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MILLPORT SLOUGH BRIDGE

Coastal Bridge Construction Incorporating Ground Improvement

presented by

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and

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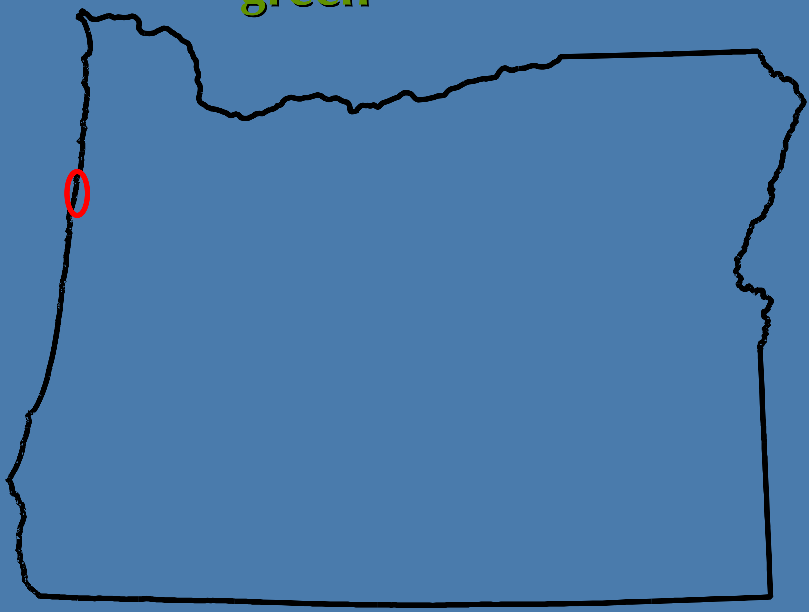
Location

- Oregon Coast Highway US101, MP 120.84
- Lincoln County
- Region 2, Area/District 4
- Siletz Bay National Wildlife Refuge (NWR) in green



Millport Slough – Environmental Issues

- Siletz Bay National Wildlife Refuge (Tidal estuary)
- Eel grass beds adjacent to bridge construction

- Shellfish habitat (predominately softshell clams)
- Winter IWWW (Nov. 1 – Feb. 15)
- Increase channel width

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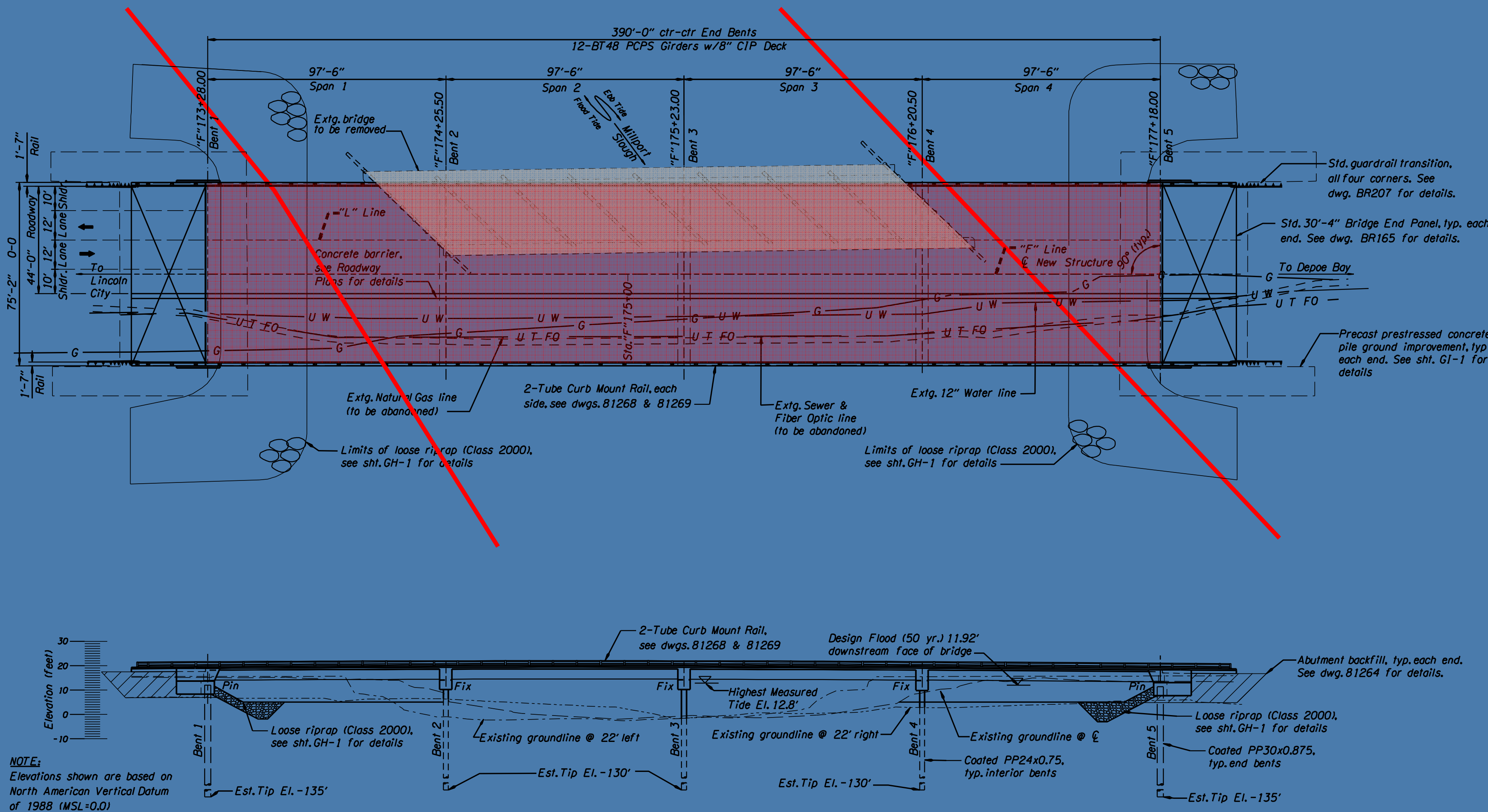
Bridge Plan and Elevation



NOTE: Elevations shown are based on North American Vertical Datum of 1988 (MSL=0.0)

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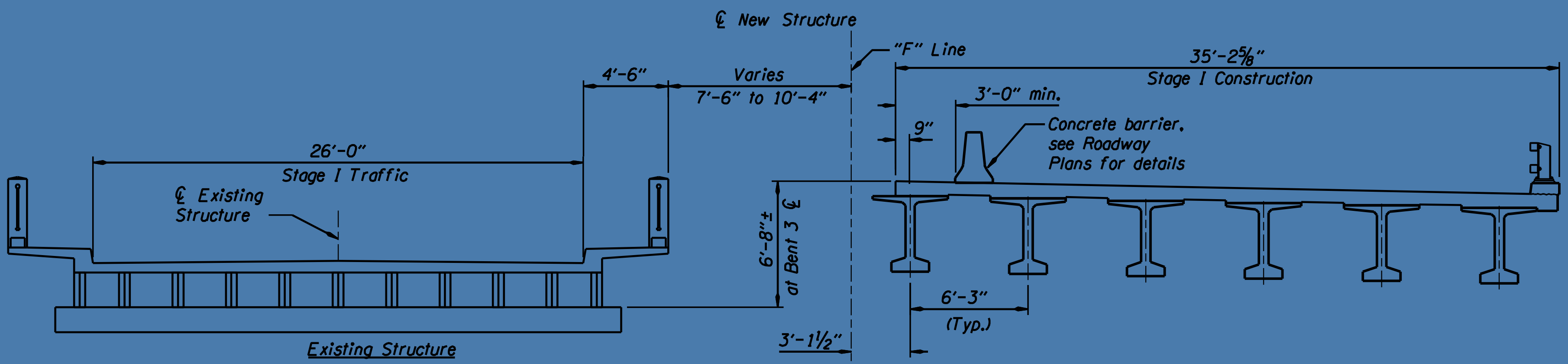
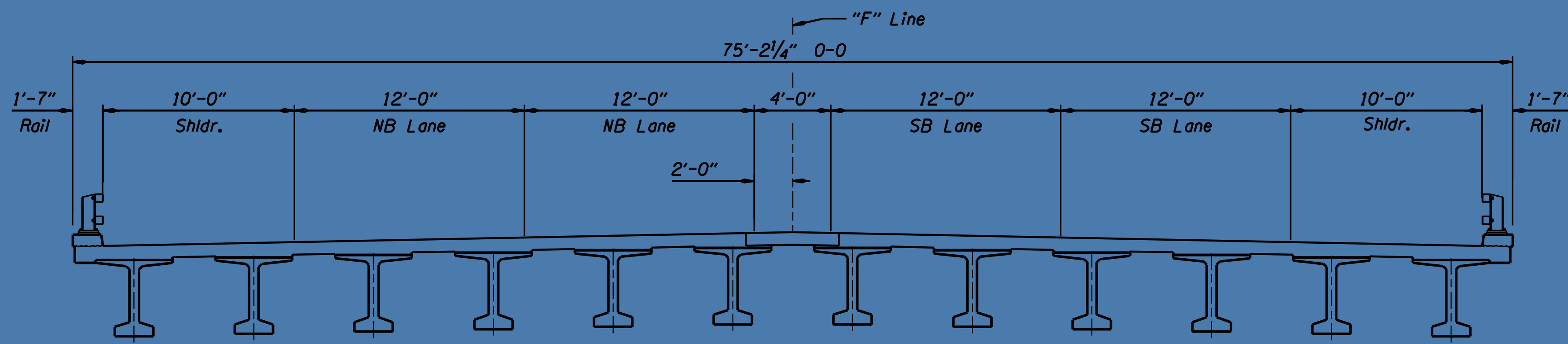
Bridge Typical Section and Staged Construction



