	Pipe joint failure, Pipe rupture

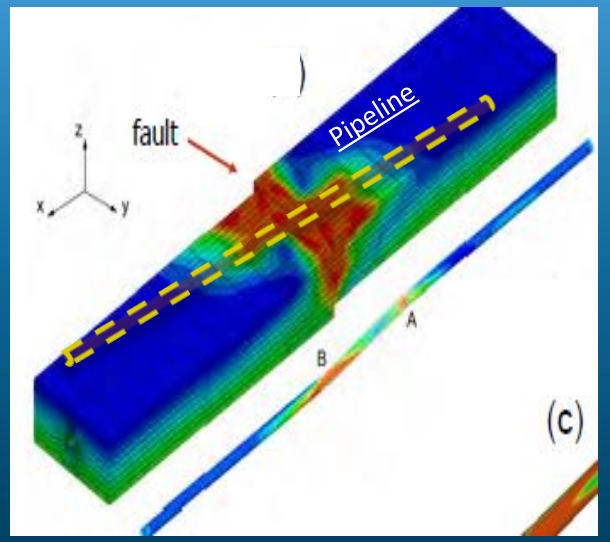
1971 San Fernando Earthquake

1994 Northridge Earthquake

1989 Loma Prieta Earthquake

Recent Advancements





1974:
First seismic resilient pipe joints installed in Japan

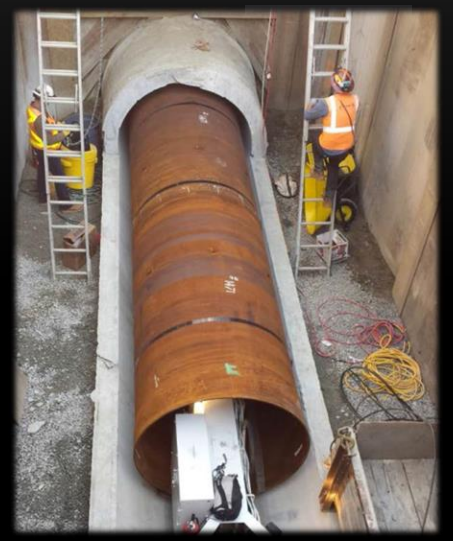
1984:
ASCE lifelines seismic design guidelines issued

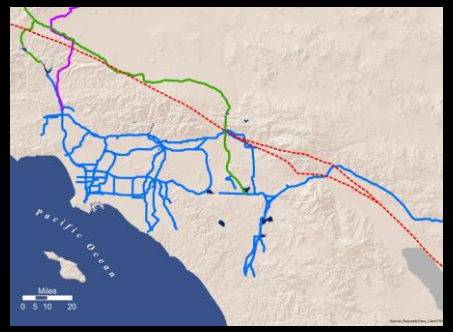
1995:
Advanced analytical techniques became available

2012:
First seismic resilient pipe installation in U.S. (Los Angeles)

