DESIGN AND CONSTRUCTION OF A MSE BERM OVER VERY SOFT SOIL

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS
OPAL
OUTSTANDING PROJECTS AND LEADERS

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Geosyntec consultants

STGEC 2012

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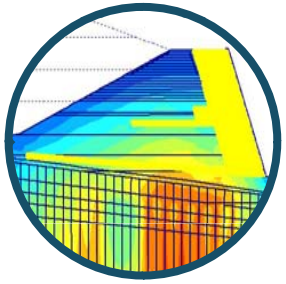

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PROJECT OVERVIEW

- Delaware Solid Waste Authority – DSWA
  - Disposal of waste from the Wilmington, Delaware area in the near future
  - Feasibility → ~20 million cubic yards
  - Approximately 20 years of life
  - Due to site location, Horizontal Expansion was not an option
  - Vertical Expansion

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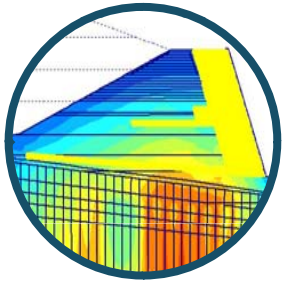

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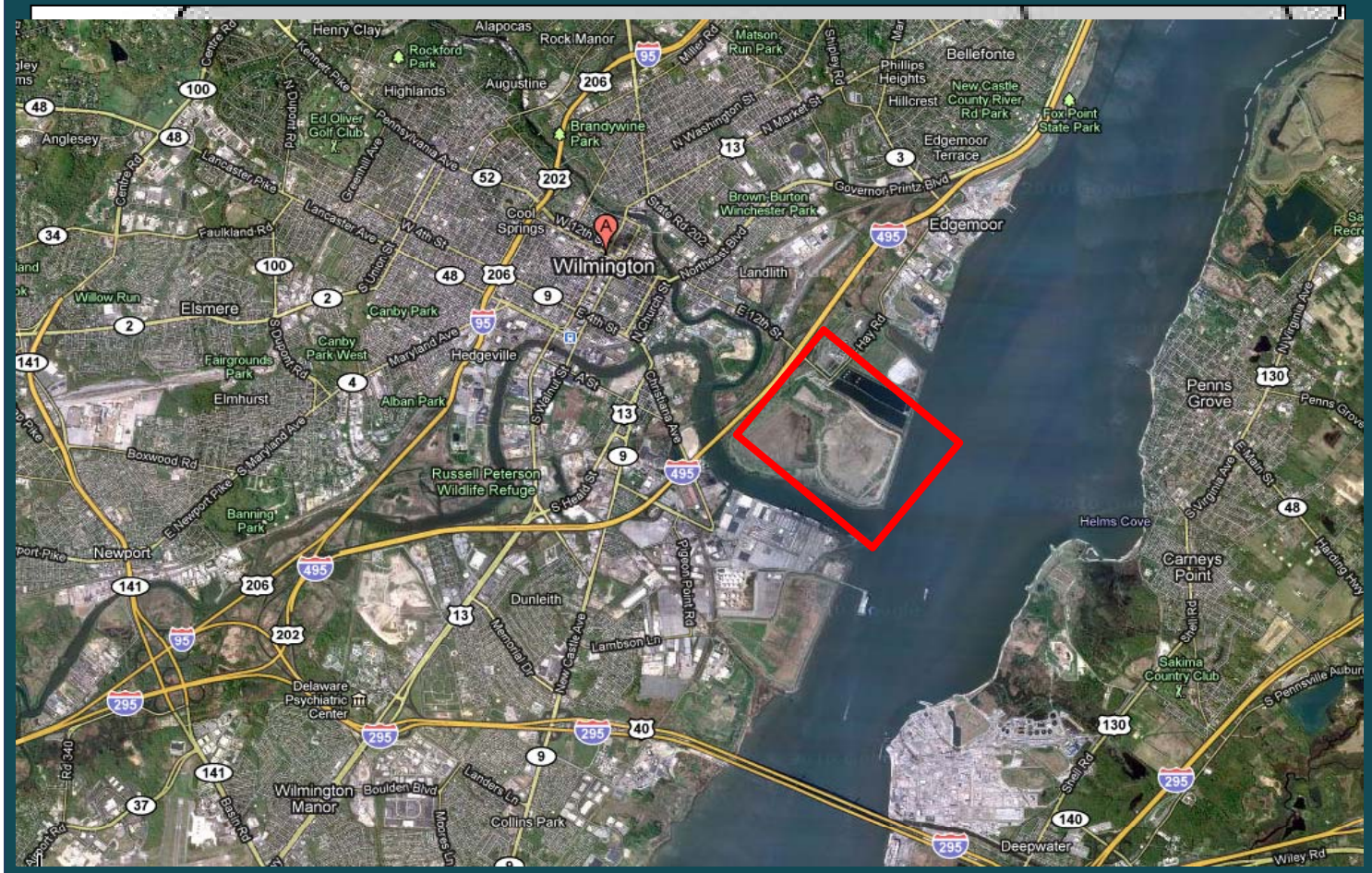
PROJECT OVERVIEW



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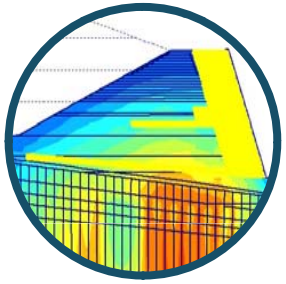
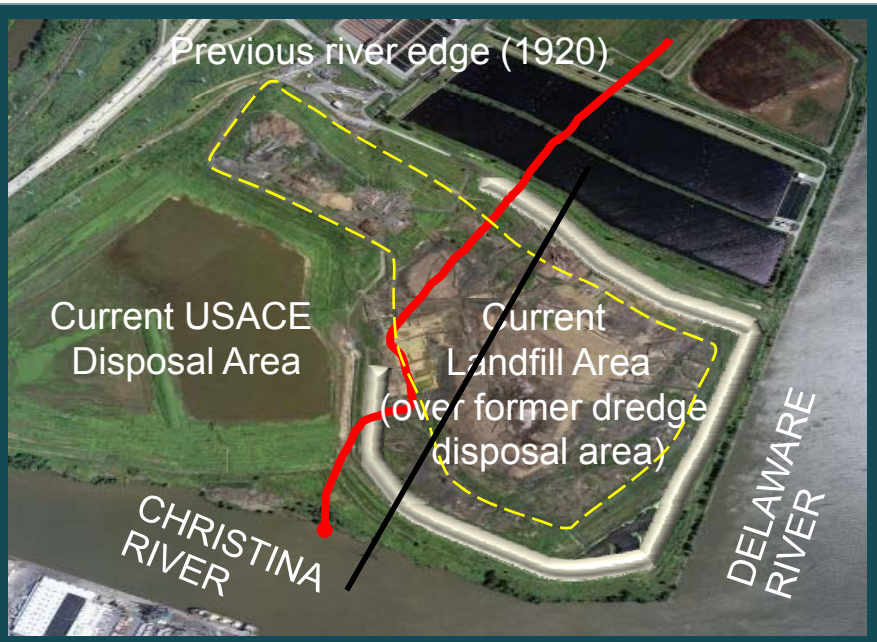
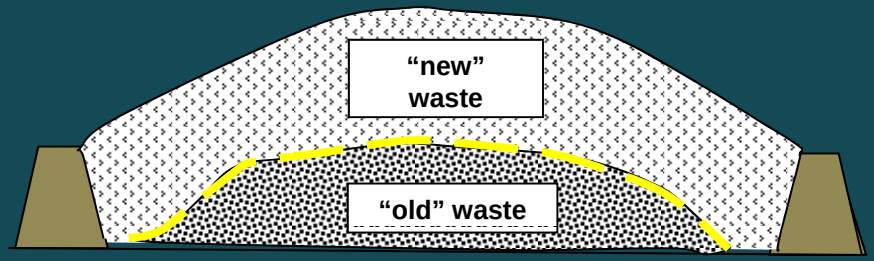
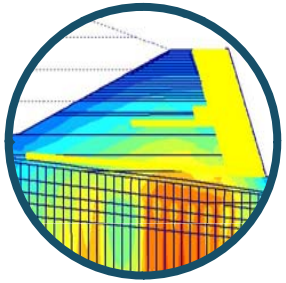