Stage I Construction



Final Future Configuration

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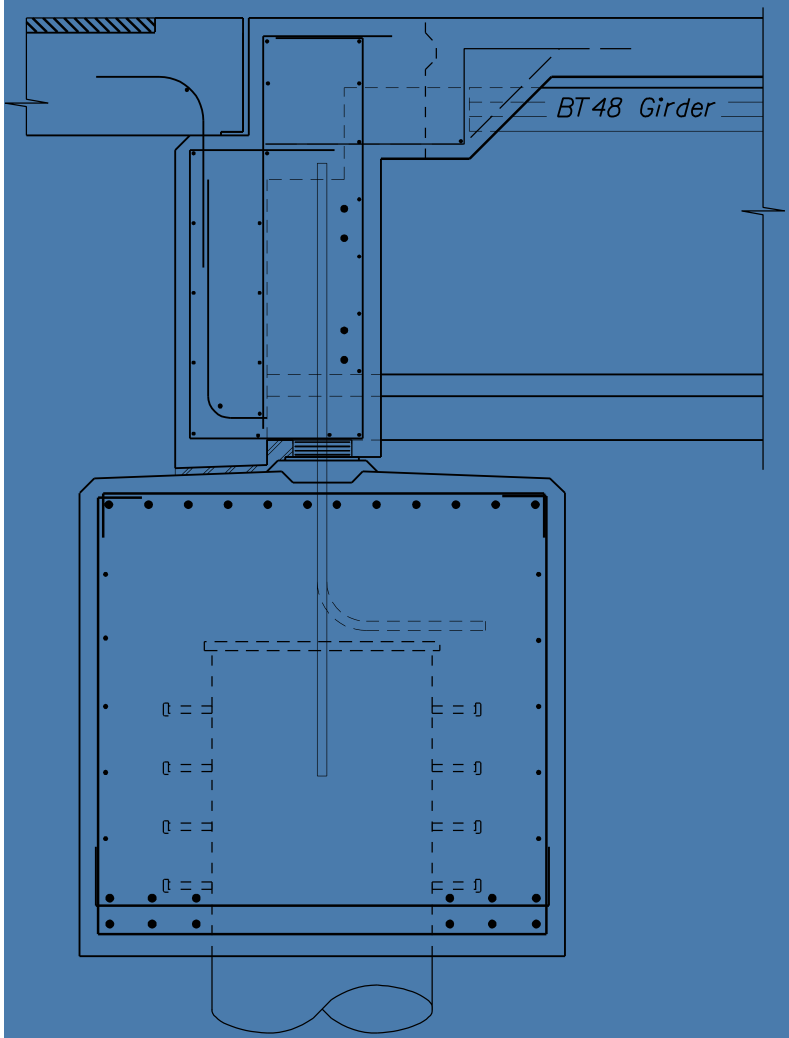
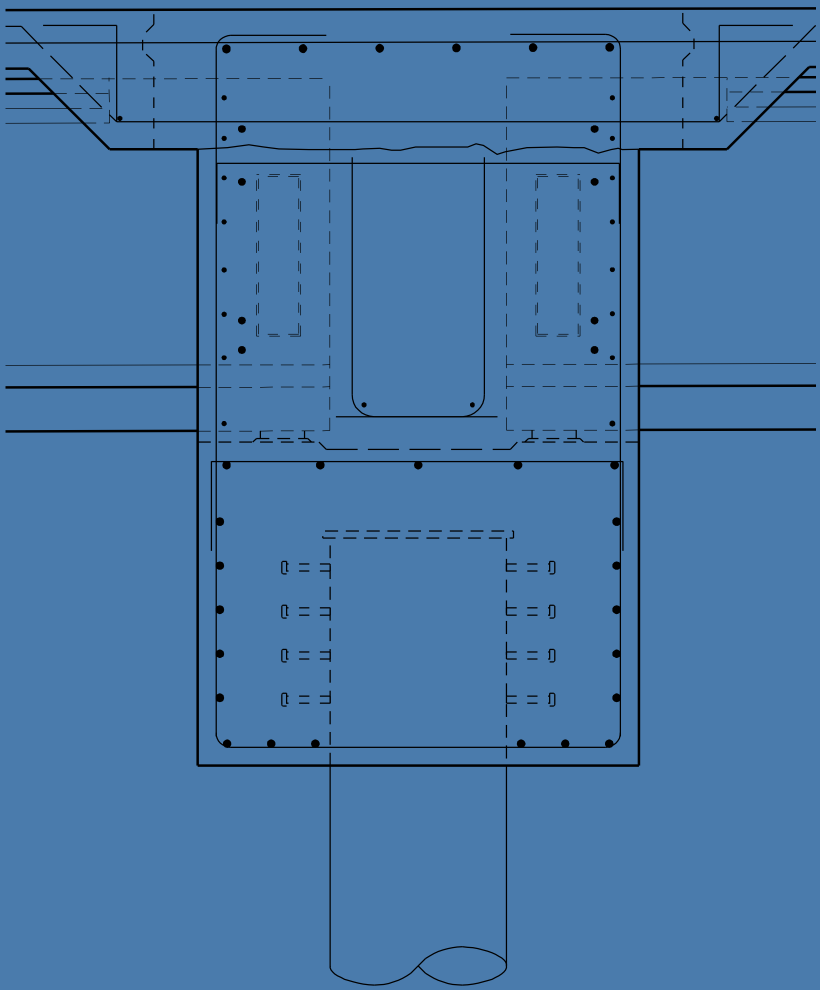
Bridge Construction (Stage 2)

Bent 1 and 5 Crossbeam Section



Bent 2, 3 and 4 Crossbeam Section



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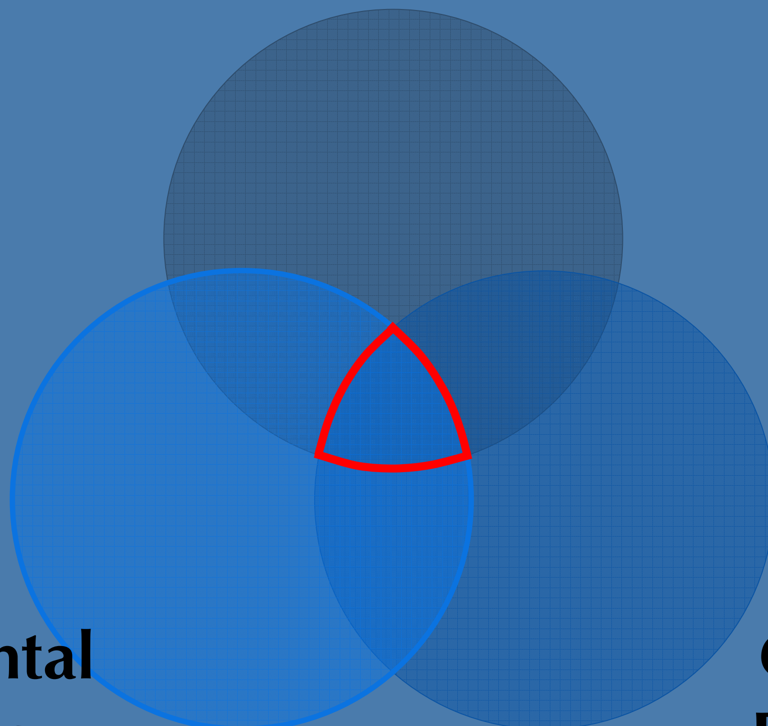
Project Challenges

High Seismic Demand
in Poor Soil Conditions



Environmental
Permitting

Corrosion
Protection

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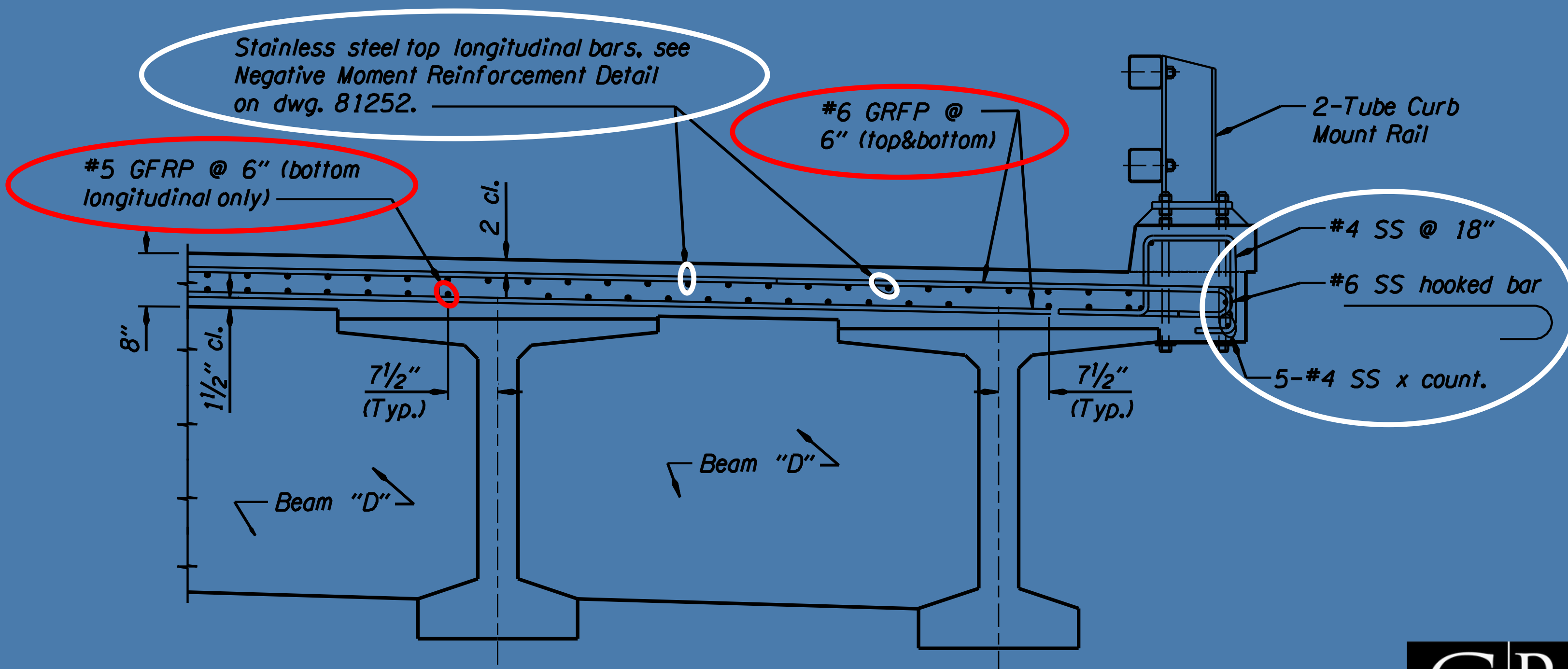
Proposed Deck Design