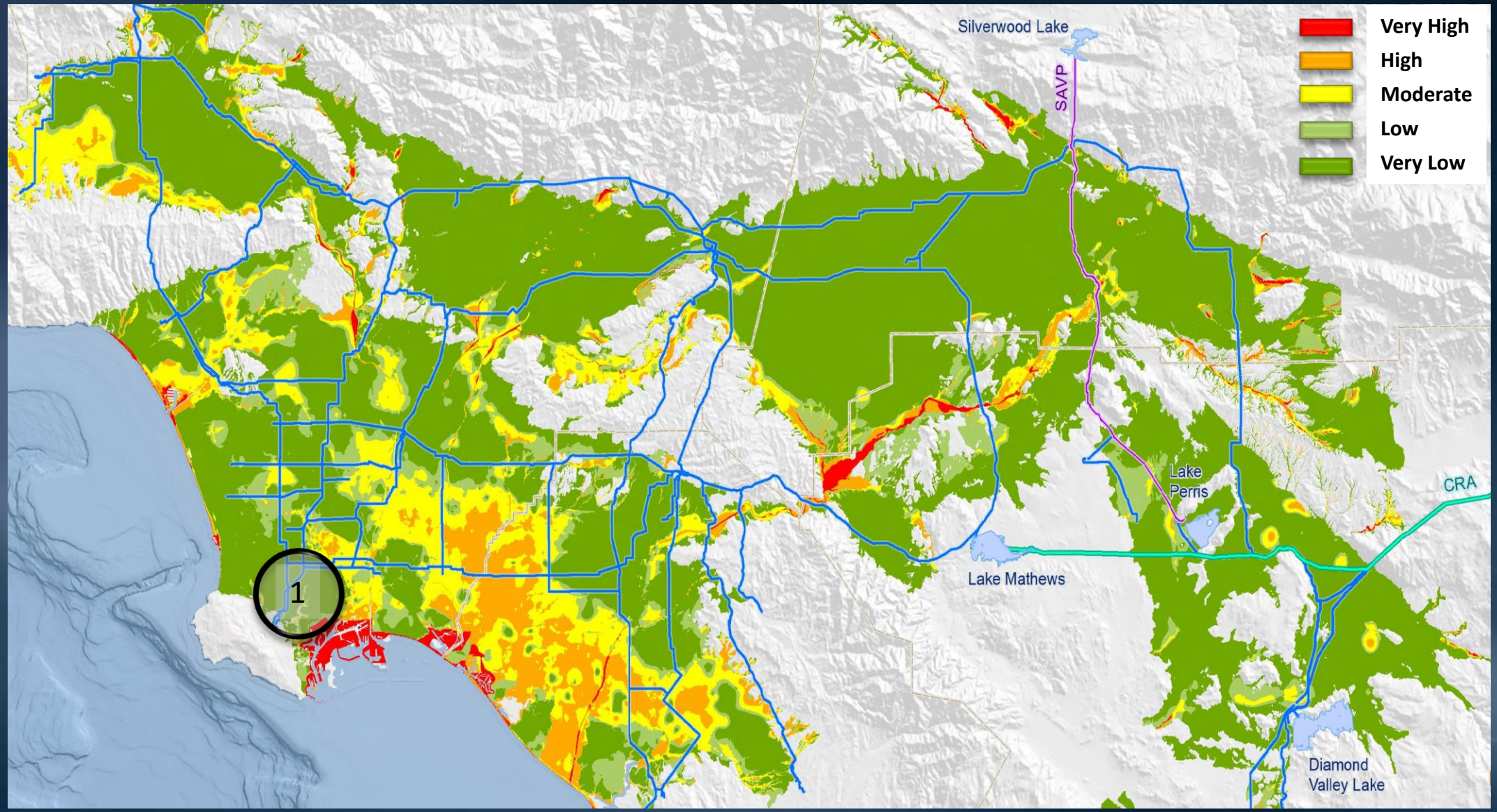
Seismic Risk Mitigation Approach

1. New Pipelines and Tunnels
   - Incorporate seismic resilience into design
2. Existing Pipelines and Tunnels
   - Prioritize mitigation efforts
   - Implement mitigation measures in R&R programs
3. Conveyance and Distribution System
   - Plan for post-event restoration