PROJECT OVERVIEW



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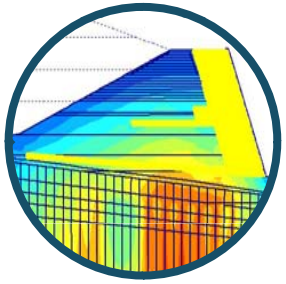

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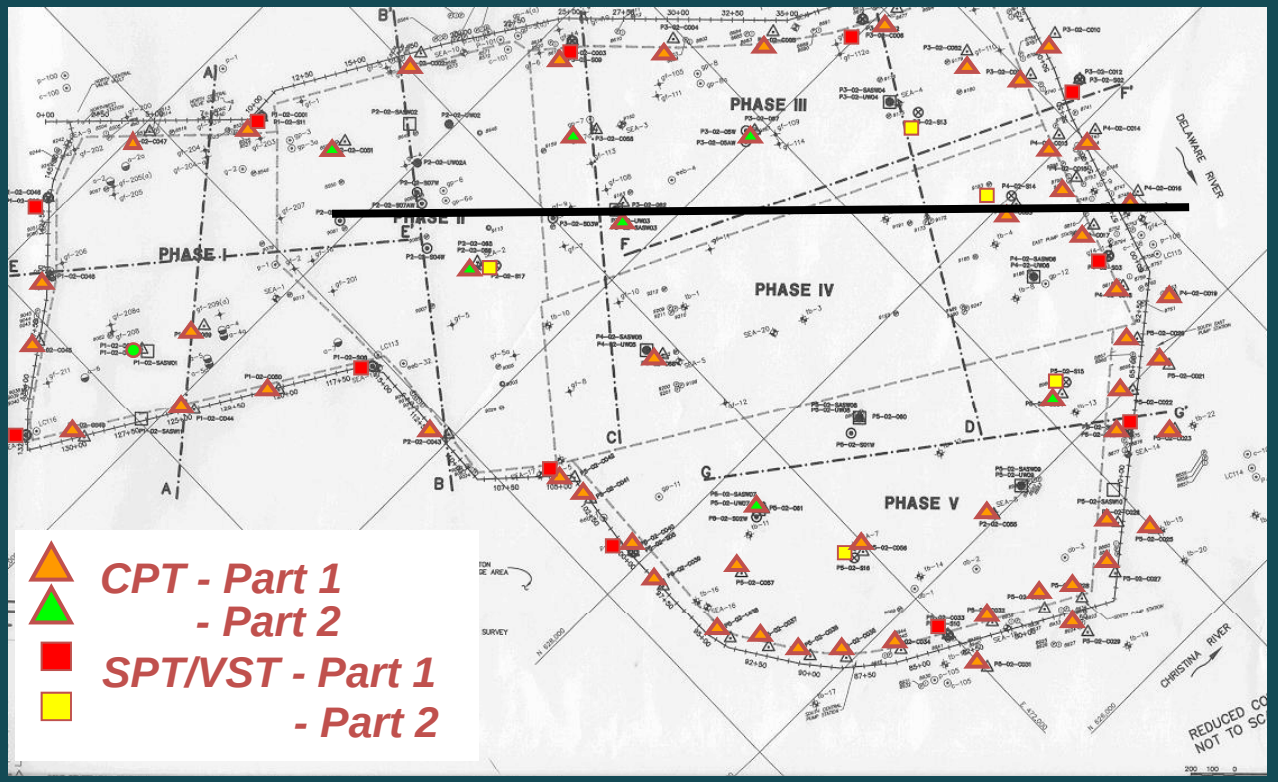
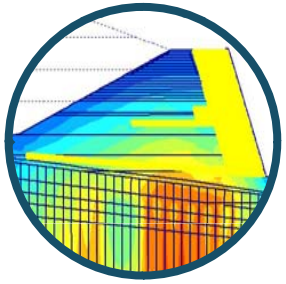
GEOTECHNICAL EXPLORATION

- Field tests
  - CPT
  - SPT
  - Vane Shear tests
- Laboratory tests
  - Triaxial Test
  - Direct Simple Shear tests
  - Direct Shear



