Liquefaction Bio-Mediation: An Industry Perspective

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WHAT WE DO

Shoring

- Soldier Pile
- Soil Nail
- Secant Pile
- Sheet Pile
- Soil Mix

Block 5 – San Francisco

WHAT WE DO

Ground Improvement

- Stone Columns
- Rigid Inclusions
- Soil Mixing
- Jet Grouting
- Compaction Grouting
- Permeation Grouting

LNG Tank– Tacoma, WA

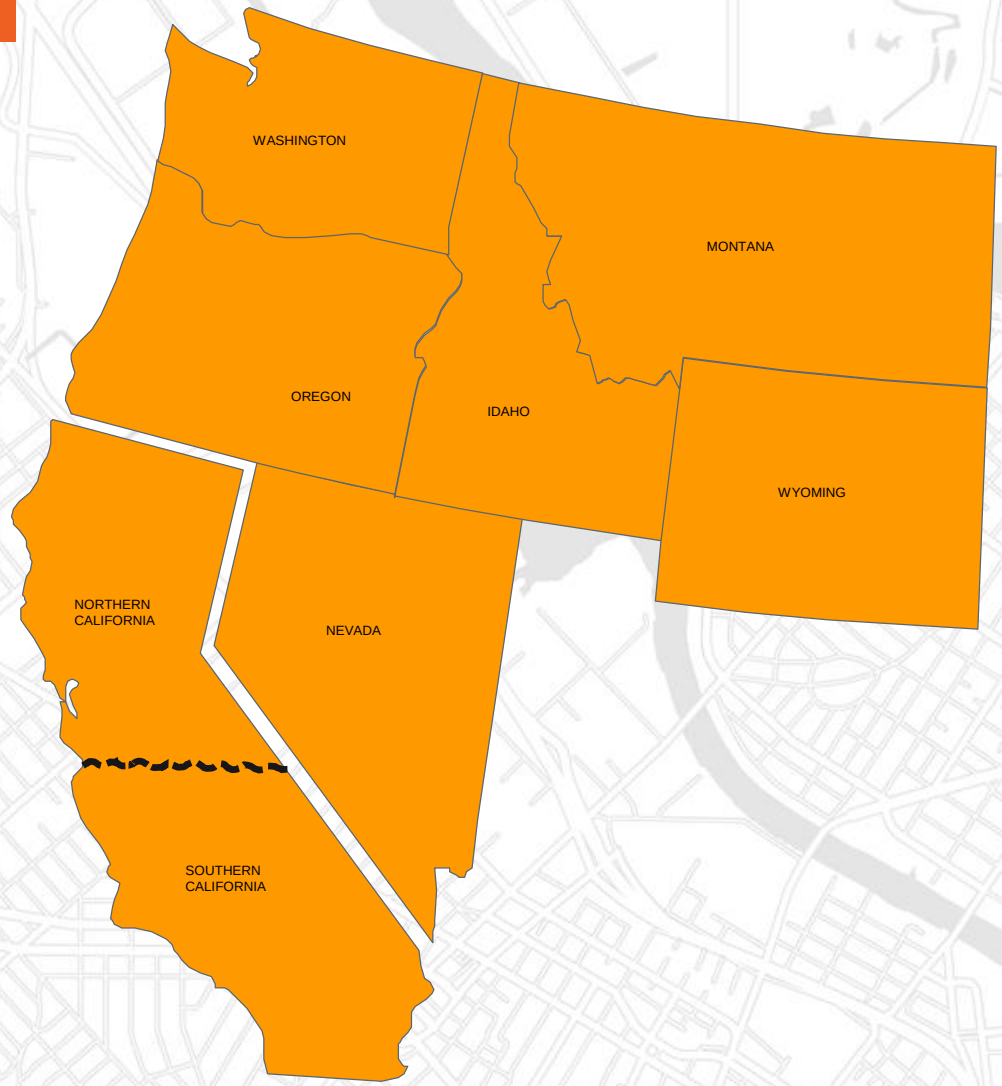
WHAT WE DO

Piles

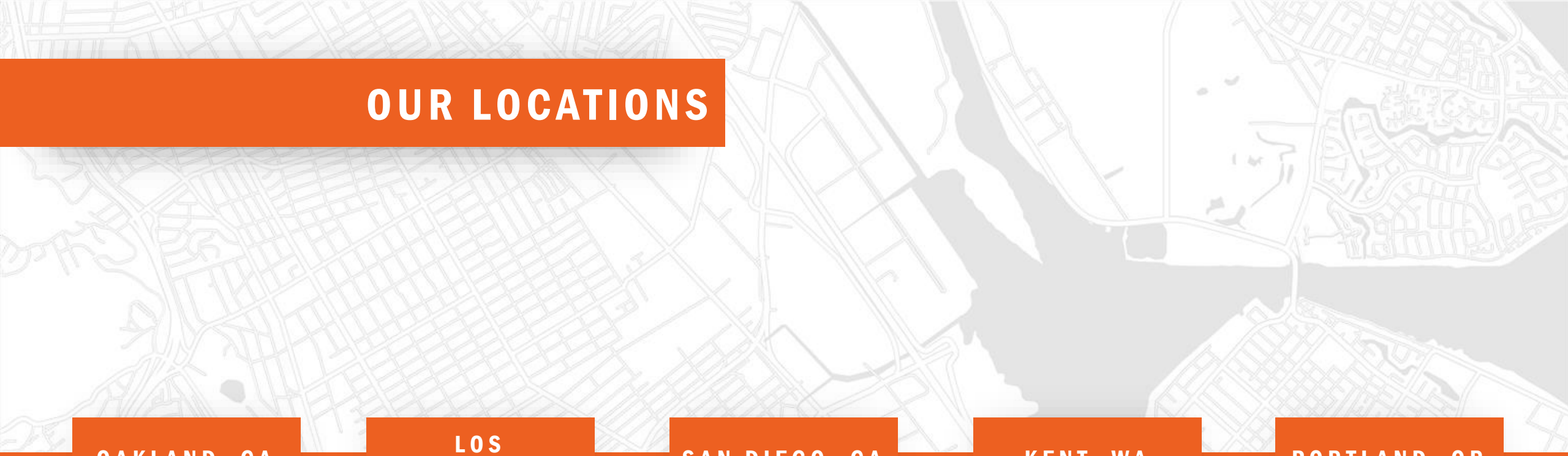
- DRILLED SHAFTS (CIDH)
  - Open Hole
  - Slurry Displacement
  - Fully Cased
- Auger Cast
- Auger Displacement
- Micro
- Driven