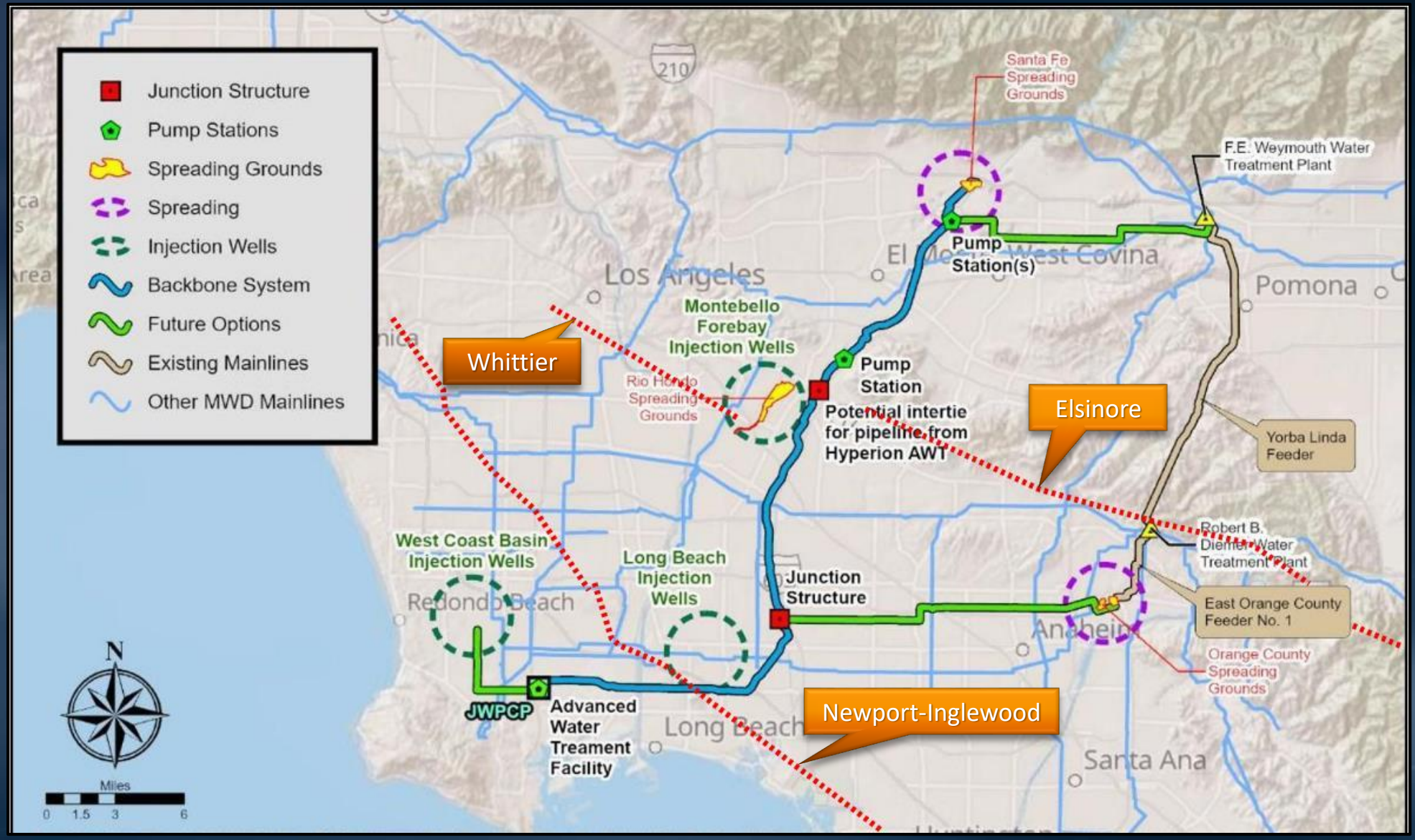




Liquefaction Susceptibility Mapping

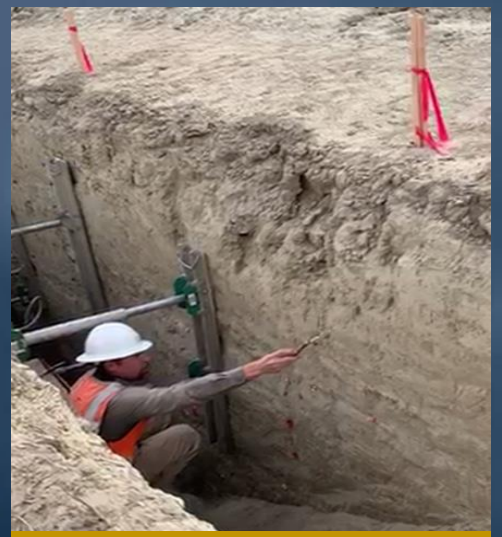


Example 1: New Pipeline (Regional Recycled Water Program)



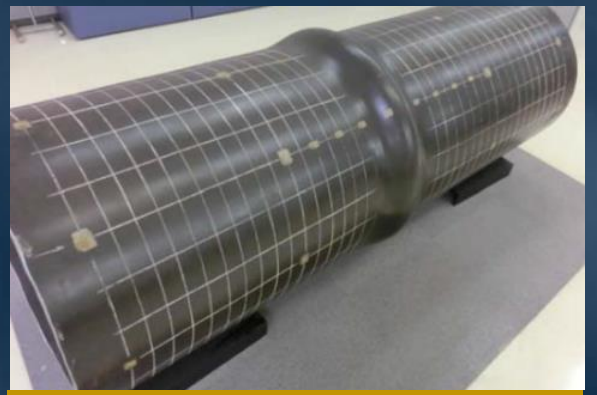
Seismic Resilience Mitigation Approach

- Establish design performance criteria
- Evaluate conditions along multiple alignments
- Use advanced modeling to analyze pipeline response
- Strategic use of specialized joints and pipe sections