- GFRP rebar used for transverse and bottom longitudinal reinforcement
- Negative moment and deck overhang reinforcement is stainless steel rebar



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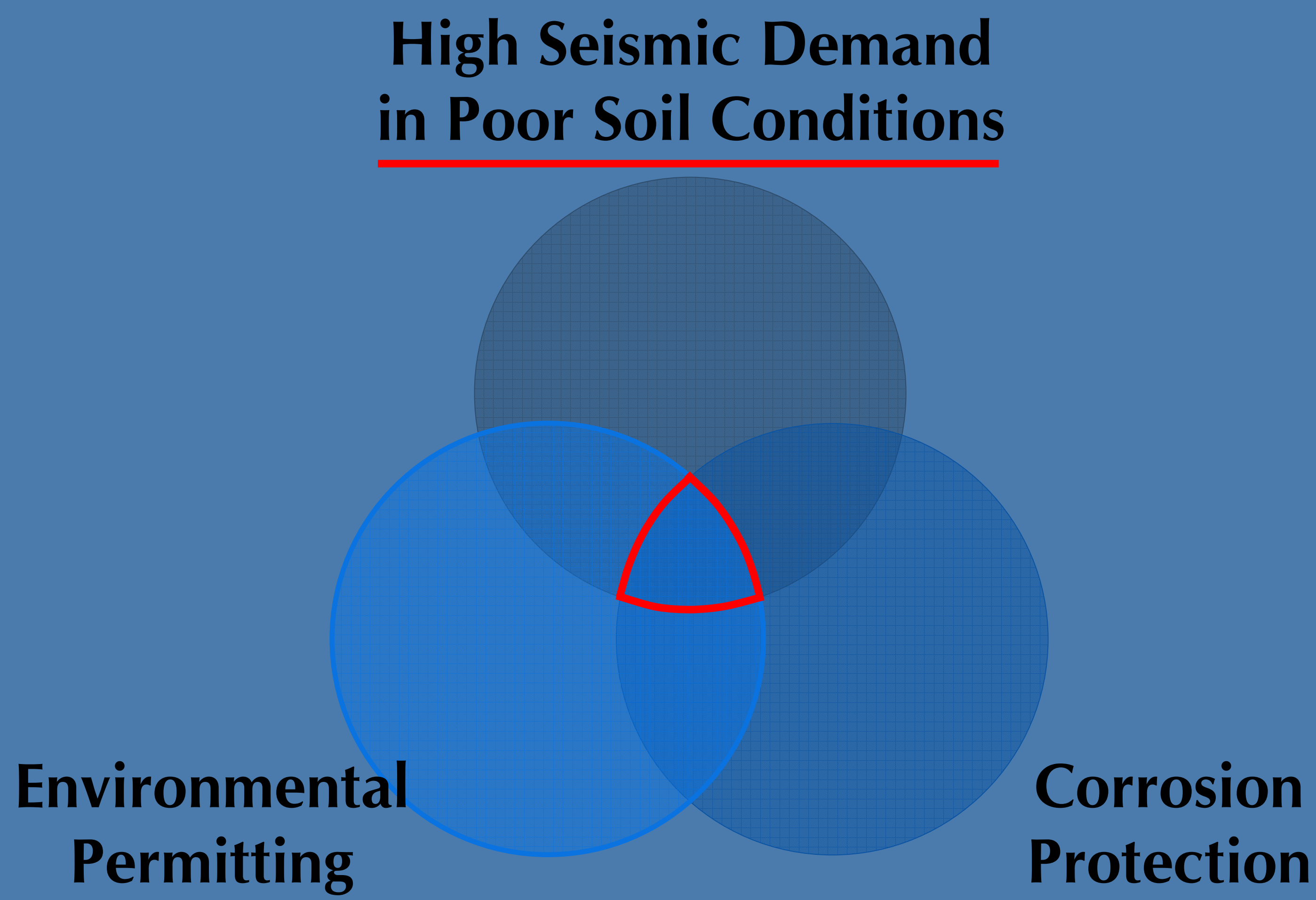
Deck Corrosion Protection

Why GFRP?

- GFRP is non-corrosive and increases the service life of the deck
- Lower cost compared to stainless steel rebar design
  - ❒ Approximately **$195,000** saved even though stainless steel rebar bid unit cost is approx. 50% of bid unit costs from 2007

	Deck Design Reinforcement Alternatives Considered		
	#4 Black Bar	#5 & #6 GFRP Bar	#4 Stainless Steel (75ksi)
Unit Cost	$1.10/lb (assumed)	$1.36/ft (wgt. avg.)	$4.25/lb
Total Length	L	1.07*L	0.91*L
Total Cost	C	1.97*C	3.53*C

Project Challenges



Foundation in Estuary Deposits - Tidal Mud Flats

Skin Friction – Typical β Range and Measured

Equivalent Effective Stress β = 0.135

Off the chart!

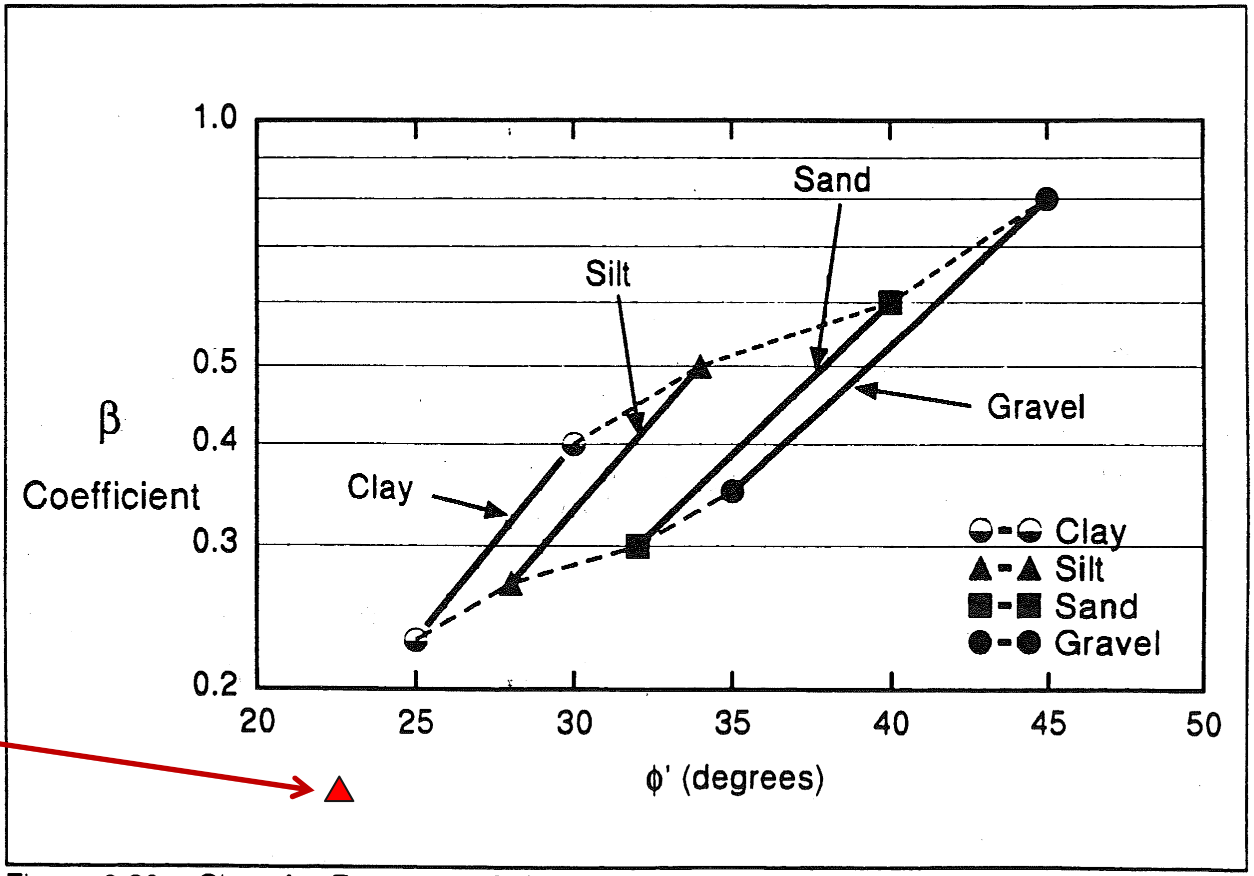
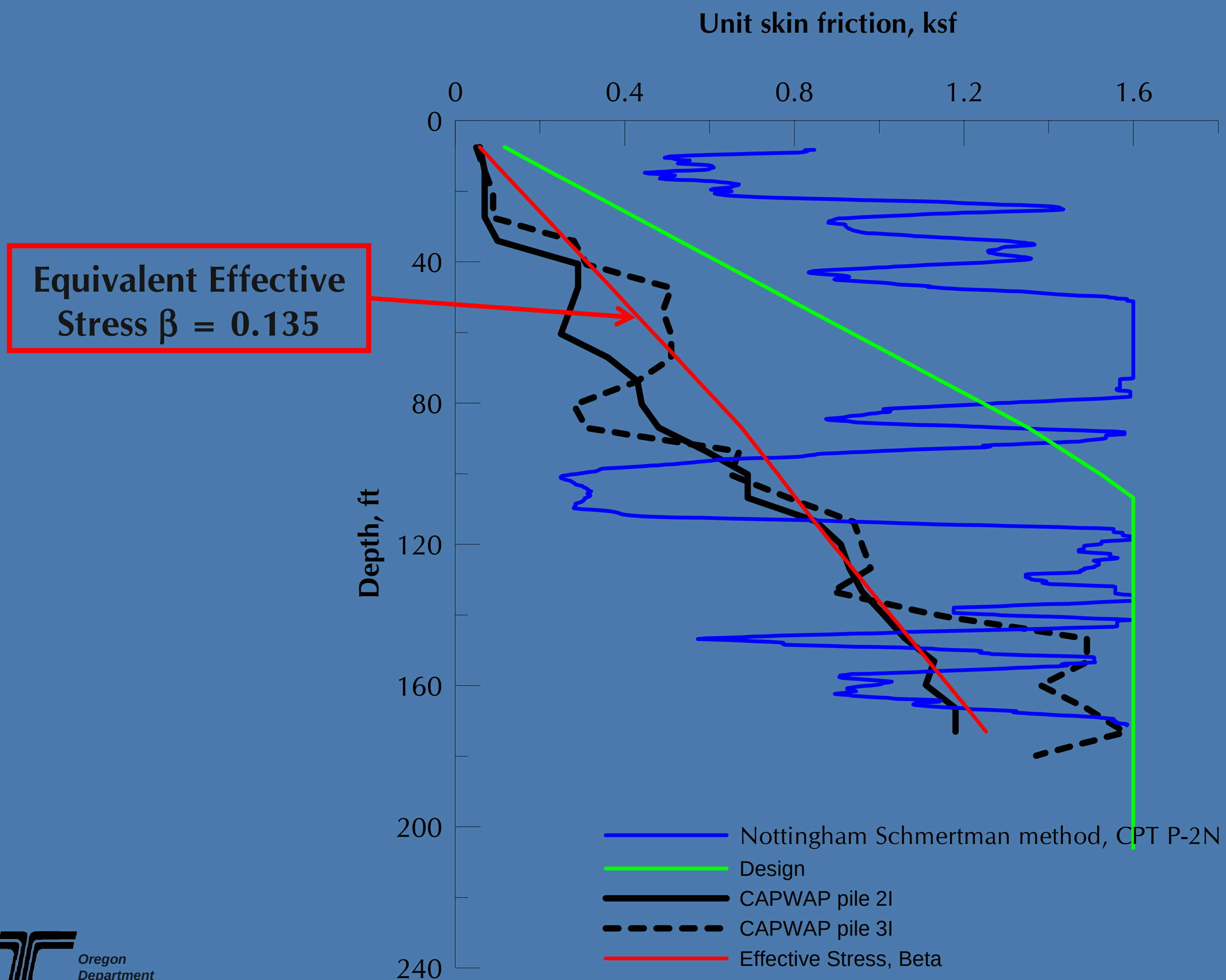