Cle Elum Dam, WA

WHERE WE WORK



OUR LOCATIONS



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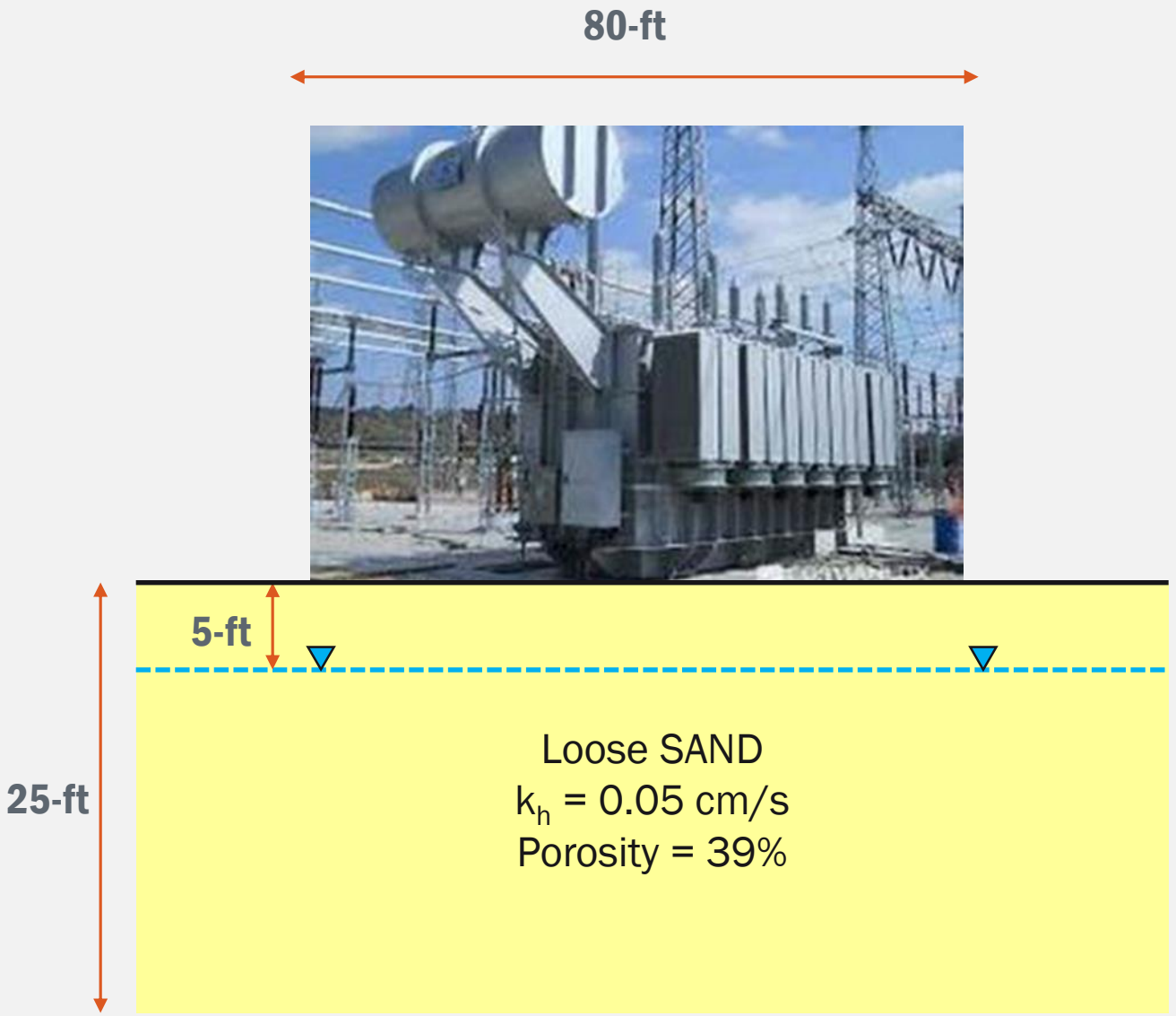
OUTLINE

- Feasibility and commercial applicability of bio-mediation
  - Scenario 1: treatment under an existing structure
    - Cost Comparison with Microfine Grouting
    - Opportunities/Challenges
  - Scenario 2: treatment for a new structure – green field site
    - Cost Comparison with Cement Deep Soil Mixing (CDSM)
    - Opportunities/Challenges
- Conclusions and remarks