Fault Trenching Study

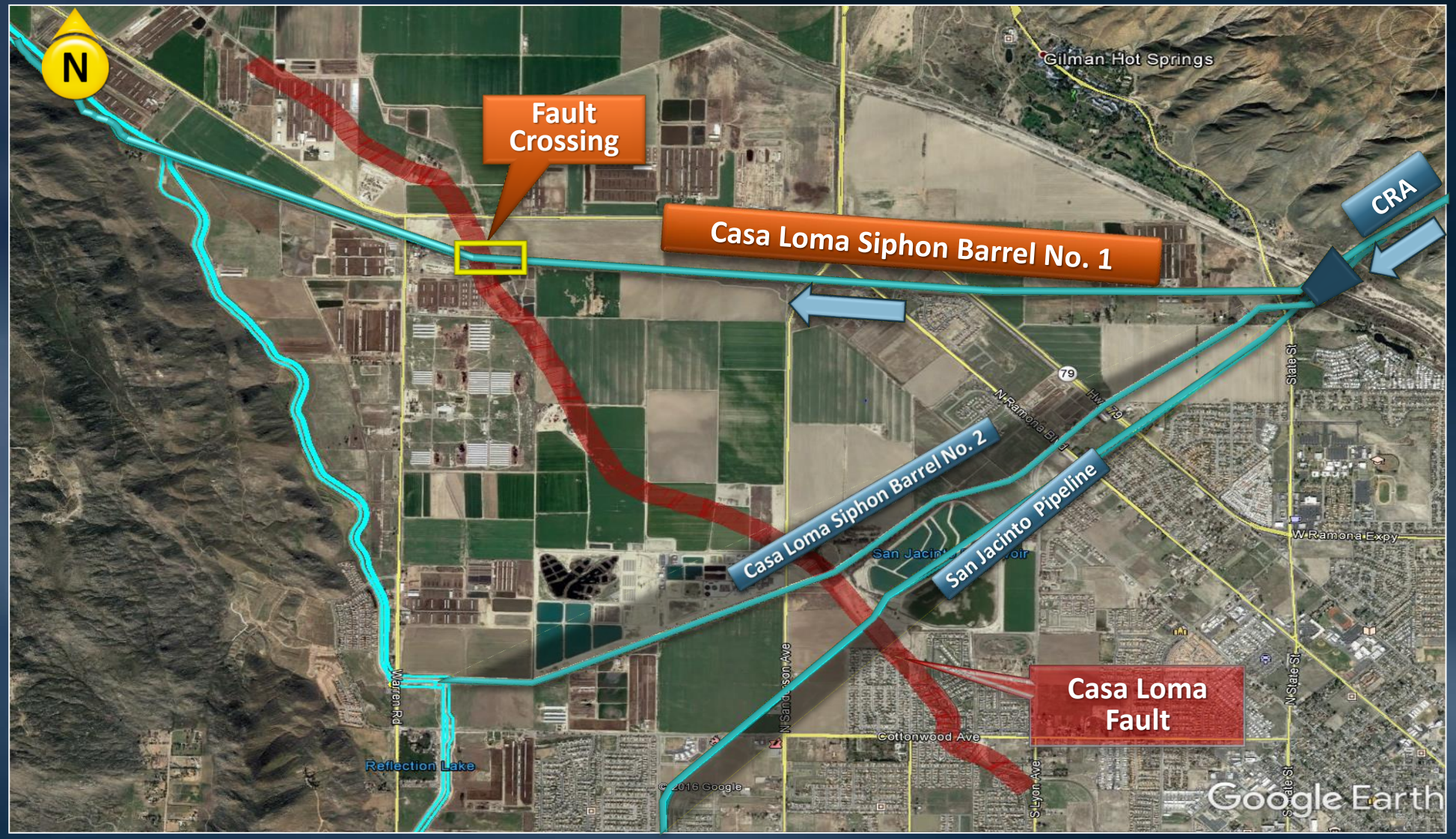
Flexible Ball Joint



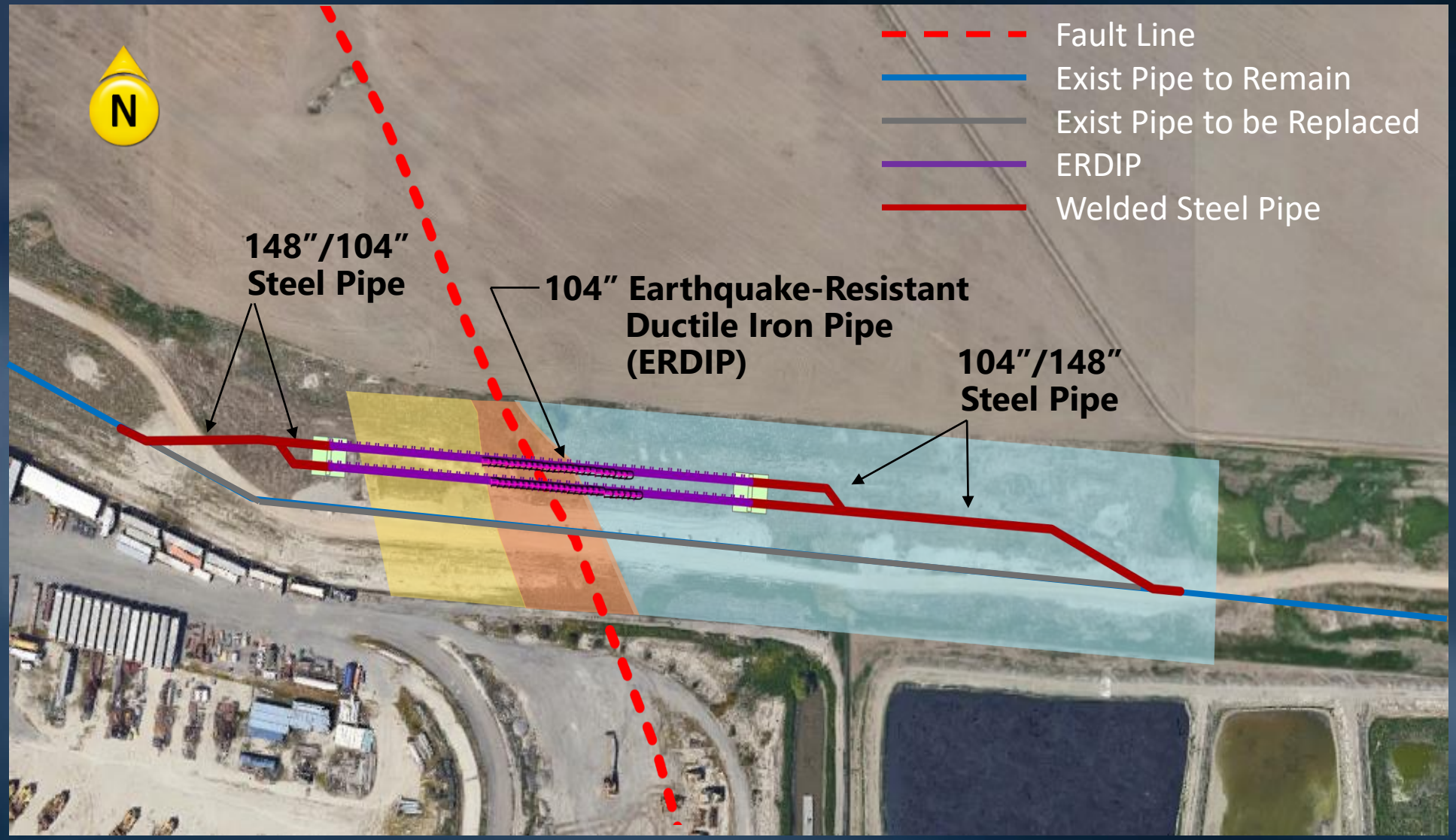
Earthquake-Resistant Steel Pipe

Welded Steel Pipe Joints

Example 2: Existing Pipeline (Casa Loma Siphon No. 1)