IDEALIZED STRATIGRAPHY



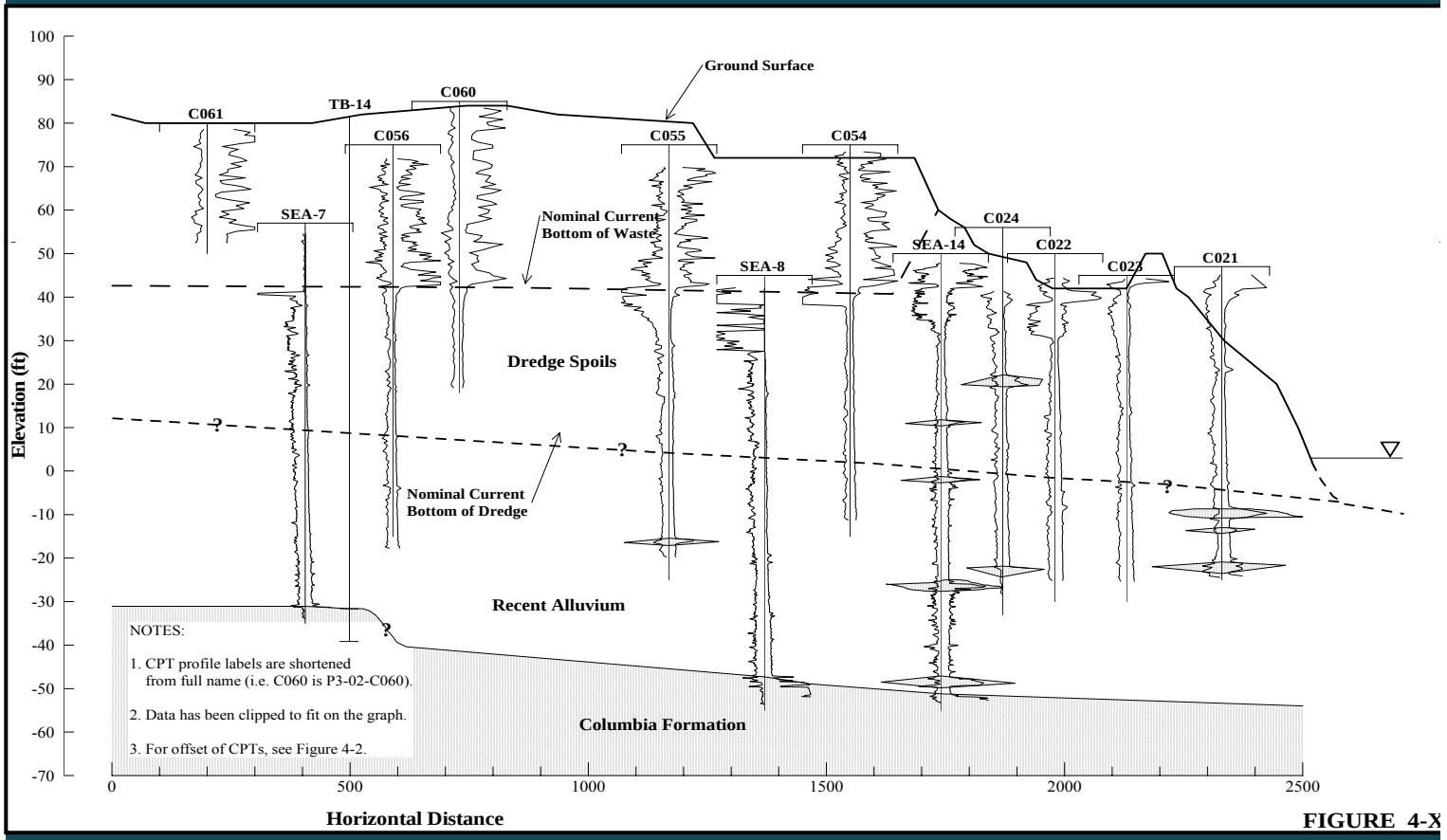
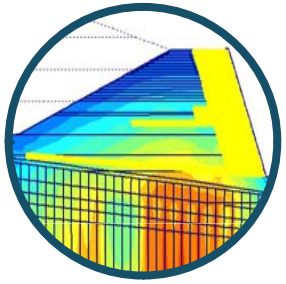
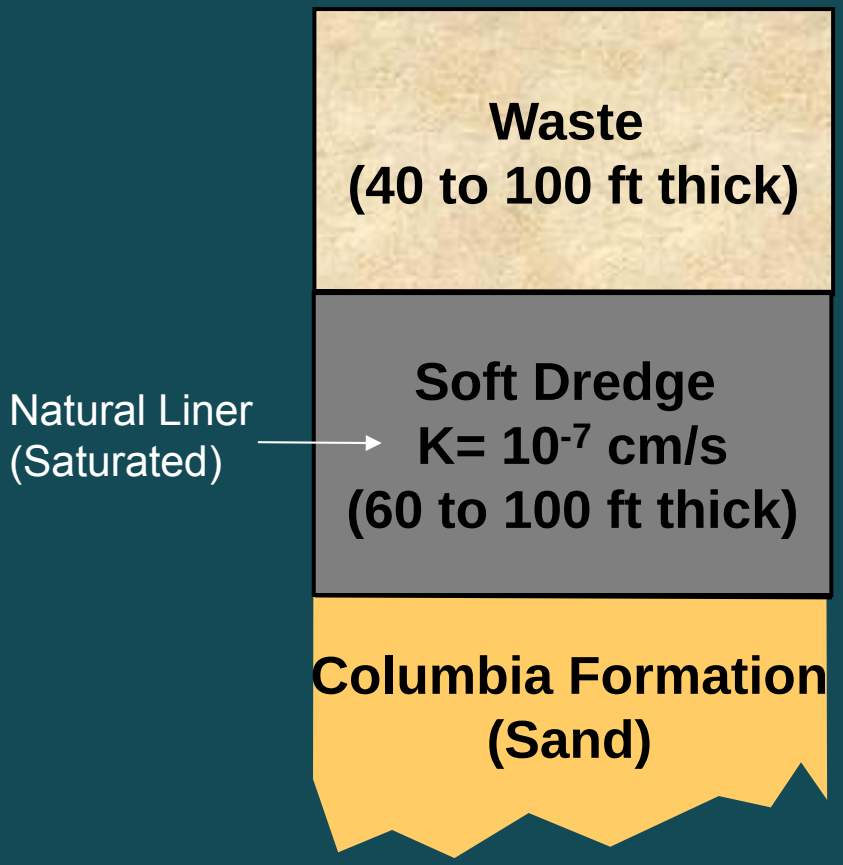


FIGURE 4-X

IDEALIZED STRATIGRAPHY (CONTINUED)





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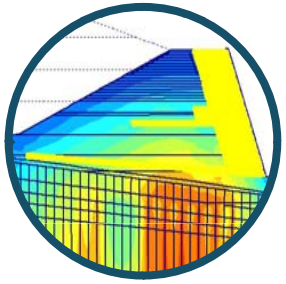

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ANALYSIS OF INITIAL SOLUTION

- Best option to obtain the required airspace with the available footprint
  - 60-ft high mechanically stabilized earth (MSE) berm
- Foundation improvement was required
- Deep soil mixing initially considered
- Advantage: Strong foundation (i.e., reduced settlements)
- Disadvantage: COST! ($170 million at the time of construction)

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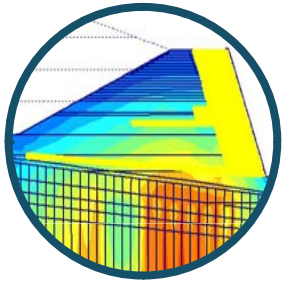