Treatment Under Existing Transformer Pad

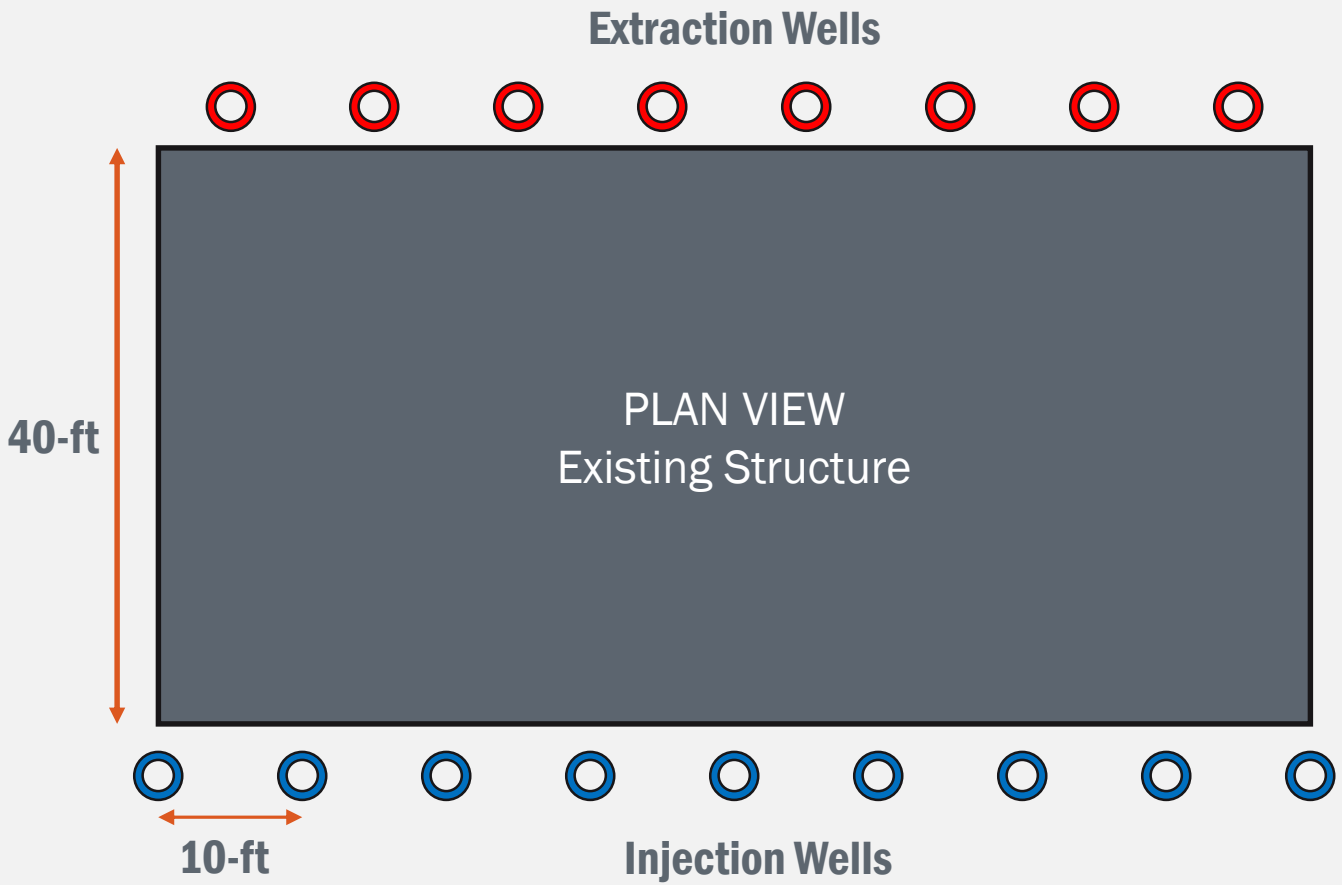
Scenario 1 - Assumptions

- **Project Scope:**
  - Substation transformer pad
  - Shallow mat foundations
  - Plan dimensions 40-ft x 80-ft
- **Soil Profile:**
  - Existing building over loose sandy ground
- **Targeted Treatment:**
  - Below water table at top 25-ft



Scenario 1 – Bio-Mediation

- Construct injection and extraction wells along the long side of pad
- Apply hydraulic gradient
  - Soil structure should not fracture
- Nutrient concentration should allow full site coverage before reactions slow down the seepage



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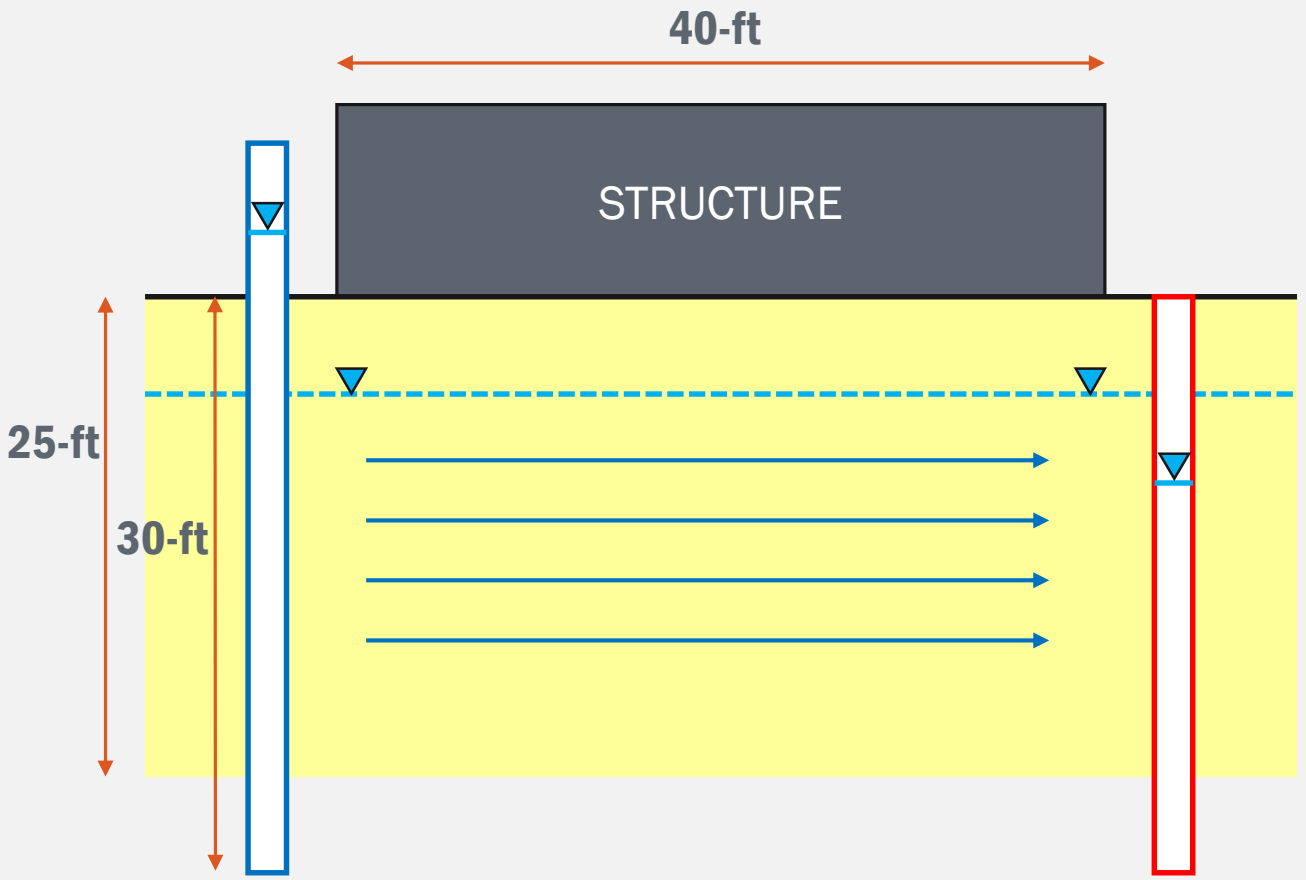
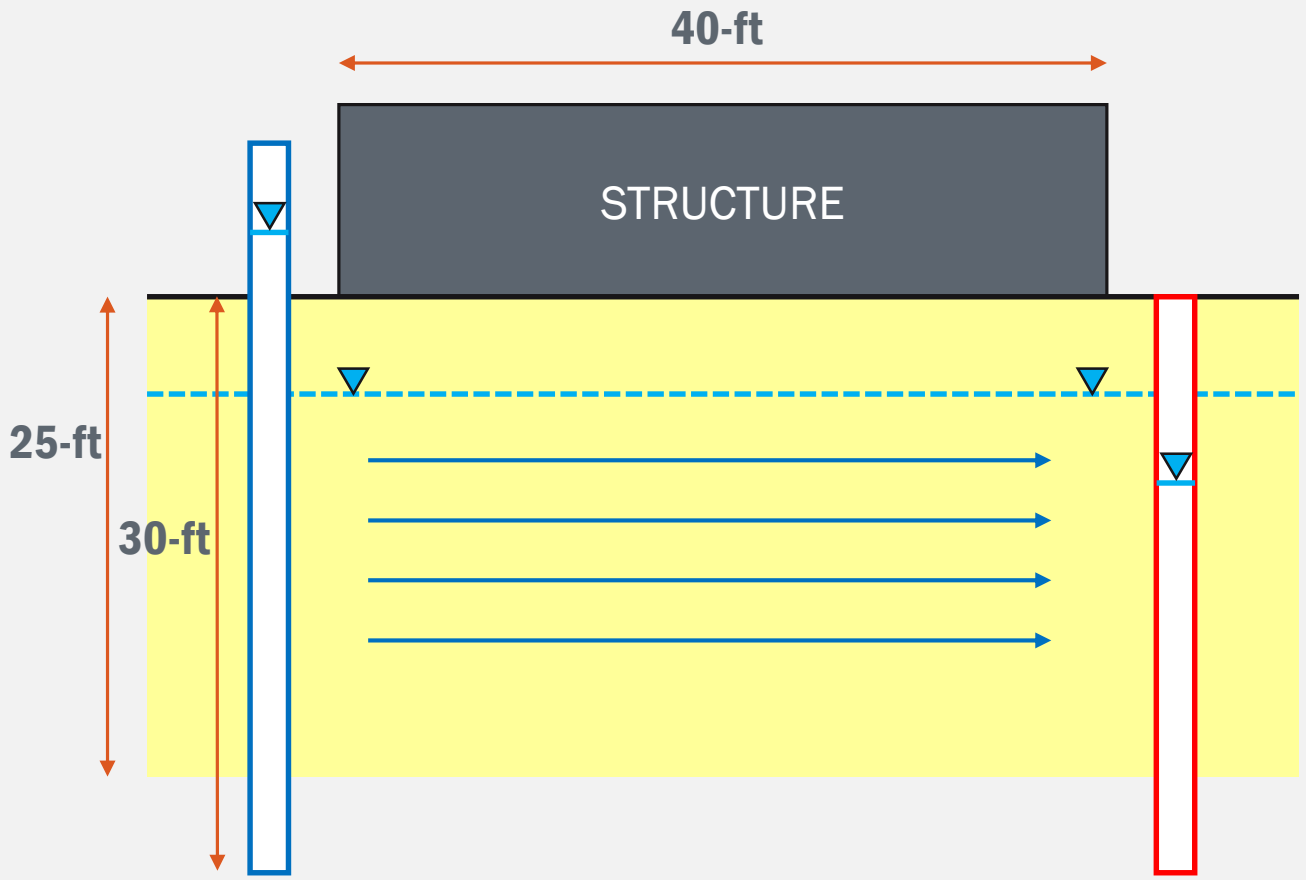