Figure 9.20 Chart for Estimating β Coefficient versus Soil Type ϕ' Angle (after Fellenius, 1991) from Fellenius, 1991, Foundation Engineering Handbook

Pile Skin Friction – Estimated and Measured



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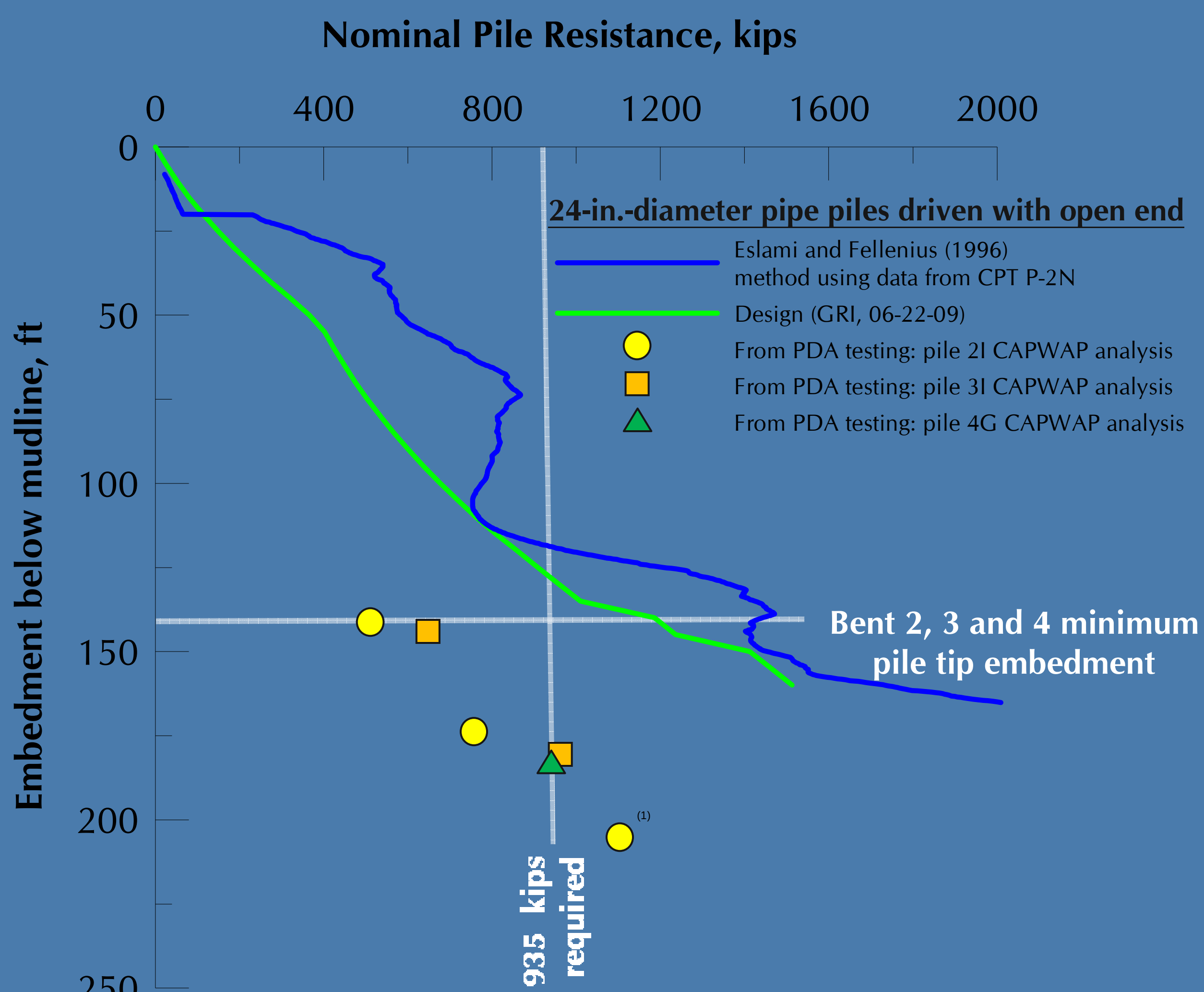
Pile Resistance – Estimated and Measured



(1) determined using ODOT Gate's Equation

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Lateral Spreading Due to Liquefaction

Capital Lake, Olympia, Washington (Nisqually event, 2001)
Lateral spreading from magnitude 6.8 earthquake

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Damage From Lateral Spreading

1976 Tangshan Earthquake - Yuehe Bridge near Tangshan, China
(M7.8 earthquake)

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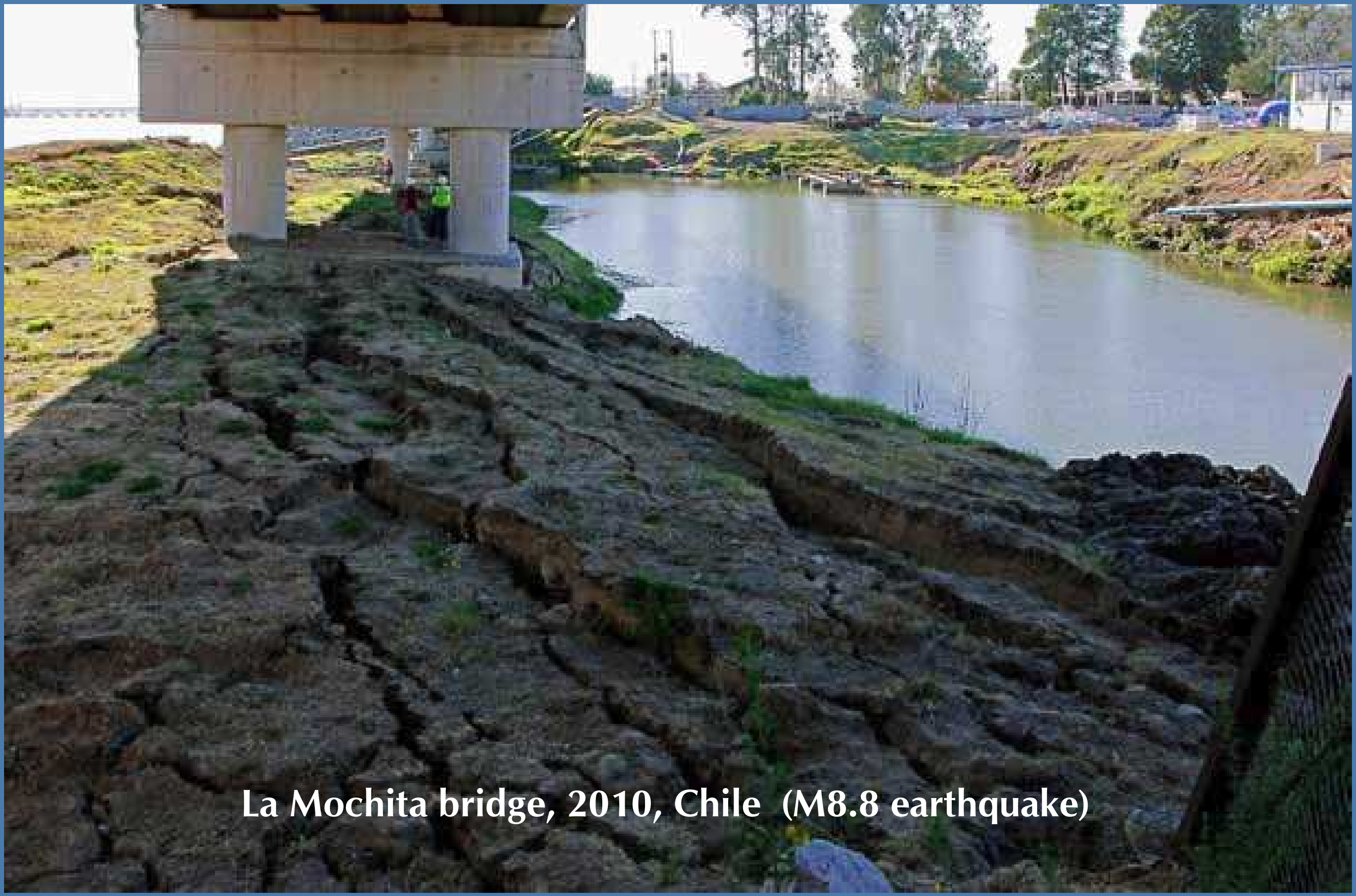
Damage From Lateral Spreading