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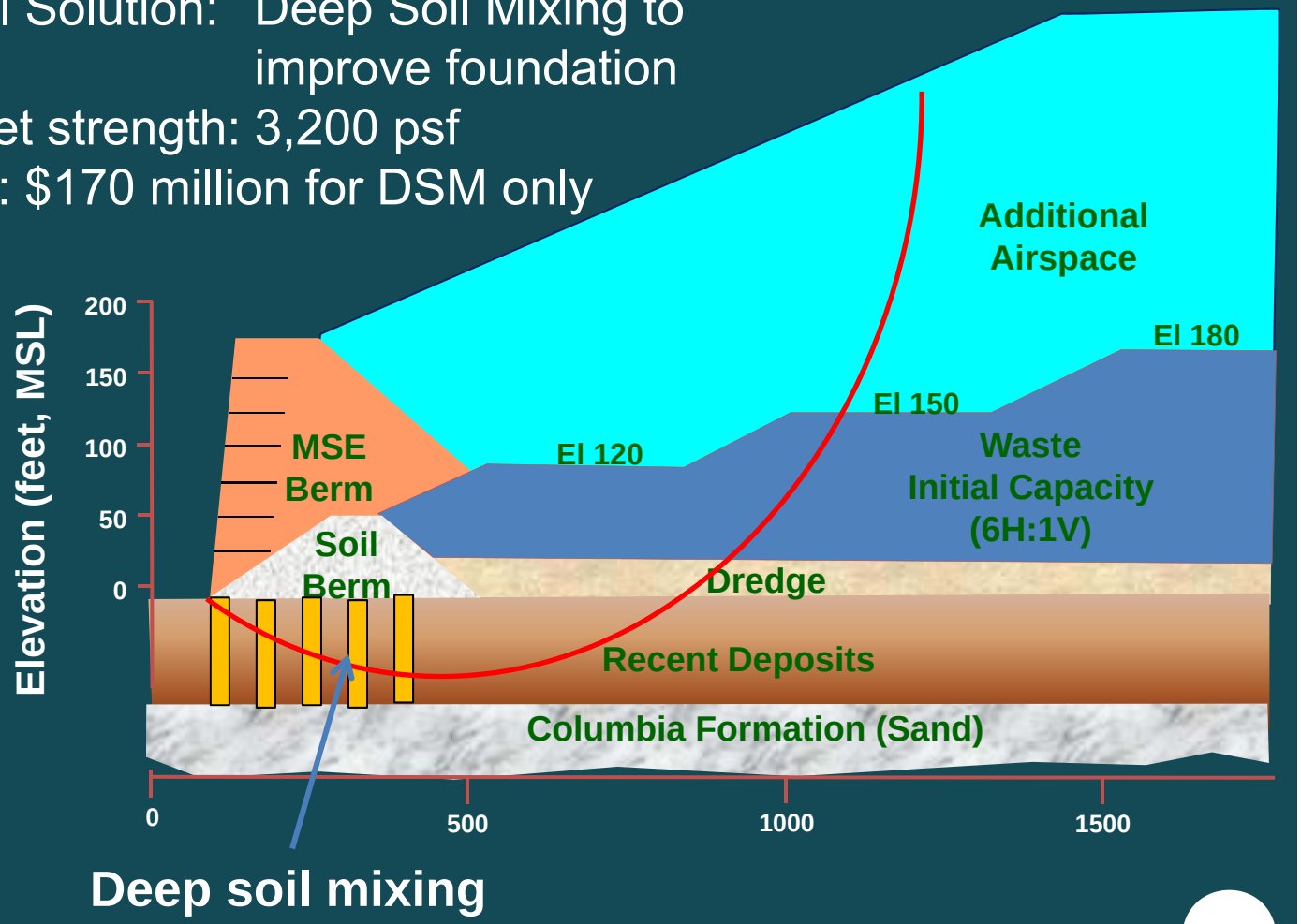
60-FT HIGH MSE BERM

Initial Solution: Deep Soil Mixing to improve foundation

Target strength: 3,200 psf

Cost: $170 million for DSM only



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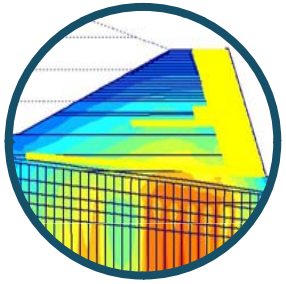

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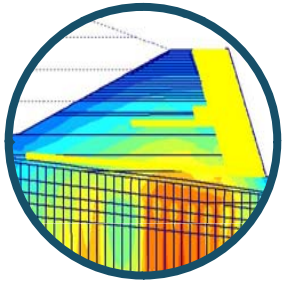
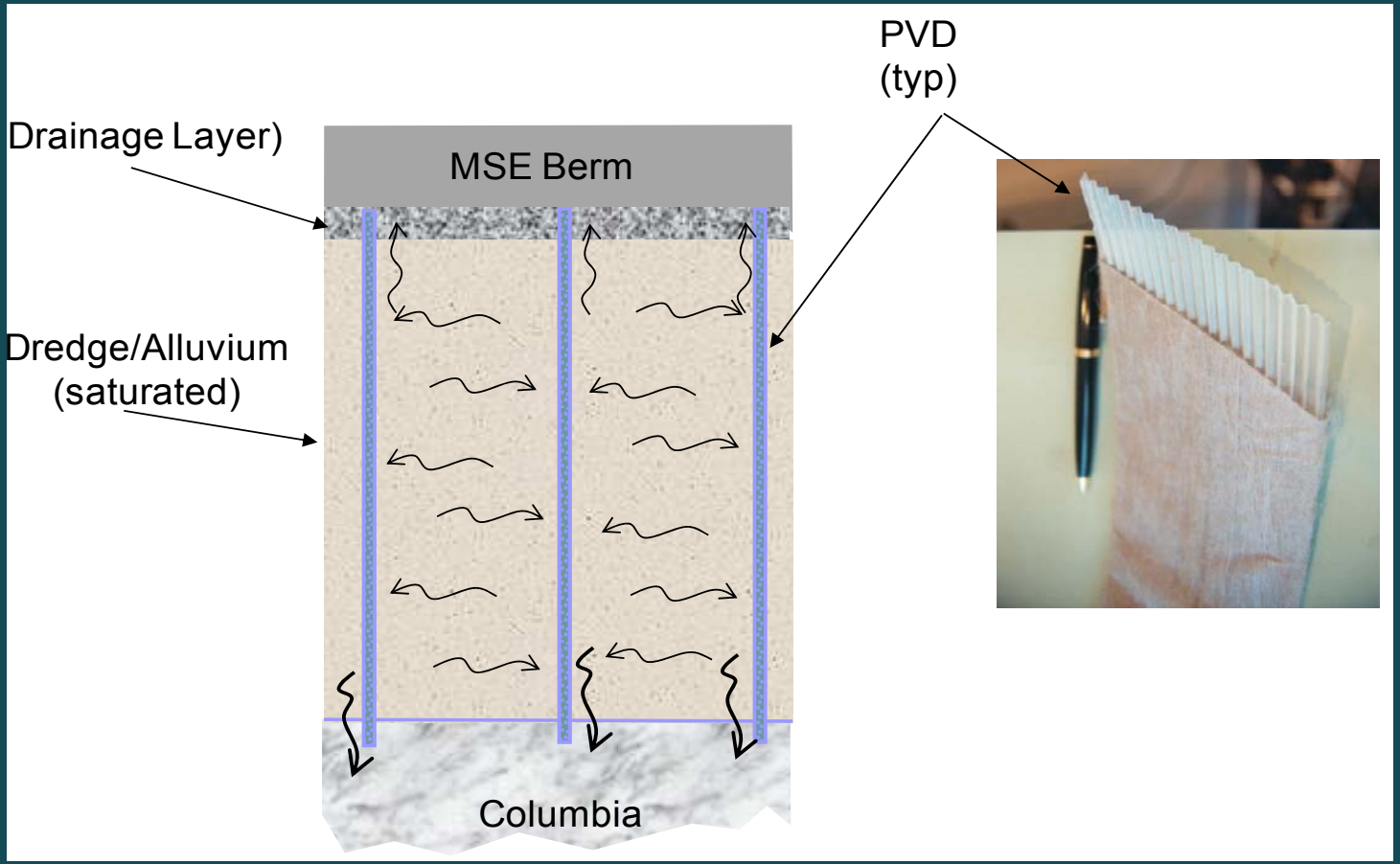
ALTERNATIVE SOLUTION