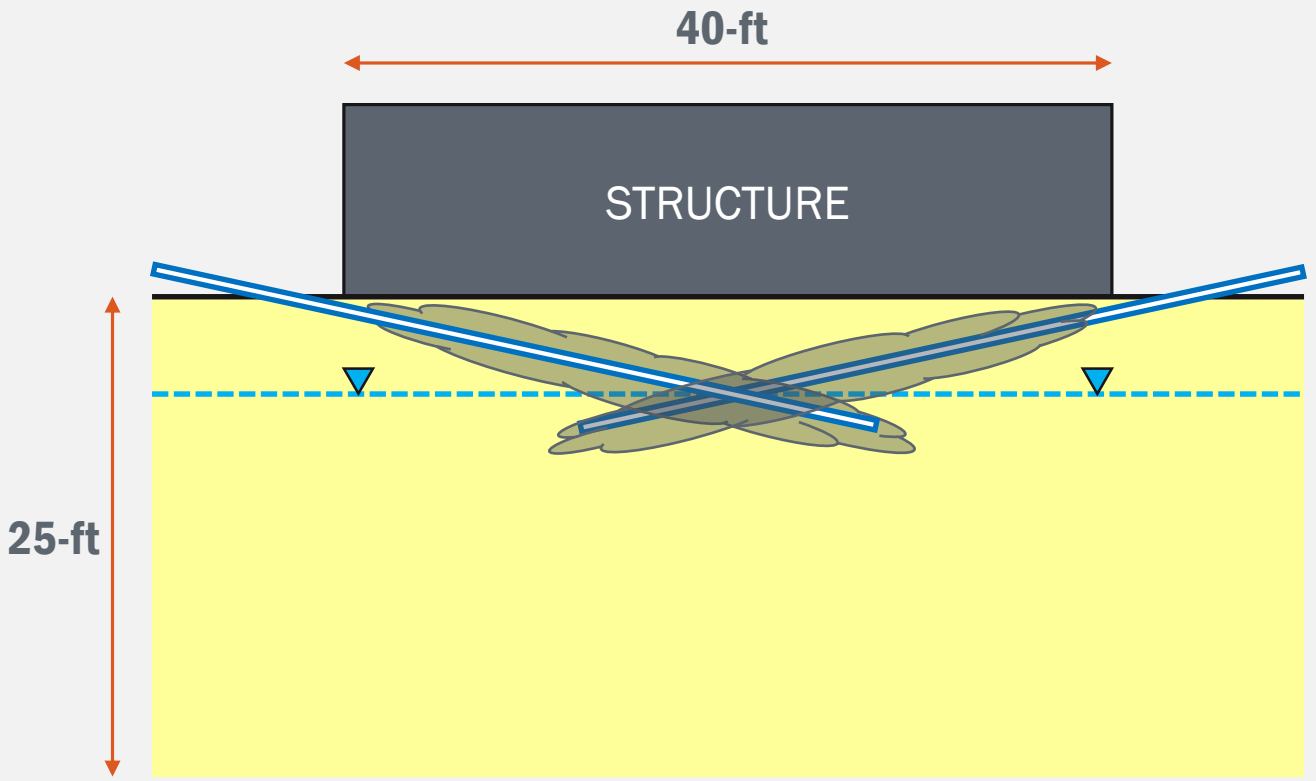
Scenario 1 – Bio-Mediation

- **Construction:**
  - 17 wells injection and extraction
  - Nutrient Injection: 190,000 gal
  - Calcium Nitrate and Calcium Acetate
    $0.92 /gal
  - Price = $240,000