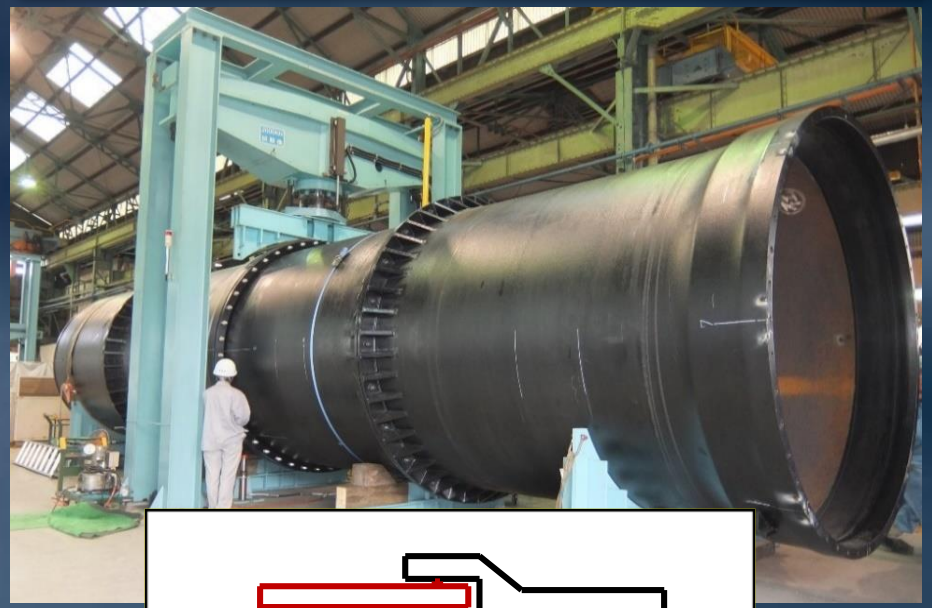


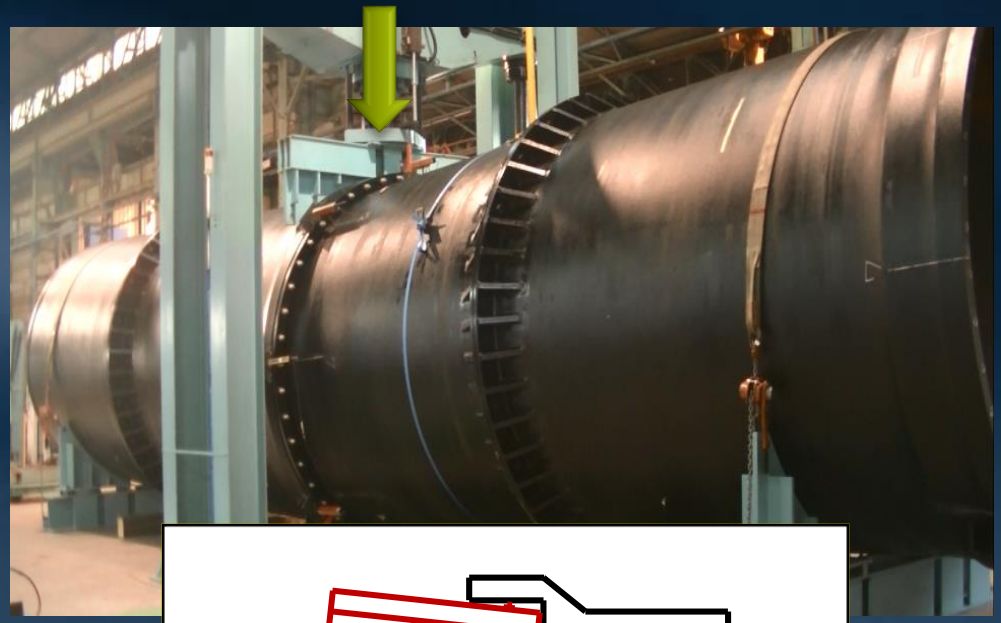
Casa Loma Siphon No. 1 Seismic Mitigation Design

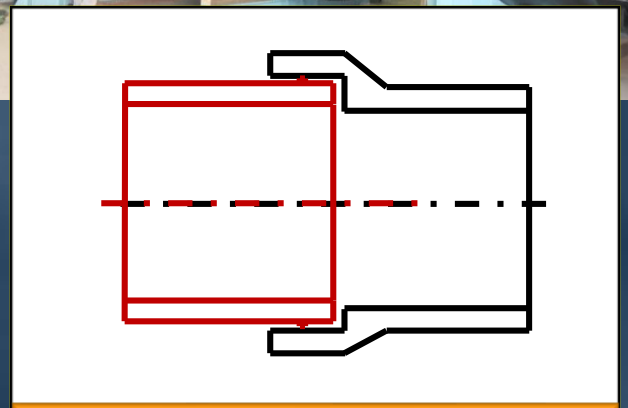


Full-Scale Testing of Large Diameter Seismic Pipe

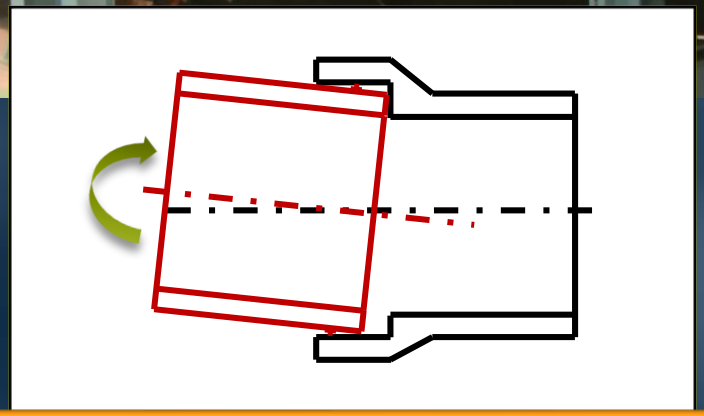
Calibrate Model w/ Test Data







Initial position



Final deflection angle = 4.3 degrees

Project Implementation

Project Timing

- Welded Steel Pipe Procurement: Completed
- ERDIP Procurement: Completed
- Final Design: Late 2021
- Construction: Mid 2022