- Use the weight of the MSE berm to improve the foundation strength
- Build MSE berm using well known Stage Construction techniques
- Use prefabricated vertical drains (PVDs)
  - PVDs – Wick Drains
  - PVDs installed beneath the MSE Berm
  - Drains excess pore pressures from the soils
  - Accelerates the consolidation of the dredge/alluvium
  - Increases material strength
- Use High strength geotextile at the base of the berm
- So far so good……

PRE-FABRICATED VERTICAL DRAINS





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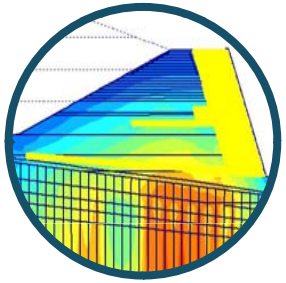

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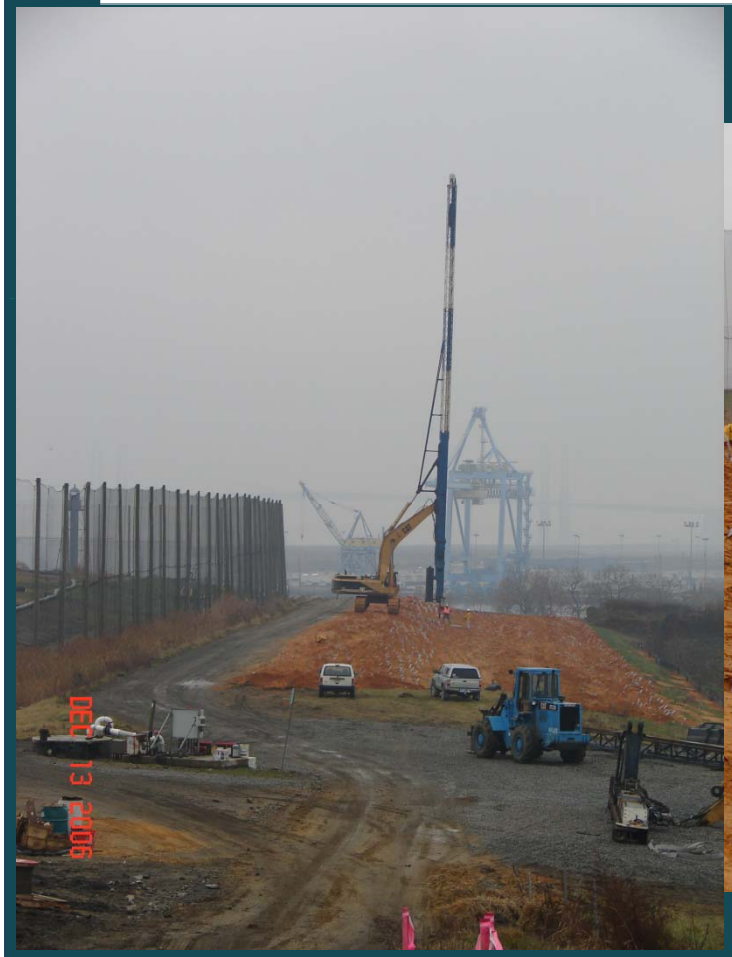
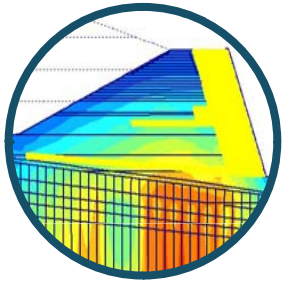
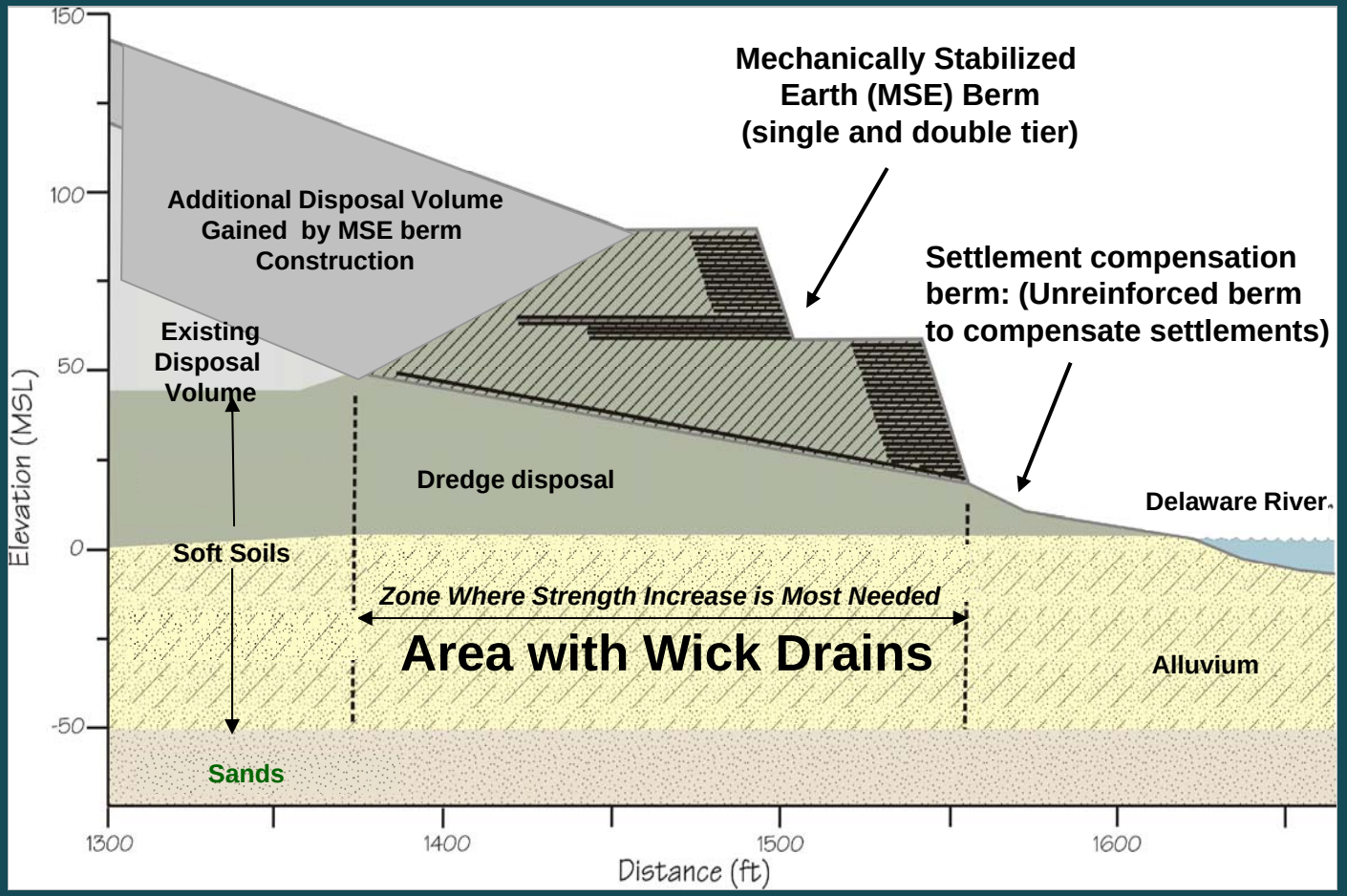
PVD Installation