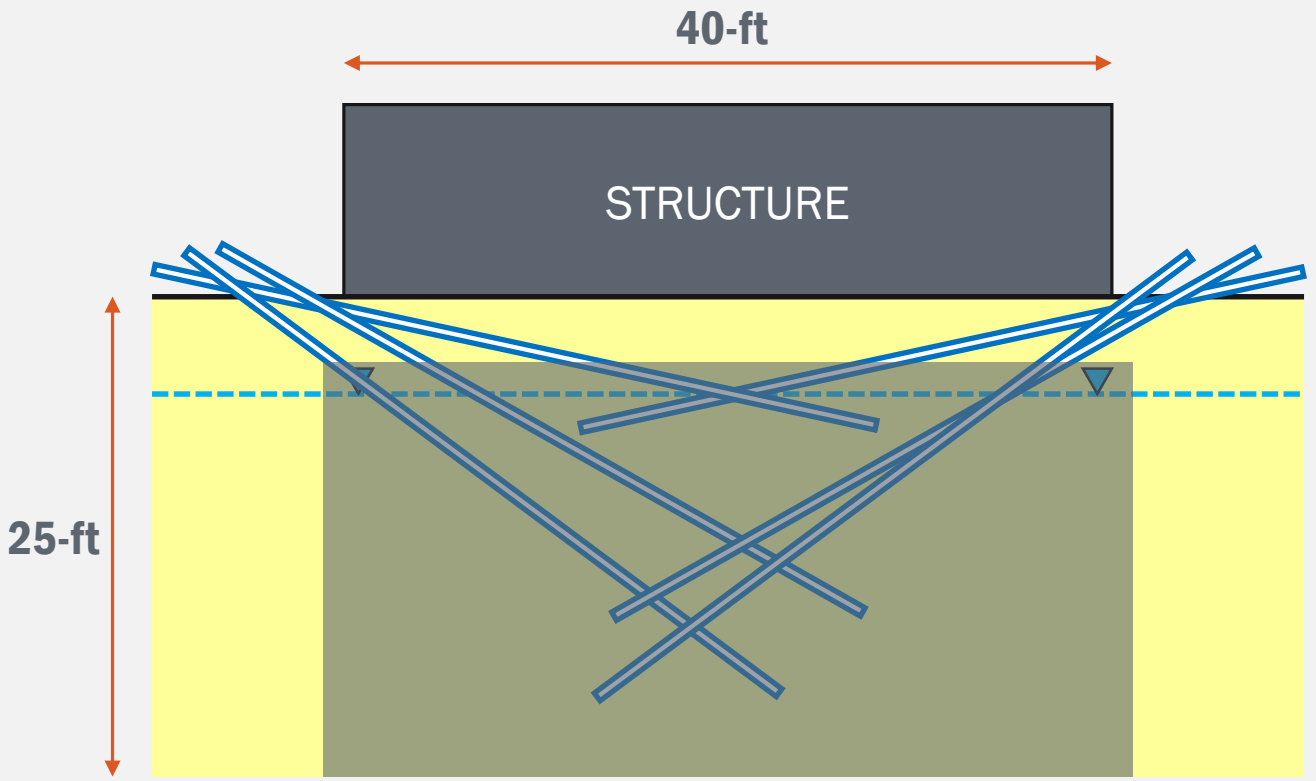
Scenario 1 – Permeation Grouting

- Battered drilling and permeation grouting
- Using micro-fine Portland cement



Scenario 1 – Permeation Grouting

- **Construction:**
  - Drilling: **2400-ft x $25 per lf**
  - Grout : 190,000 gal
    Micro-fine cement: **$2.7**/gal
  - Price: $600,000



Scenario 1 - Summary

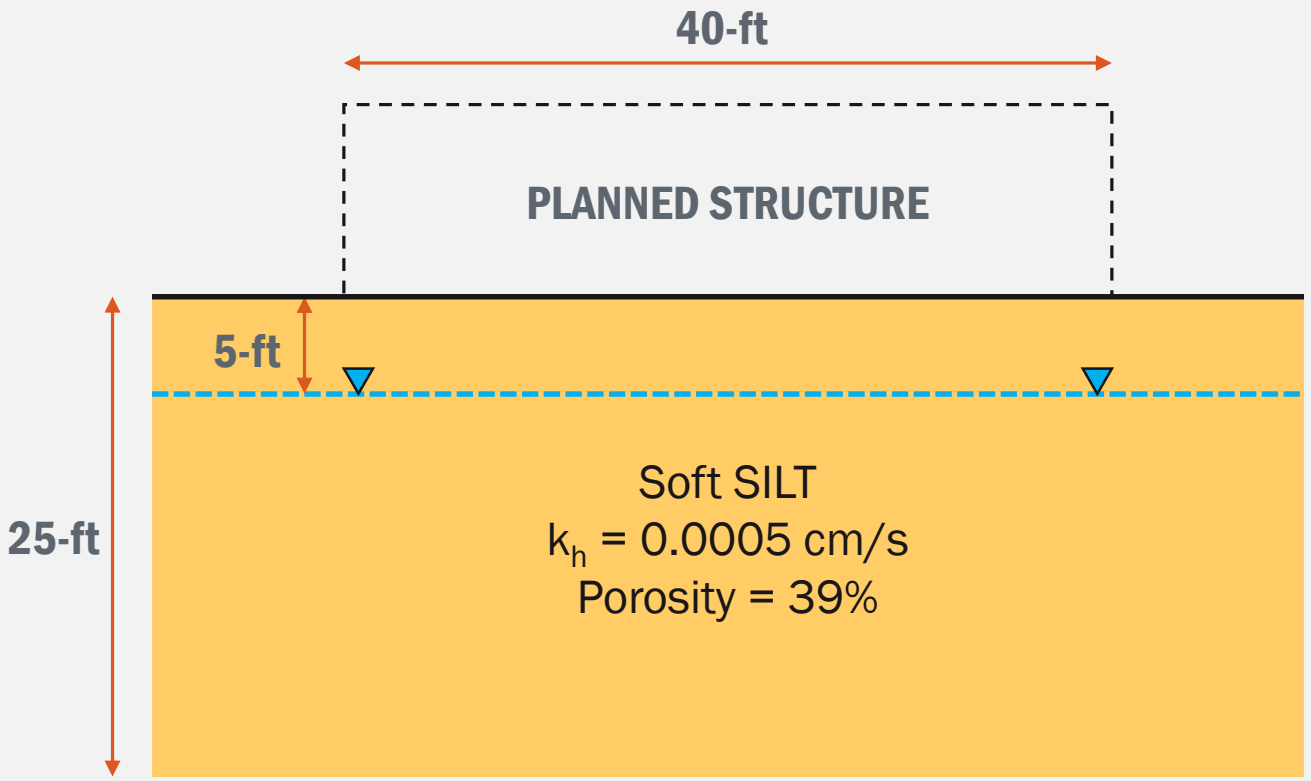
- Feasibility for existing structures
  - Conventional ground improvement techniques are very limited and expensive in sands and essentially non-existent in silts.
  - Bio-mediation appears to have economical viability
  - Ease of re-injection of wells over time if necessary.

- Technical challenges
  - Reliable assessment of horizontal permeability and its variation with nutrient injection/micro-reaction
  - Proportioning nutrients for proper reaction-travel through the profile
  - Confirming extent/consistency of desaturation.
  - Sustainability of desaturation.