Photograph from FHWA, 2011, Post-Earthquake Reconnaissance Report on Transportation Infrastructure: Impact of the February 27, 2010, Offshore Maule Earthquake in Chile

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Geotechnical Seismic Considerations

- **Site-specific Seismic Embankment Deformation for Unmitigated Liquefaction**
  - 8 ft of lateral spreading toward slough
  - 5 ft of lateral spreading perpendicular to roadway
  - Lateral spreading exerts full passive force on bridge components (pile and pile cap)

- **ODOT's Liquefaction Mitigation Policy requires that the project mitigate soil liquefaction at bridge abutments**

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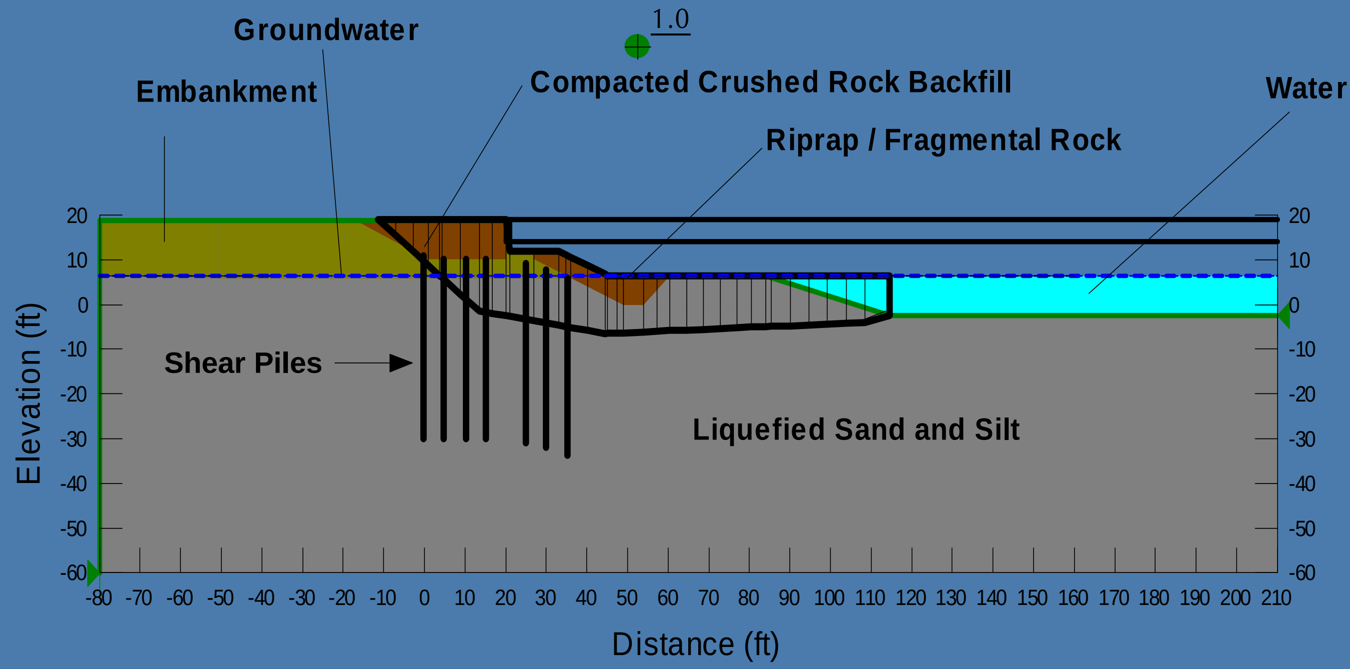
Slope Stability Model



Yield Acceleration:

0.00 g without ground improvement after soil has liquefied

0.12 g with PCPS concrete piles

Estimated Embankment Deformation (1,000–year event):

Without ground improvement: 8 ft

With ground improvement: 1 ft

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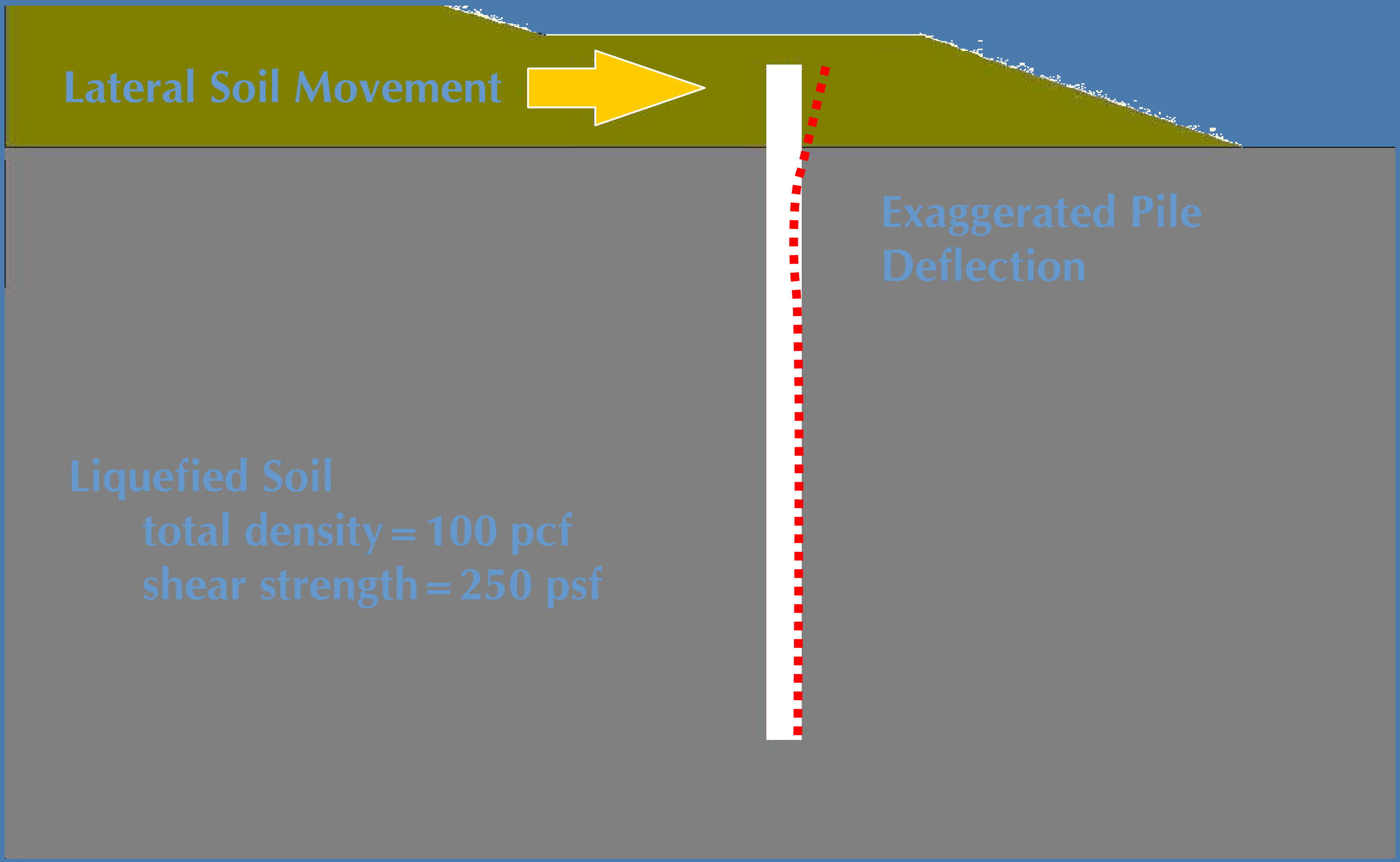
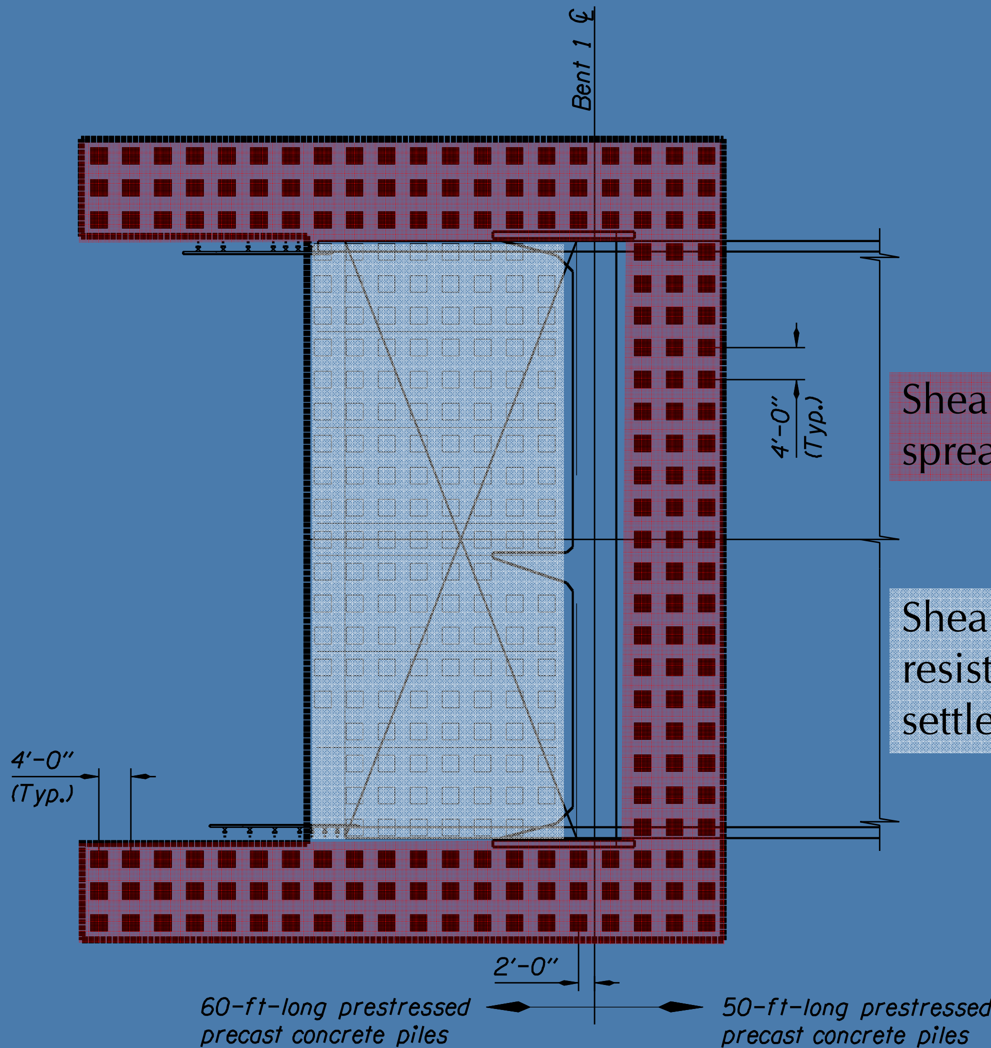
LPile Lateral Resistance Model