ALTERNATIVE SOLUTION (CONTINUED)





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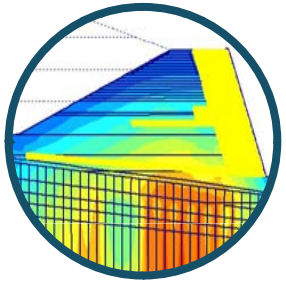

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ARE PVDS FEASIBLE?

- Remember: a 60-ft high MSE berm is needed to obtain a ~20 mcy increase in airspace
- PVDs are typically installed to accelerate consolidation (i.e., undrained)
- Is the undrained strength of the dredge/alluvium enough?
- Preliminary analysis indicated 3,200 psf

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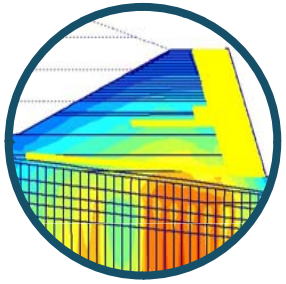

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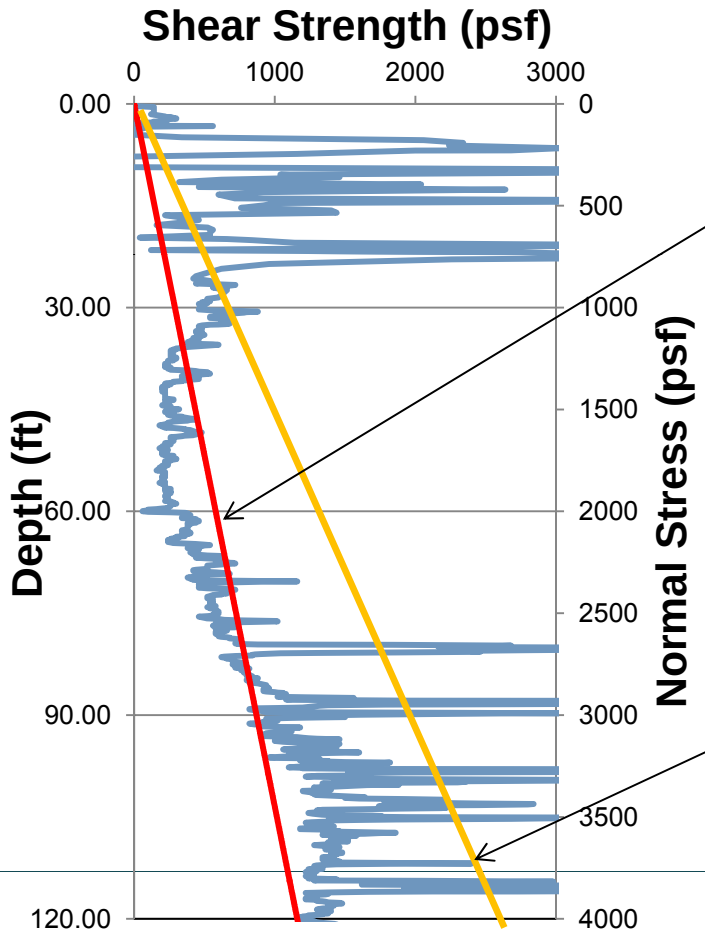
SHEAR STRENGTH



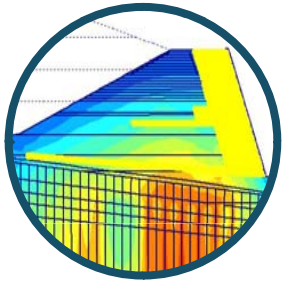
Undrained

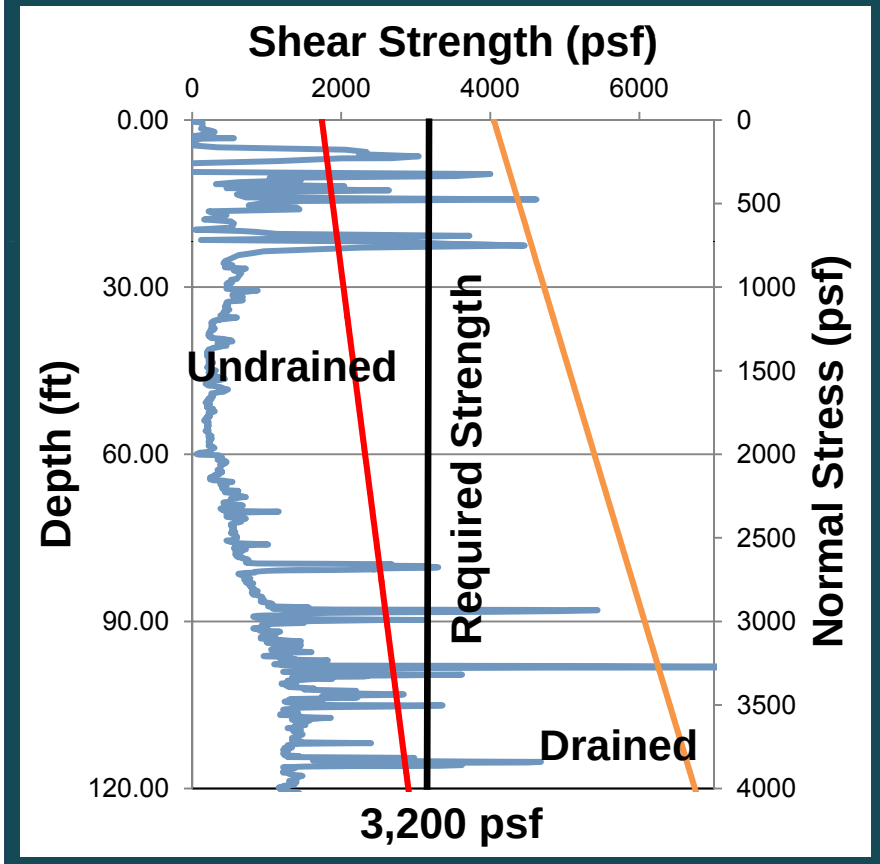
$$\frac{S_u}{\sigma_o} = 0.29$$

Drained

$$\frac{\tau}{\sigma_o} = \tan\phi = 0.67$$

SHEAR STRENGTH (WITH MSE BERM)





- MSE berm applied load: **6,000 psf**
- Undrained contribution 6,000 x 0.29 = **1,740 psf**
- Drained contribution 6,000 x 0.67 = **4,047 psf**

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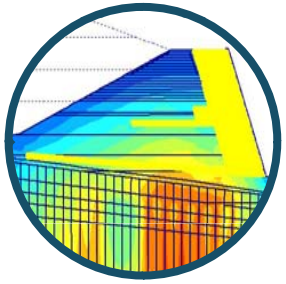

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ARE PVDS FEASIBLE?