Treatment for New Structure

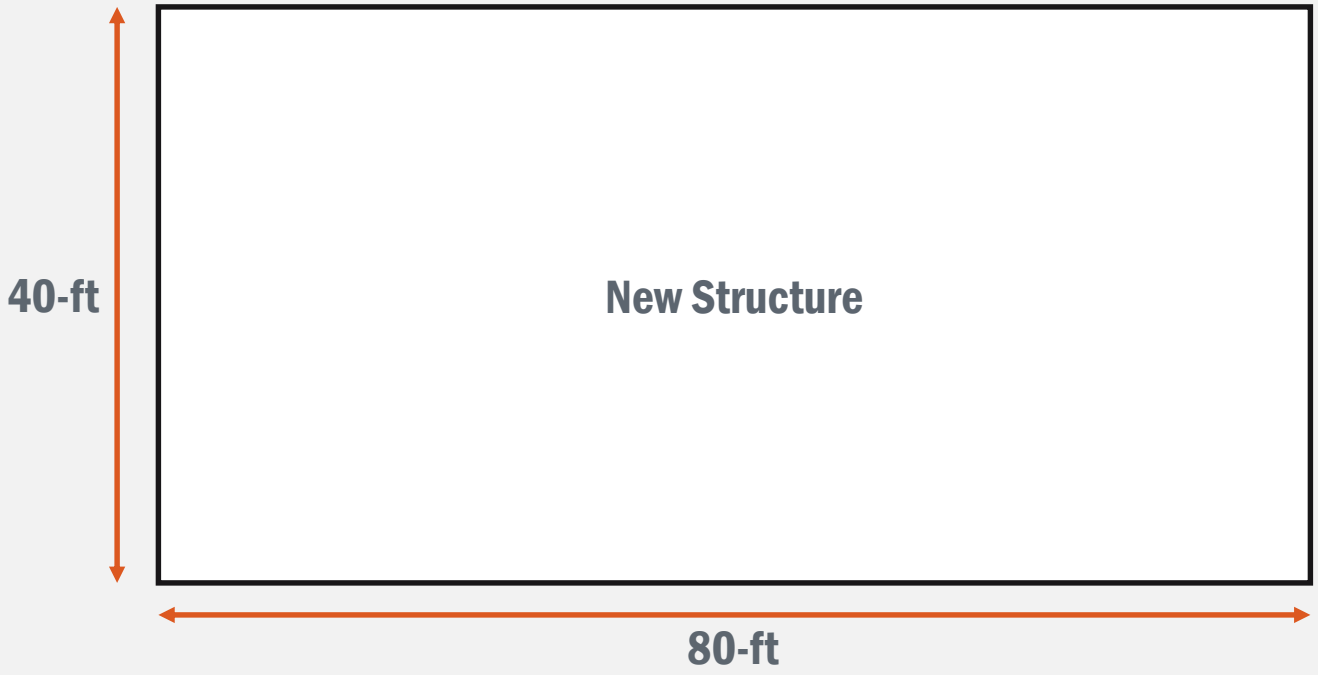
Scenario 2 - Assumptions

- **Project Scope:**
  - Greenfield development
  - Shallow foundations
- **Soil Profile:**
  - New building over soft silts
- **Targeted Treatment:**
  - Below water table to depth of 25-ft



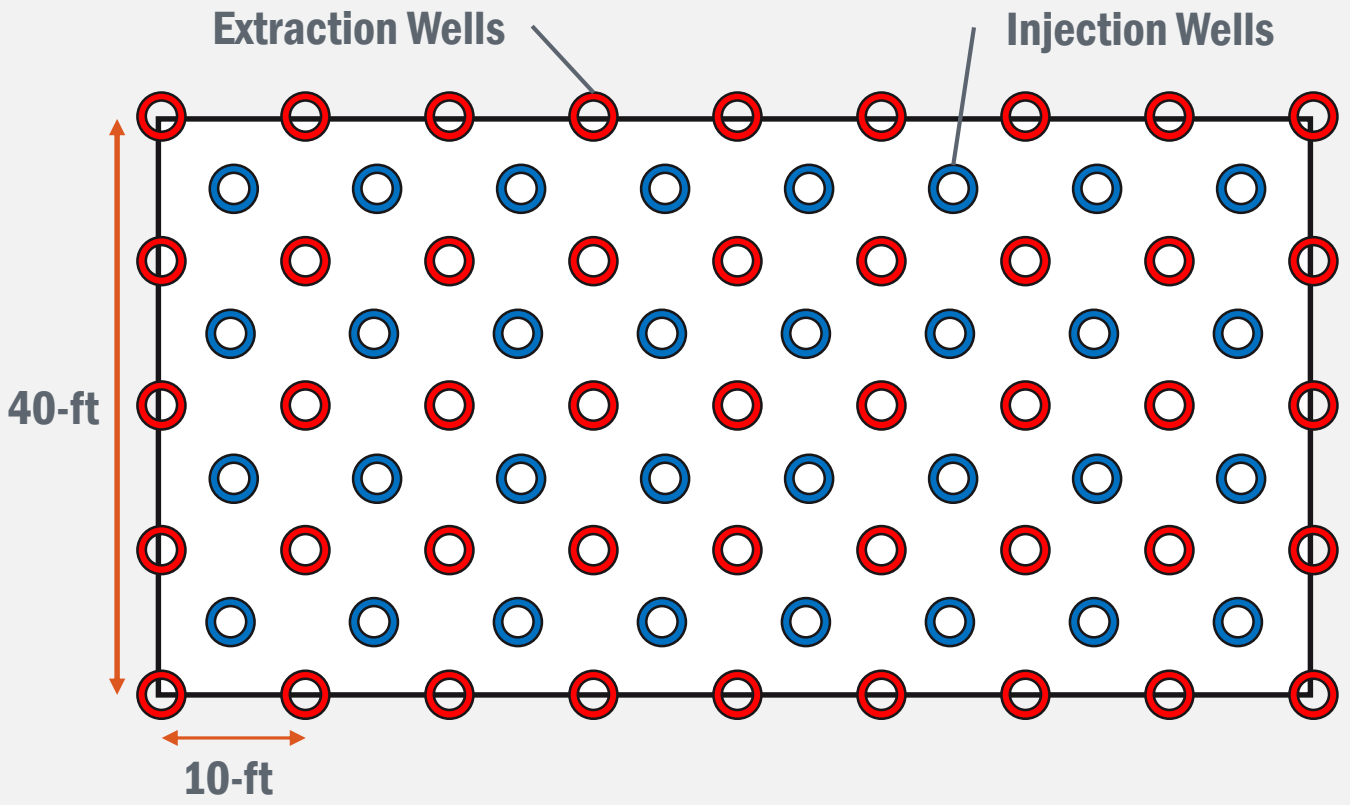
Scenario 2 – New Building

- Due to silty/low permeability nature of the site:
  - Ground cannot be densified
    - No stone columns
    - No grouted displacement column
    - No compaction grouting
  - Ground cannot be grouted
    - No permeation grouting with micro-fines and sodium silicates
  - Low permeability limits extent of efficient nutrient spread.