Note: Lateral soil movement modeled using the LPile "soil movement" option with horizontal and vertical loads set to zero

PCPS Concrete Pile Ground Improvement



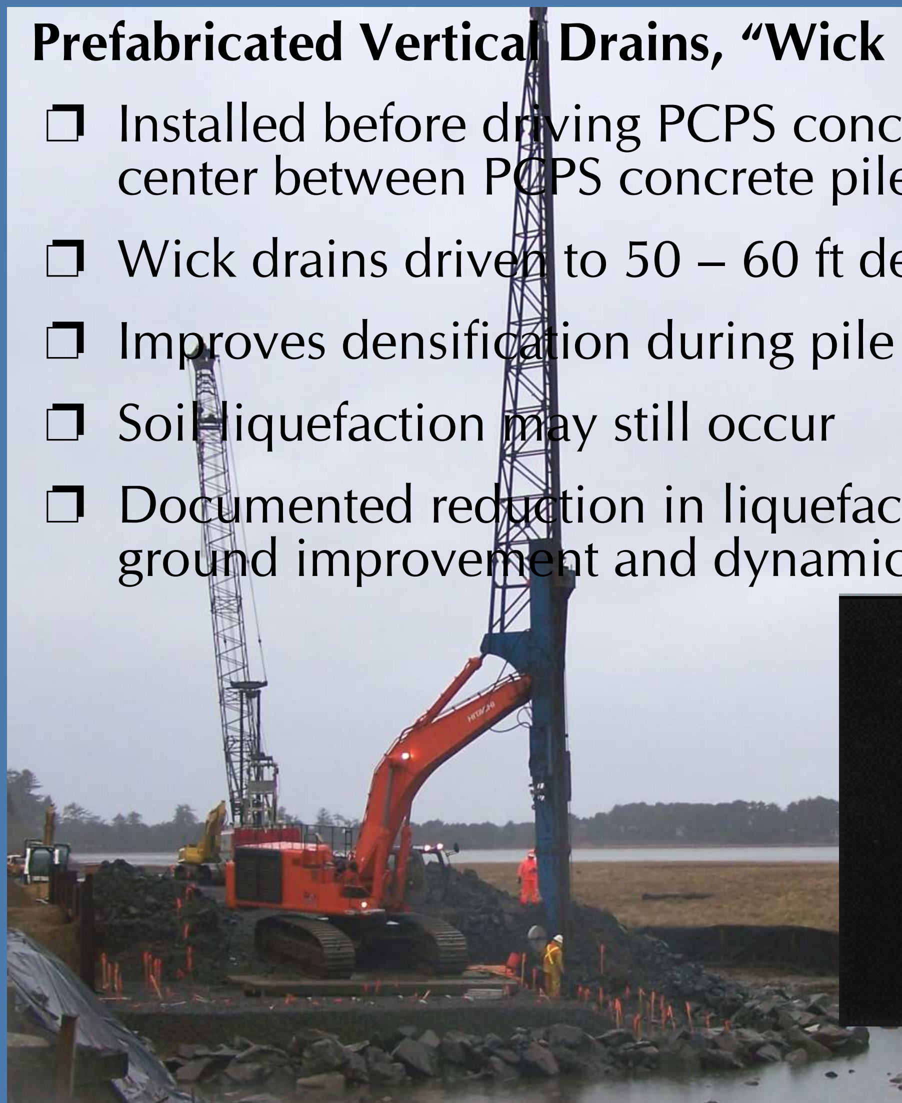
Shear piles for lateral spreading resistance – 177 piles

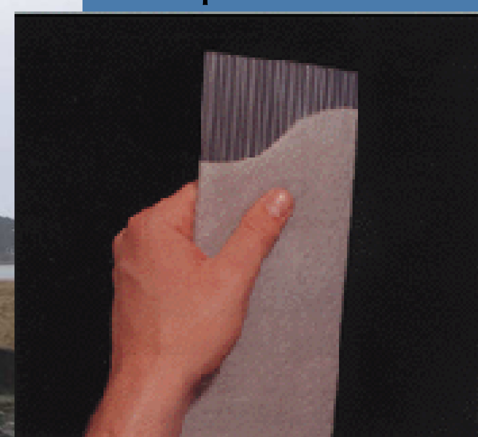
Shear piles for lateral spreading resistance, abutment resistance and settlement resistance – 142 piles

Concrete Piles During Bridge Construction (Stage 2)

Prefabricated Vertical Drains in Ground Improvement

- **Prefabricated Vertical Drains, “Wick Drains”**
  - Installed before driving PCPS concrete pile and placed 4 ft on-center between PCPS concrete pile locations
  - Wick drains driven to 50 – 60 ft depth
  - Improves densification during pile driving
  - Soil liquefaction may still occur
  - Documented reduction in liquefaction for stone column ground improvement and dynamic compaction





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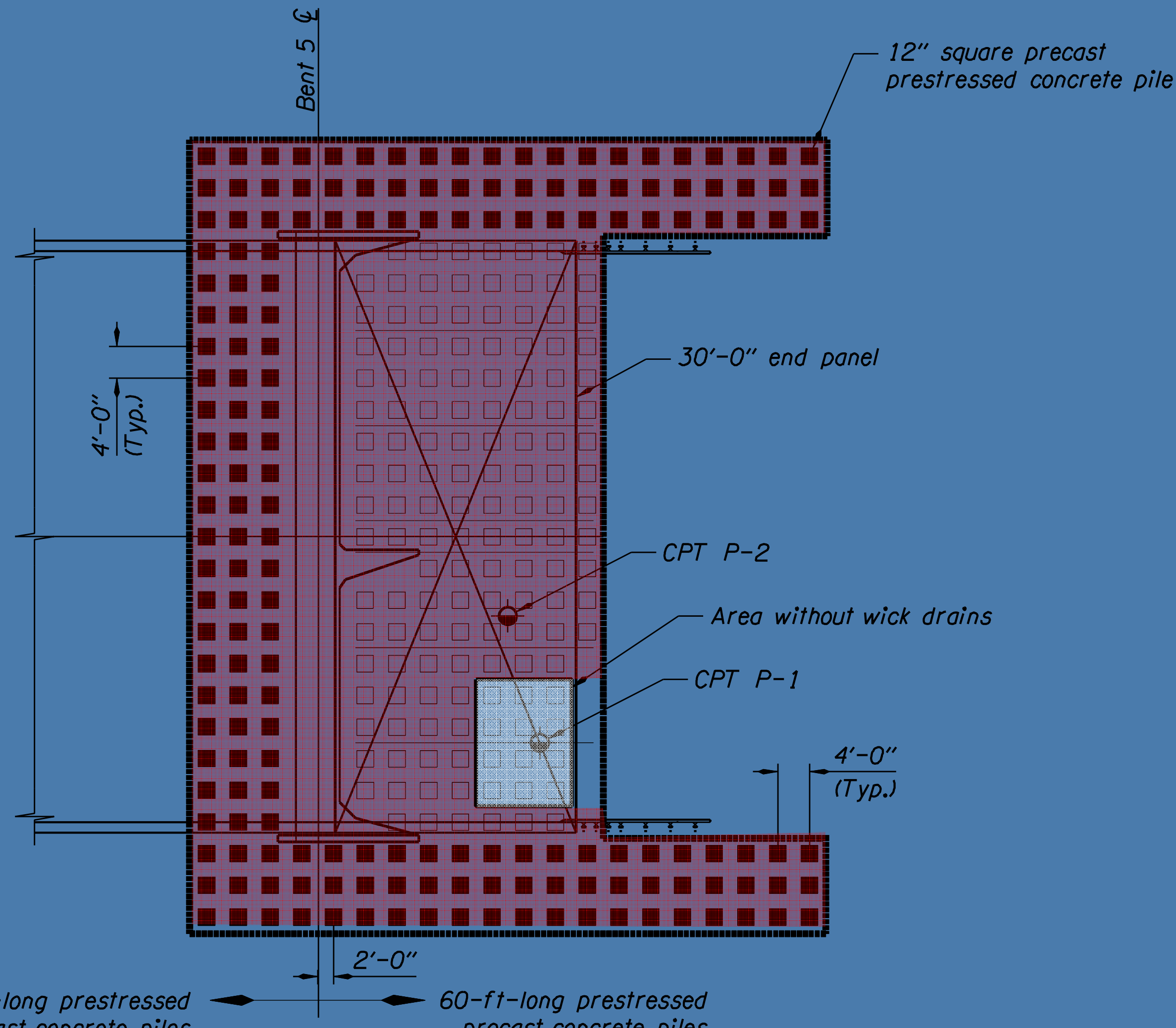
Limits of Prefabricated Vertical Drains