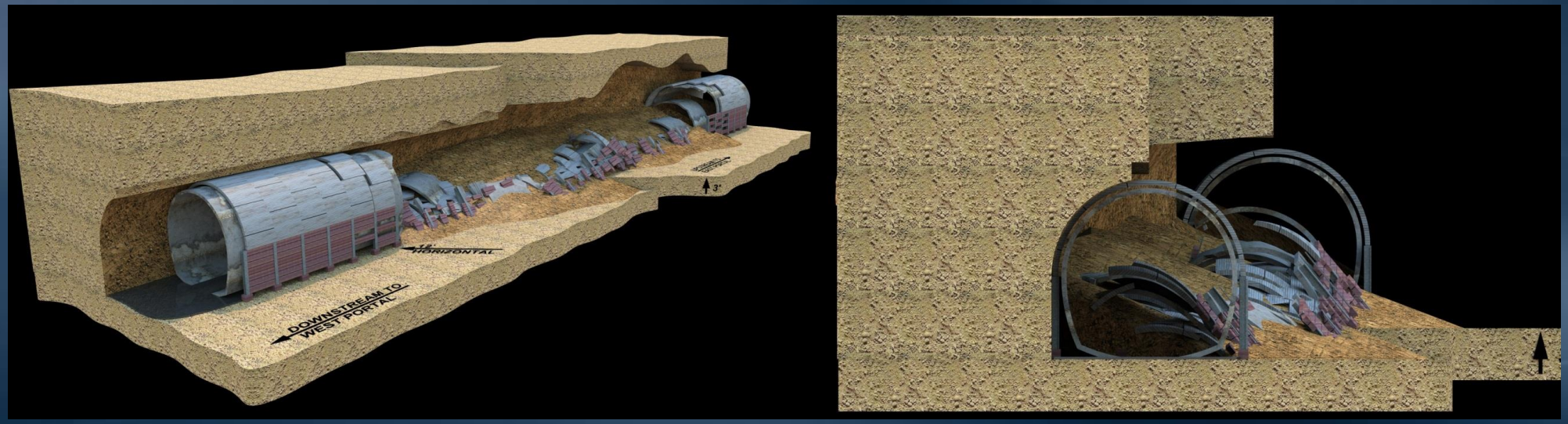

Earthquake Resistant Ductile Iron Pipe (ERDIP)



Welded Steel Pipe

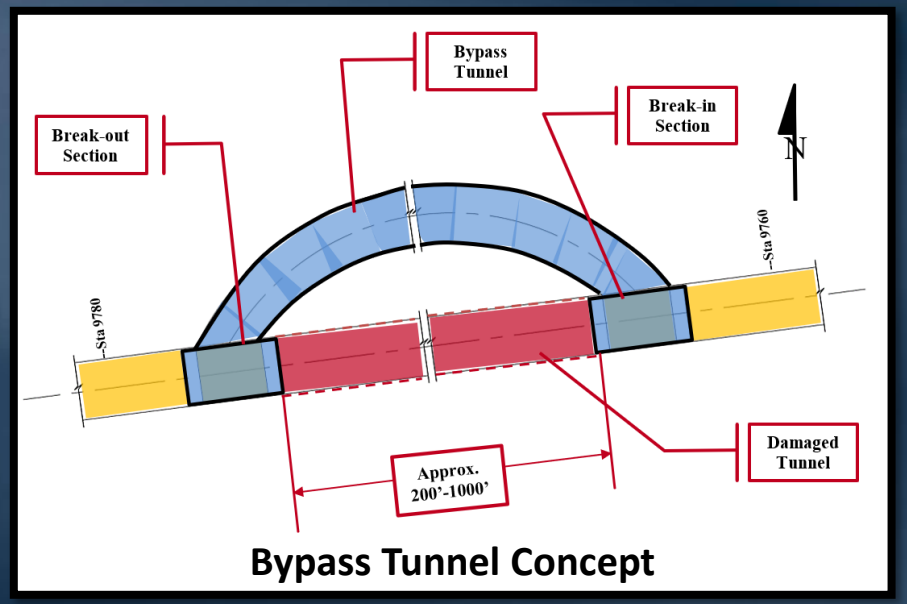
Example 3: Addressing System Vulnerabilities by Planning for Post-event Restoration (CRA Tunnel Restoration)

- CRA Whitewater Tunnel No. 2 at the San Andreas Fault could see up to:
  - 3-ft vertical displacement
  - 12-ft horizontal displacement
- Completed study to identify methods to decrease potential outage duration

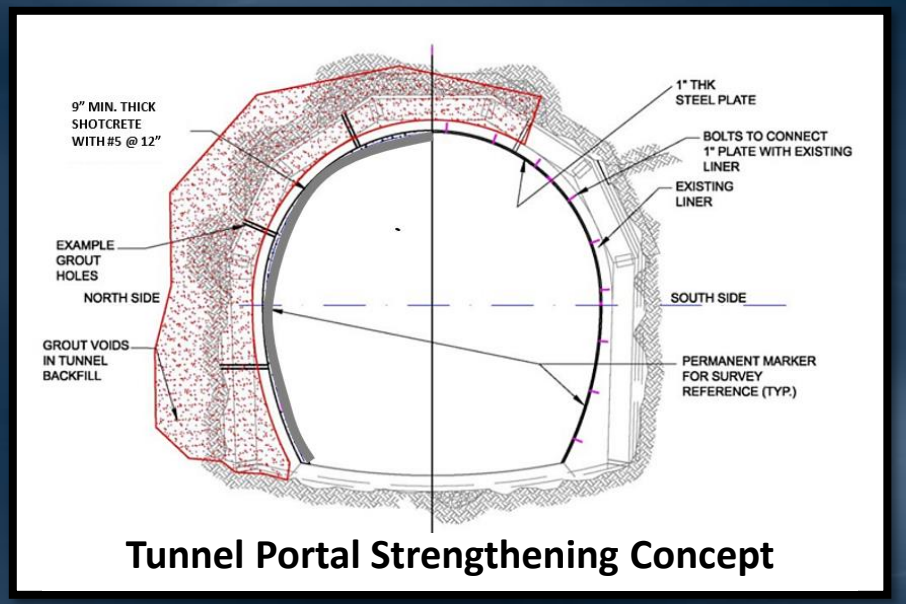


Proposed Mitigation Strategies

- Pre-qualify tunnel contractors
- Pre-design of bypass tunnel
- Stockpiling of key repair materials
- Evaluate and strengthen vulnerable regions of the tunnel portals