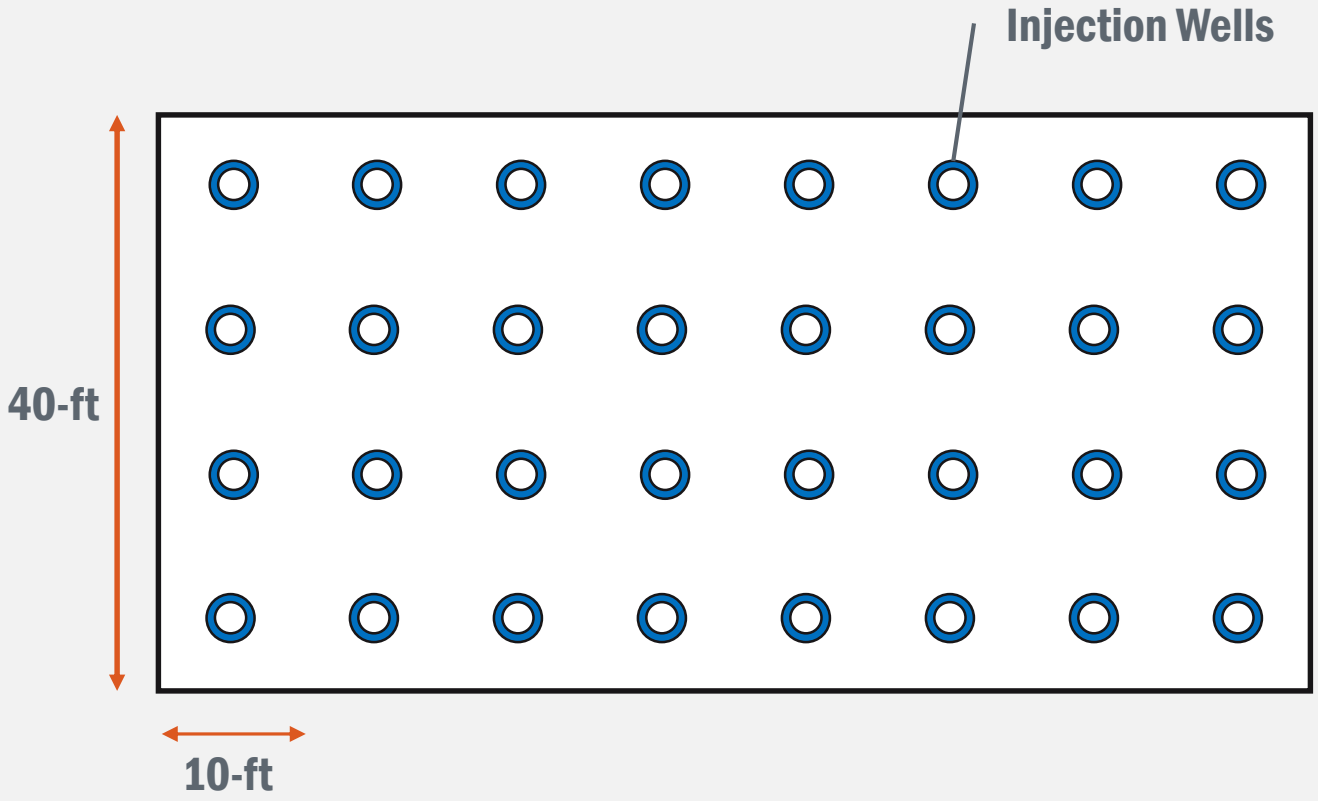
Scenario 2 – Bio-Mediation

- Construct wells across the site:
  - 32 injection wells
  - 45 extraction wells
  - Nutrient Injection: 180,000 gal
  - Price = $390,000



Scenario 2 – Bio-Mediation

- Construct wells across the site:
  - 32 injection wells
  - No extraction wells
  - Nutrient Injection: 180,000 gal
  - Price = $270,000