- Standard design procedures
  - Accelerate consolidation → increase shear strength
  - Use of PVDs is **not** a feasible solution

- If dredge/alluvium assumed undrained
  - Shorter MSE berm height → lower volume

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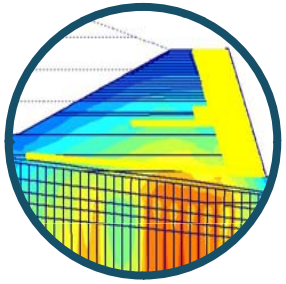

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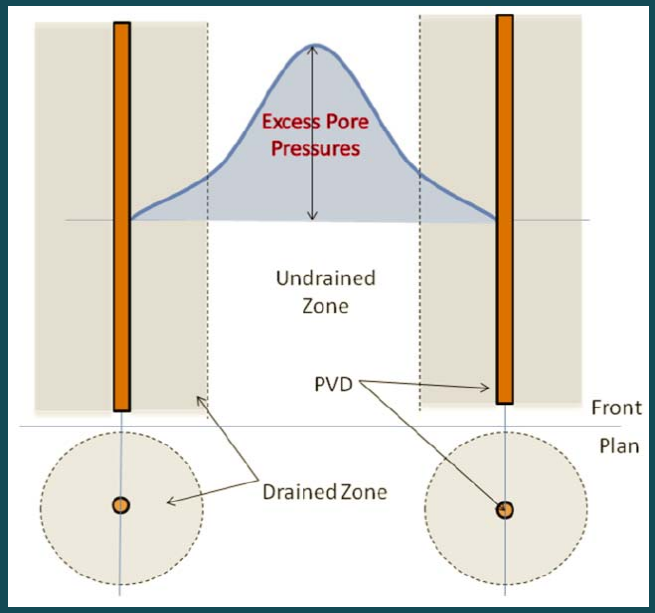
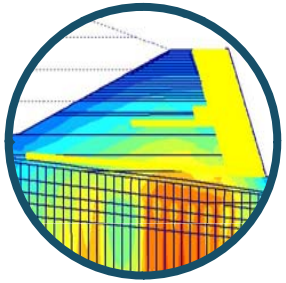
How to make PVDs feasible

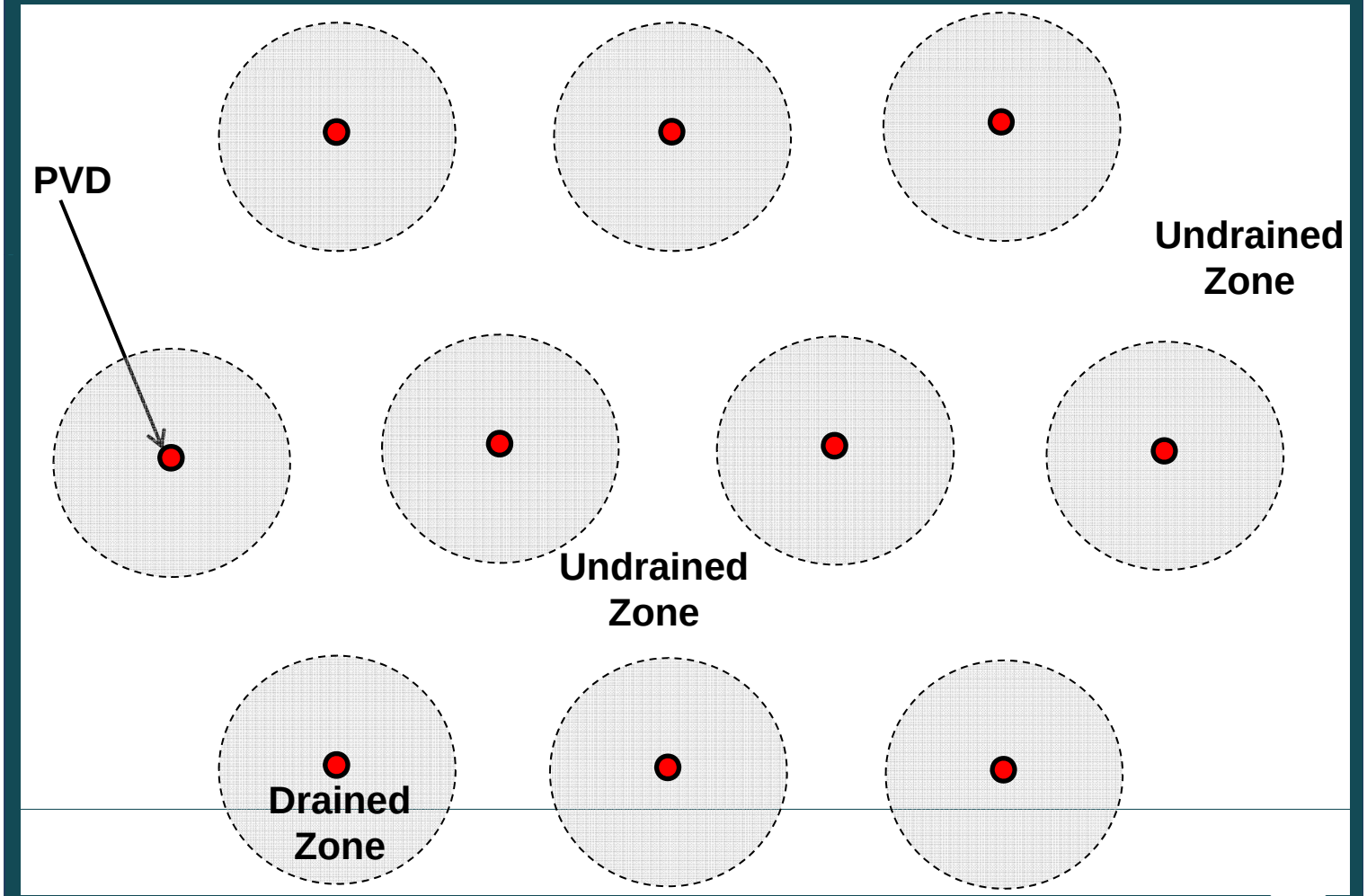
Hybrid Drained-Undrained (HDU) Model



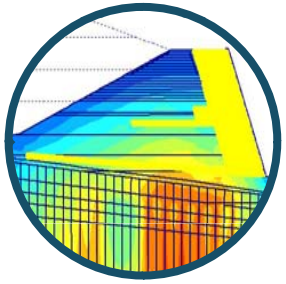
- Paradigm shift
- Drained zone, near the PVDs
- Undrained zone farther from the PVDs
- "Drained radius" calculated based on rate of loading and site-specific soils
- Drained → $\varphi = 34°$
- Undrained → $Su/\sigma' = 0.29$