Area with wick drains

Area without wick drains



Cone penetration test made by GRI (December 28, 2009 and March 26, 2010)

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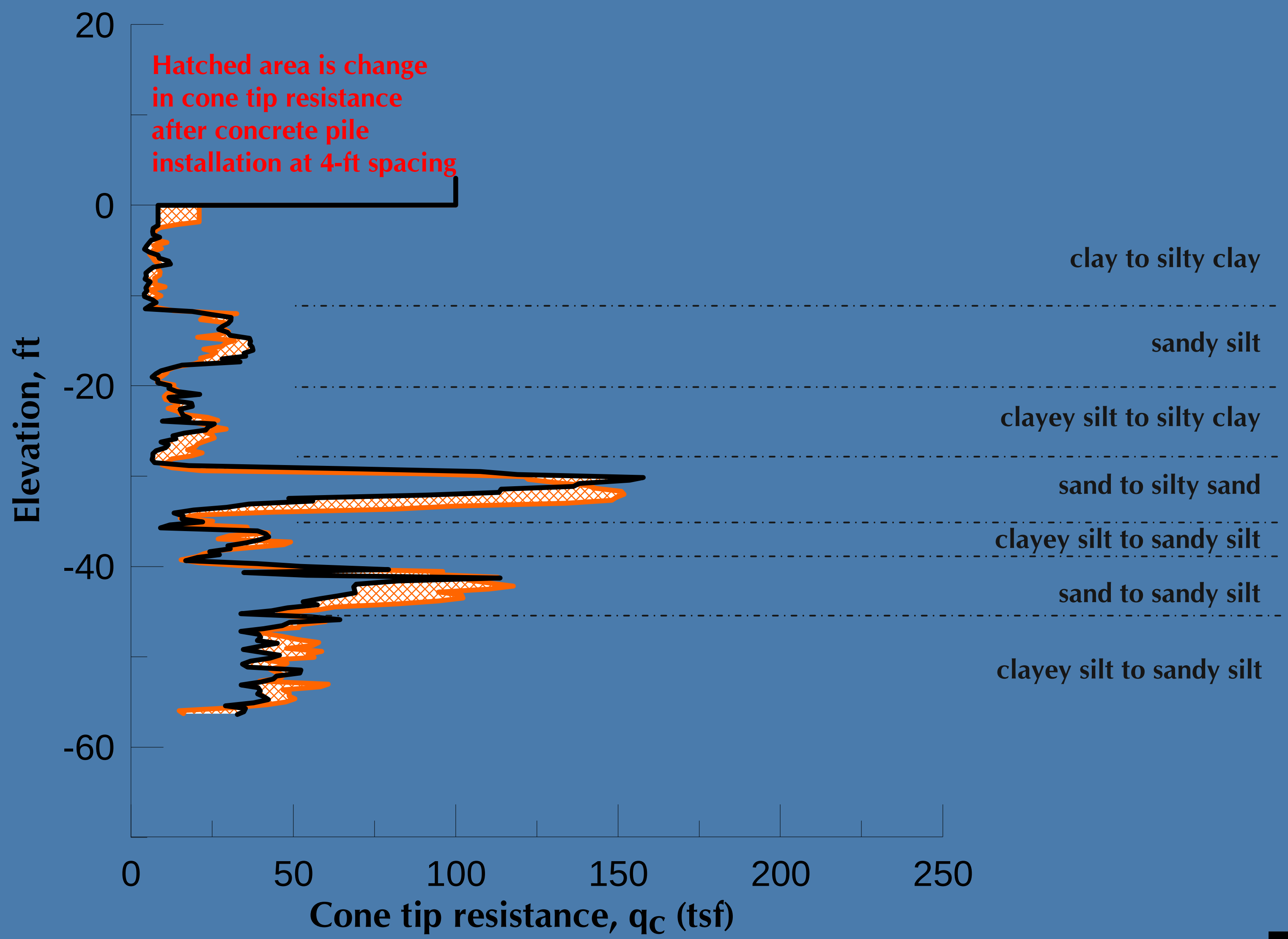
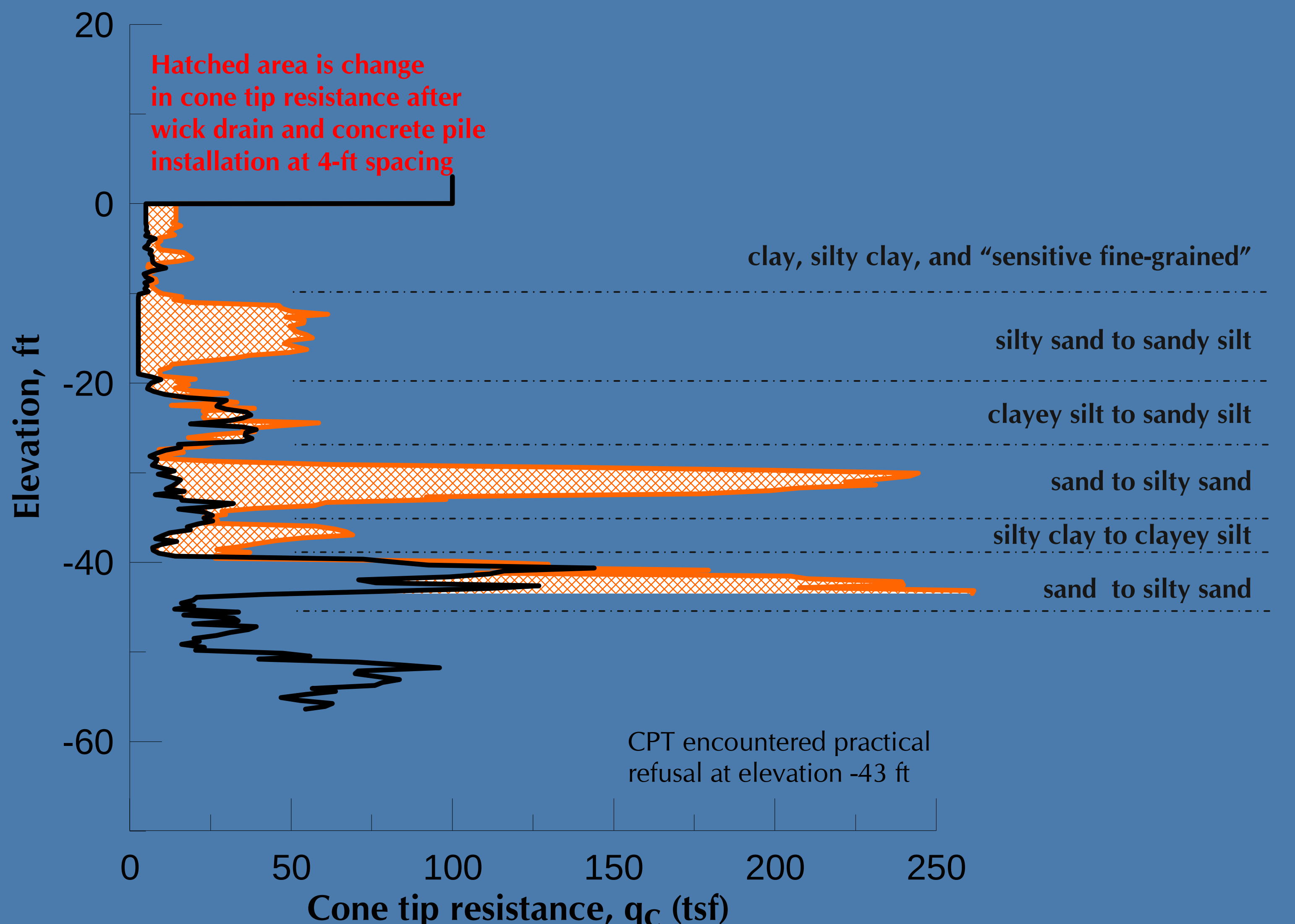
CPT Tip Resistance – Without Wick Drains