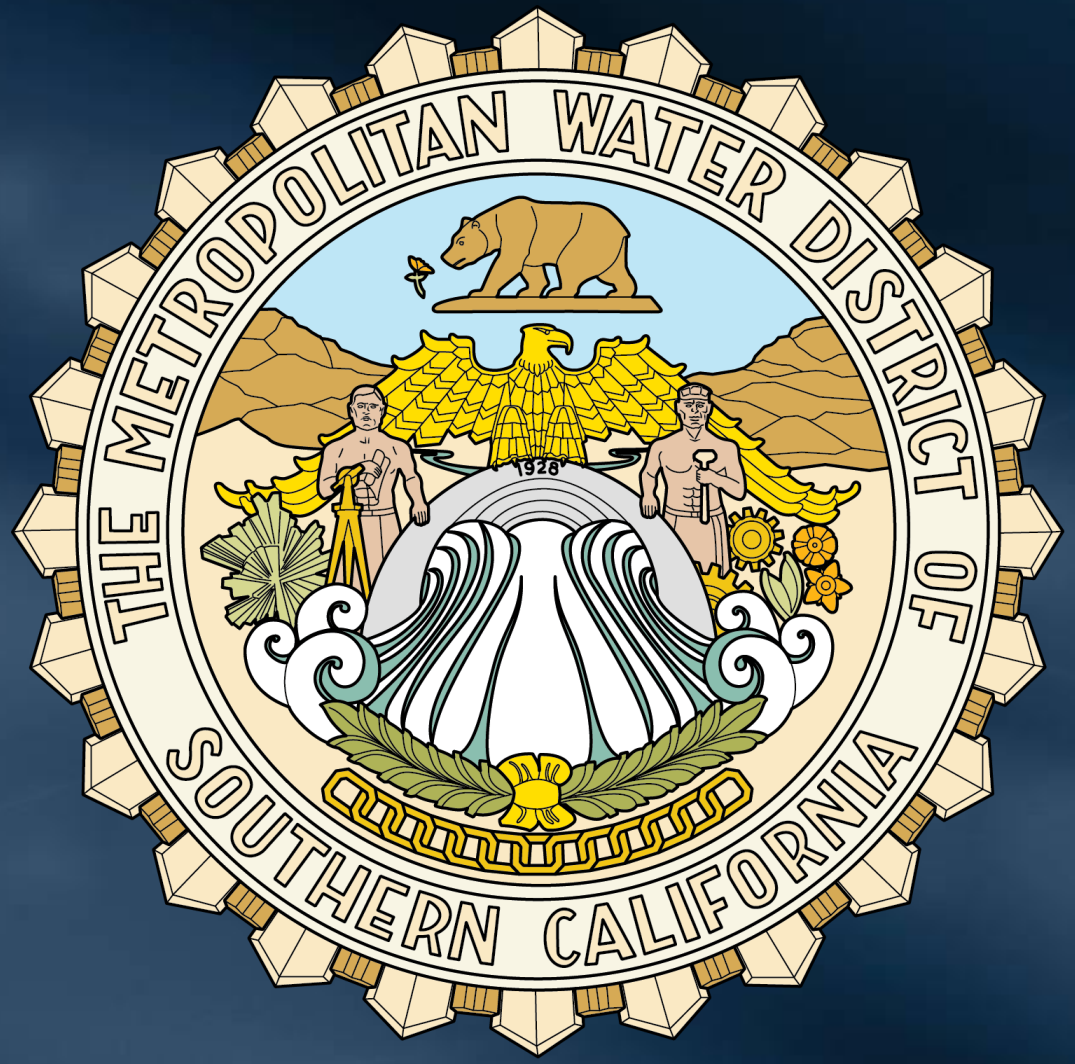
Bypass Tunnel Concept



Tunnel Portal Strengthening Concept

Conclusion/Next Steps

- Metropolitan's system is unique
- Recent advancements expands the application of innovative solutions to large diameter pipelines and tunnels
- Metropolitan has become a leader in designing seismic mitigation of large diameter pipelines
- Metropolitan will:
  - Apply the latest seismic mitigation practices on the RRWP
  - Continue to improve seismic resilience of our system


THE METROPOLITAN WATER DISTRICT OF
SOUTHERN CALIFORNIA
1928