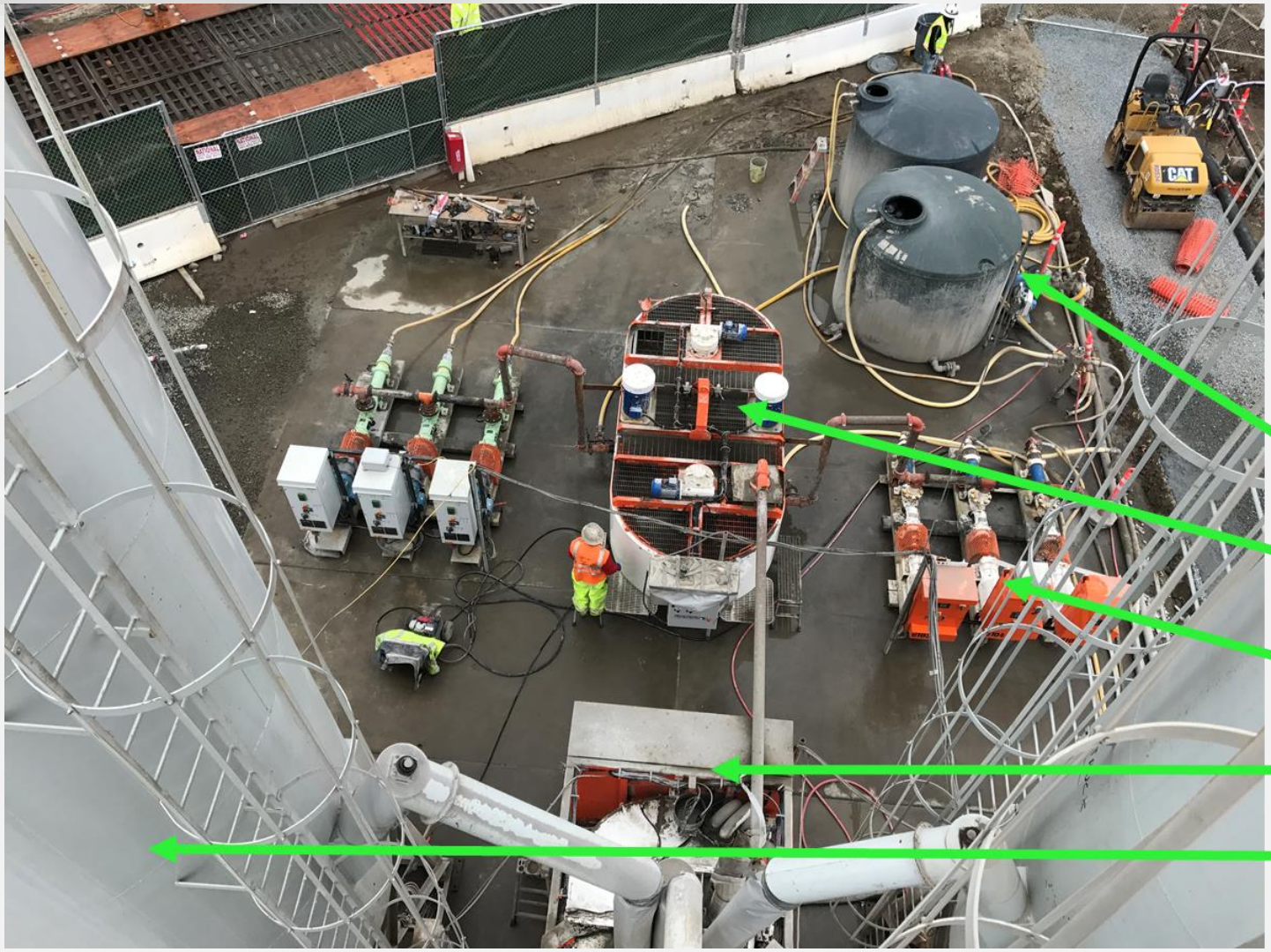


Scenario 2 – Deep Soil Mixing

Triple Auger Mixer

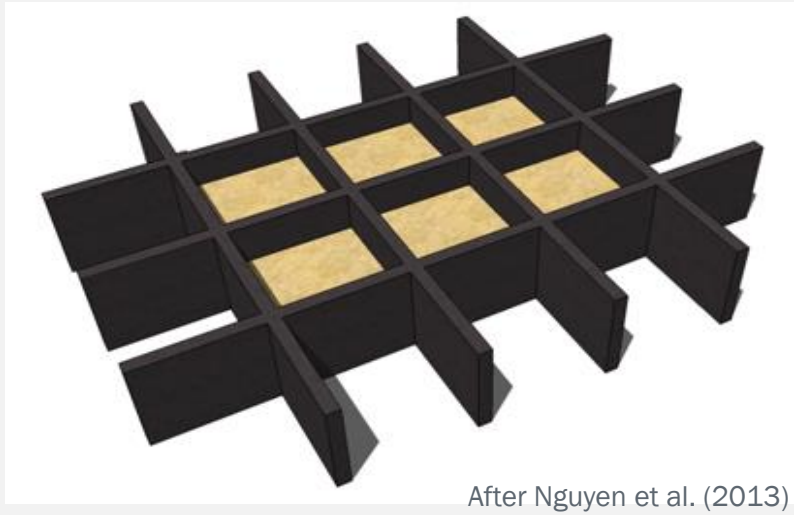
Cutter Head Mixer

Scenario 2 – Deep Soil Mixing

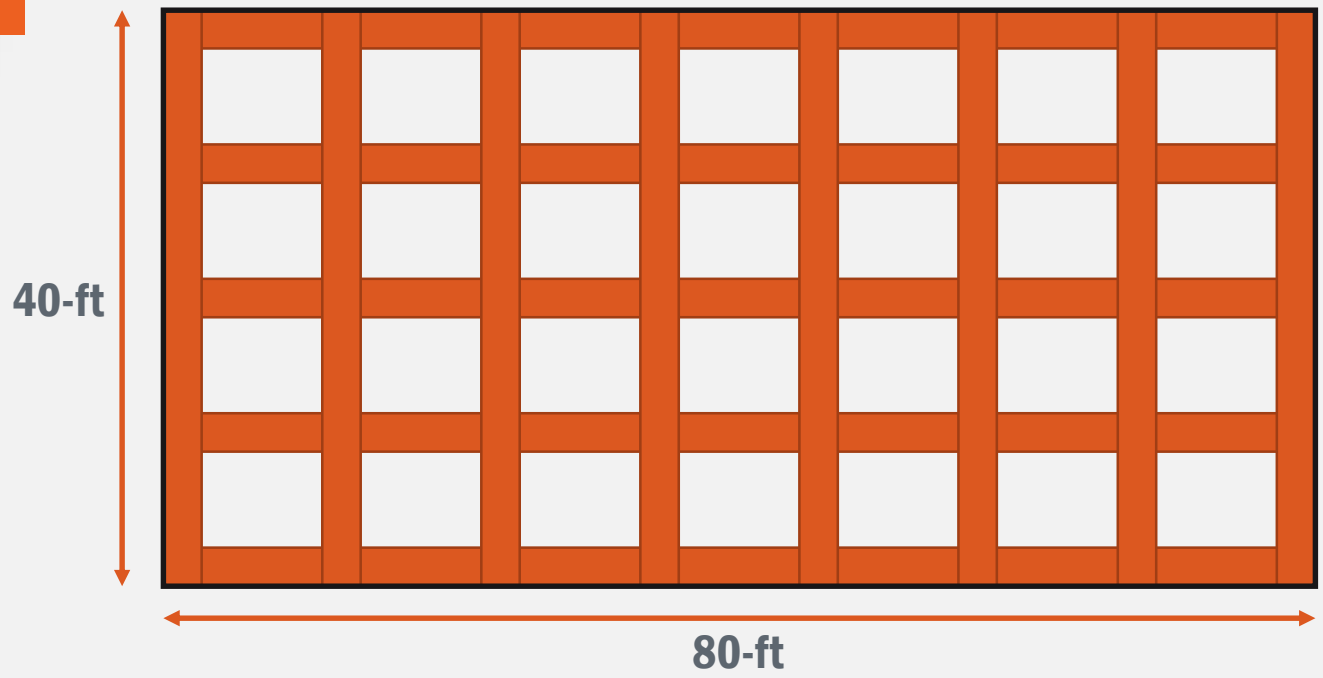


Scenario 2 - Deep Soil Mixing

- Construct soil-cement grids to enclose soft silts.
- Typically 40% area replacement ratio with 250 pci strength.



After Nguyen et al. (2013)



- 1,200 cy of soil-cement x $125/cy
- 400 cy of spoils x $40/cy
- Budget Price : $320,000

Scenario 2 - Summary

- Feasibility for new structures
  - Conventional ground improvement techniques in fine silts are generally limited to deep-soil-cement mixing with a grid pattern
  - Bio-mediation may have economical viability
  - Direct push methods and vacuum well points have potential to reduce time/cost

- Technical challenges
  - DSM provides increase in static bearing capacity. What does bio-remediation do to static capacity of the silts?
  - Confirming extent/consistency of desaturation.
  - Sustainability of desaturation
  - Difficult/impossible to re-inject once building constructed.

Conclusions

- Bio Mediation for Liquefaction Mitigation
  - Opportunities
    - Economically Viable for Existing Structures over Sands or Silts
    - Economically Possible for New Structures over Silts
  - Challenges
    - Sustainability of desaturation
    - Extent of liquefaction mitigation for layered desaturation
    - Regulatory stance on injection/extraction points as wells with associated permits/reporting

THANK YOU

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