CPT Tip Resistance – With Wick Drains



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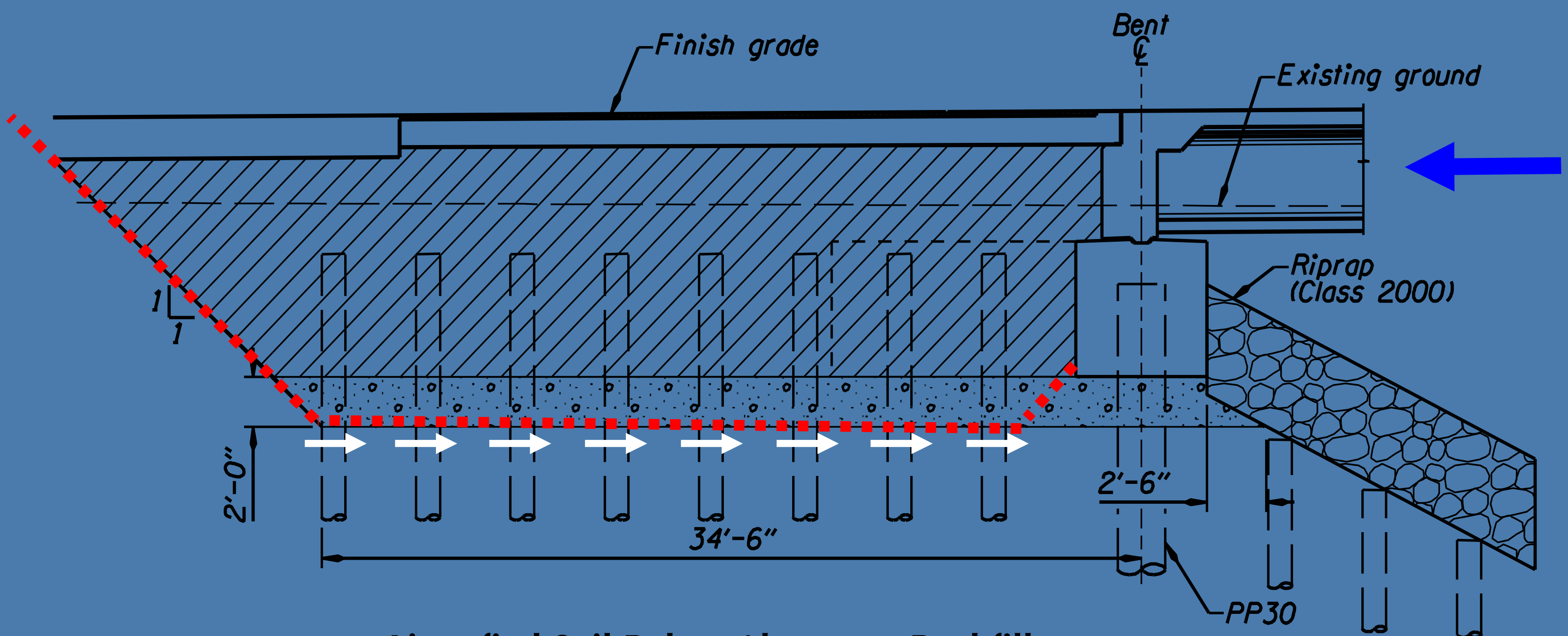
PCPS Concrete Piles for Backfill Shear Resistance



Liquefied Soil Below Abutment Backfill

Anticipated failure path without PCPS concrete shear piles

Resistance provided by PCPS concrete shear piles

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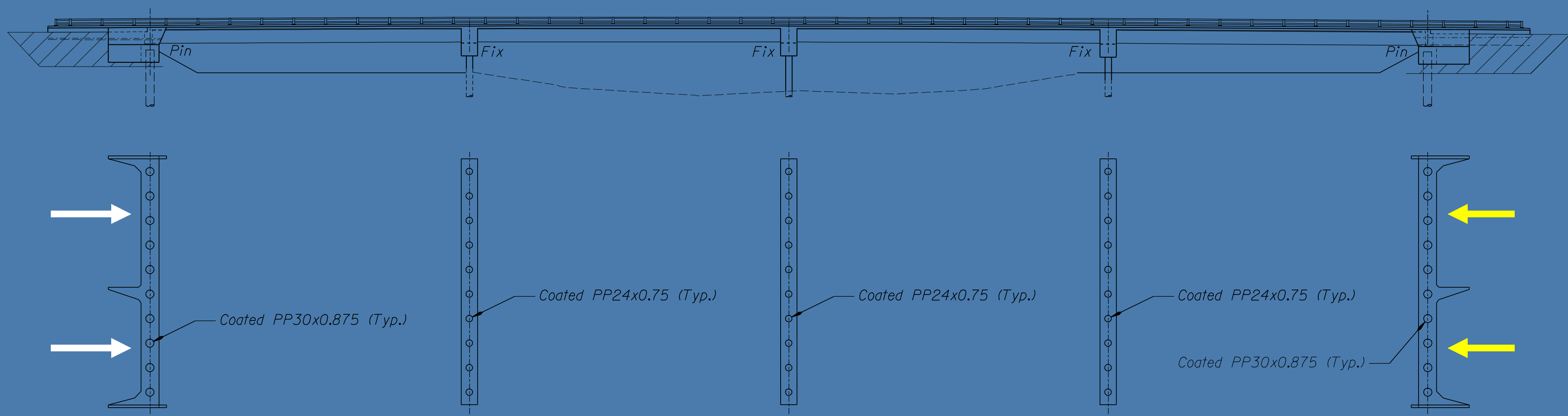
Distribution of Longitudinal Seismic Loads



Bent 1		**Bent 2**	**Bent 3**	**Bent 4**	**Bent 5**	
Abutment Backfill (Comp. Only)	Pipe Pile	Pipe Pile	Pipe Pile	Pipe Pile	Pipe Pile	Abutment Backfill (Comp. Only)
3800 Kips	650 Kips	680 Kips	420 Kips	680 Kips	650 Kips	3800 Kips
	← 9%	← 10%	← 6%	← 10%	← 9%	← 56%
→ 56%	→ 9%	→ 10%	→ 6%	→ 10%	→ 9%	

Load Conditions Considered

1000 Year Event – Liquefied Soils

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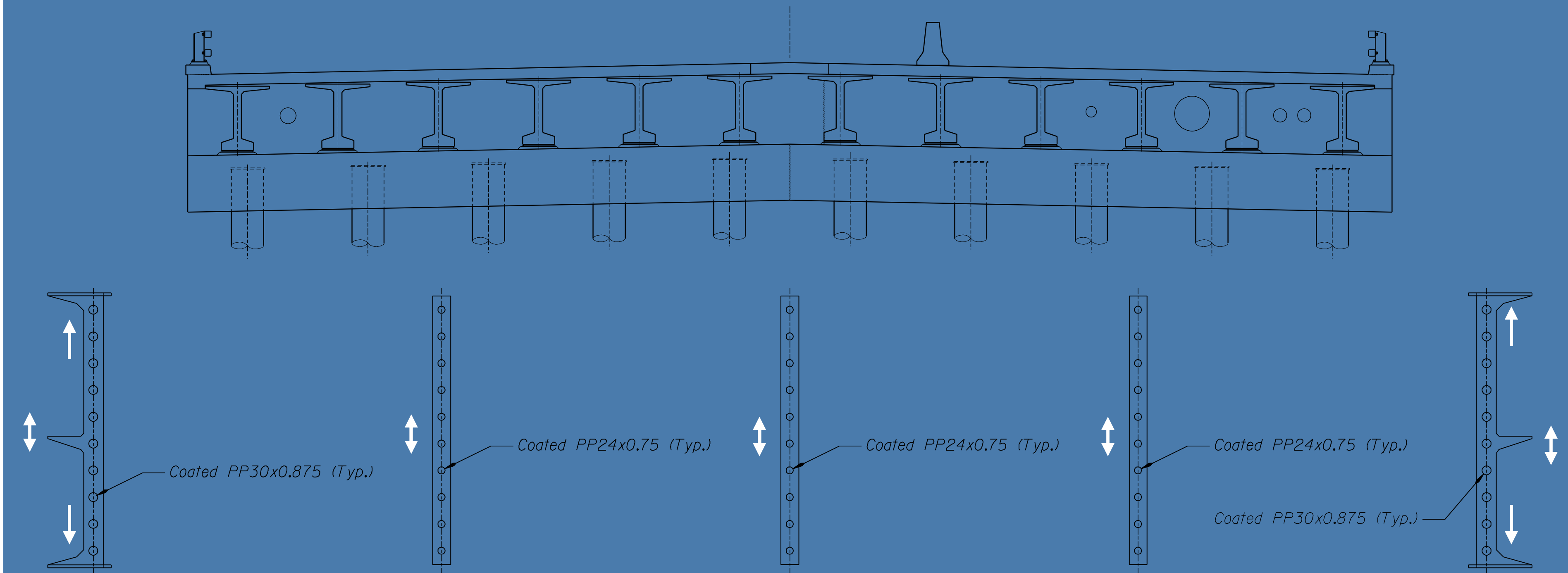
Distribution of Transverse Seismic Loads



Bent 1		**Bent 2**	**Bent 3**	**Bent 4**	**Bent 5**	
Wingwall Backfill (Comp. Only)	**Pipe Pile**	**Pipe Pile**	**Pipe Pile**	**Pipe Pile**	**Pipe Pile**	**Wingwall Backfill (Comp. Only)**
670 Kips	**1620 Kips**	**720 Kips**	**495 Kips**	**720 Kips**	**1620 Kips**	**670 Kips**
10%	**25%**	**11%**	**8%**	**11%**	**25%**	**10%**

Load Conditions Considered

1000-Year Event – Liquefied Soils

Conclusion

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Questions?

Photograph from: ODOT Photo and Video Services

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Bid Cost Data

- **Contractor: CP Construction of Oakland, OR**
- **Bid Cost Data**
  - Total project bid - $11.36M
  - Total bridge items cost (including liquefaction mitigation and work bridge) - $7.96M
  - Liquefaction mitigation items cost - $1.40M
  - Unit area cost of bridge (including liquefaction mitigation and work bridge) - $269/sq. ft.
  - Unit area cost (including work bridge and excluding liquefaction mitigation items) - $221/sq. ft.
  - Unit area cost (excluding work bridge and liquefaction mitigation items) - $189/sq. ft.