HDU MODEL (CONTINUED)

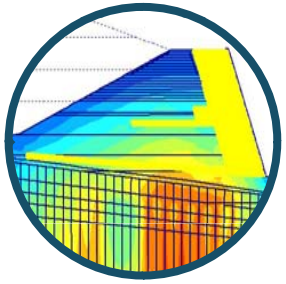




HDU Model (Continued)

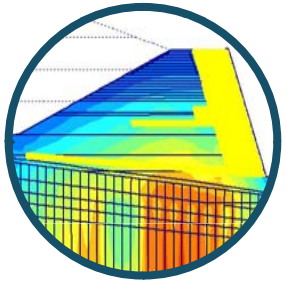


Assessment of Drained Conditions



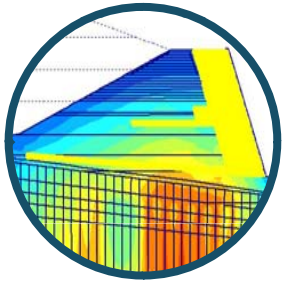
- Virtual Sand Piles
  - Pore Pressure generation model for the expected loading conditions
    - MSE Berm Construction
    - Waste Placement
  - Consider both shear and compression
  - Used lab data to estimate pp parameters
  - Pore pressure dissipation model
  - Definition of virtual sand piles diameter

ASSESSMENT OF DRAINED CONDITIONS…



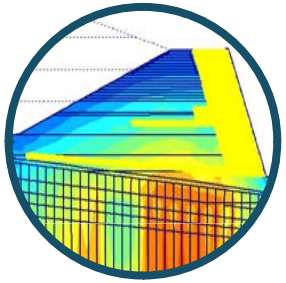
- For the expected MSE construction rates:
  - Analysis showed that 50% of the dredge/alluvium could be considered drained during berm construction
  - Used pilot test to verify dissipation model

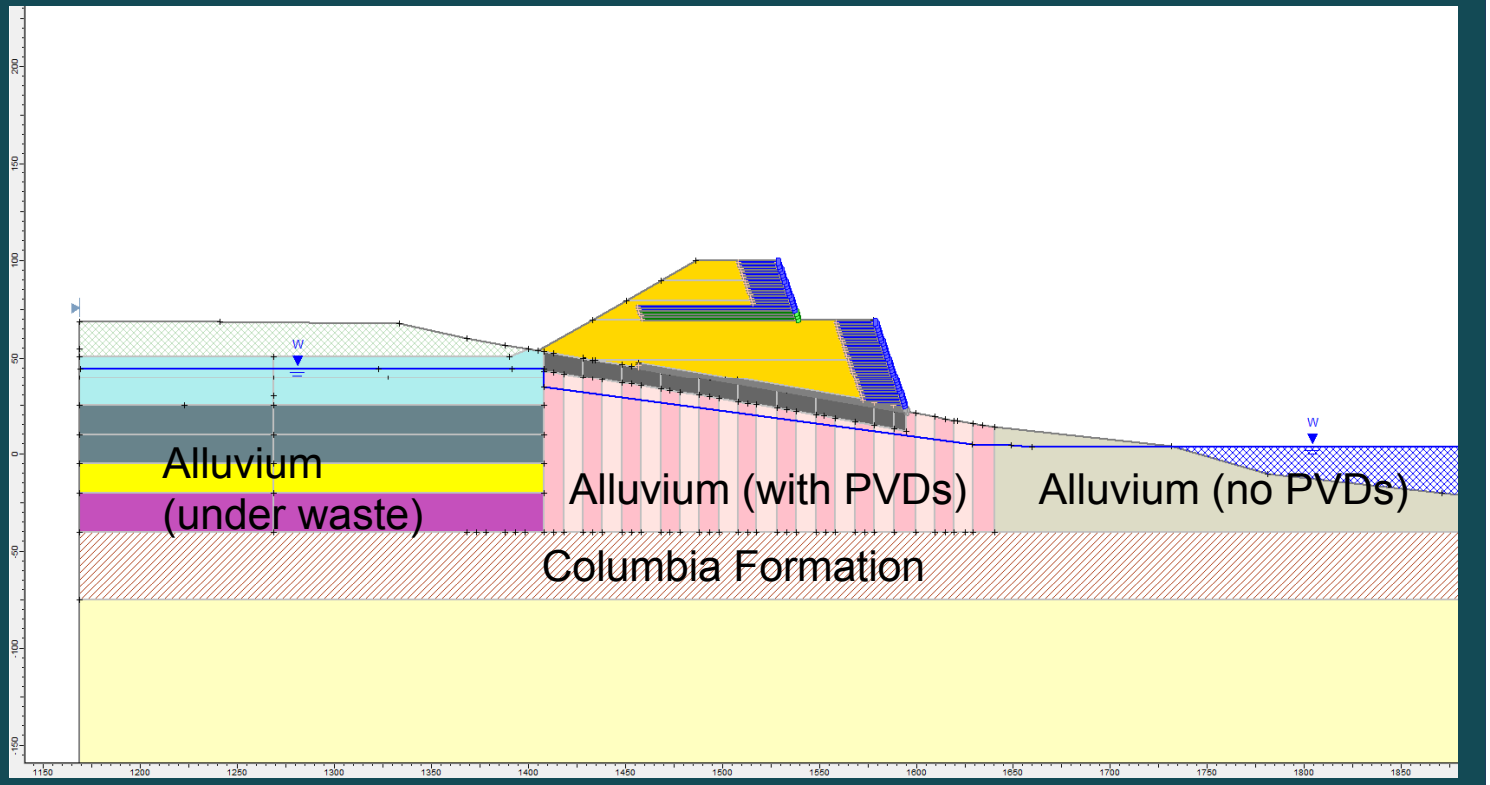
MSE Berm Design



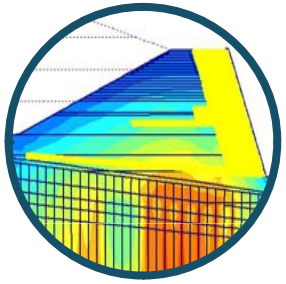
- Short Term Conditions (FS>1.3)
- Dredge/alluvium with PVDs modeled as hybrid drained-undrained soil (i.e., 50% drained, 50% undrained)
- Calculate pore pressure
- Geometry and Reinforcement calculated using SLIDE

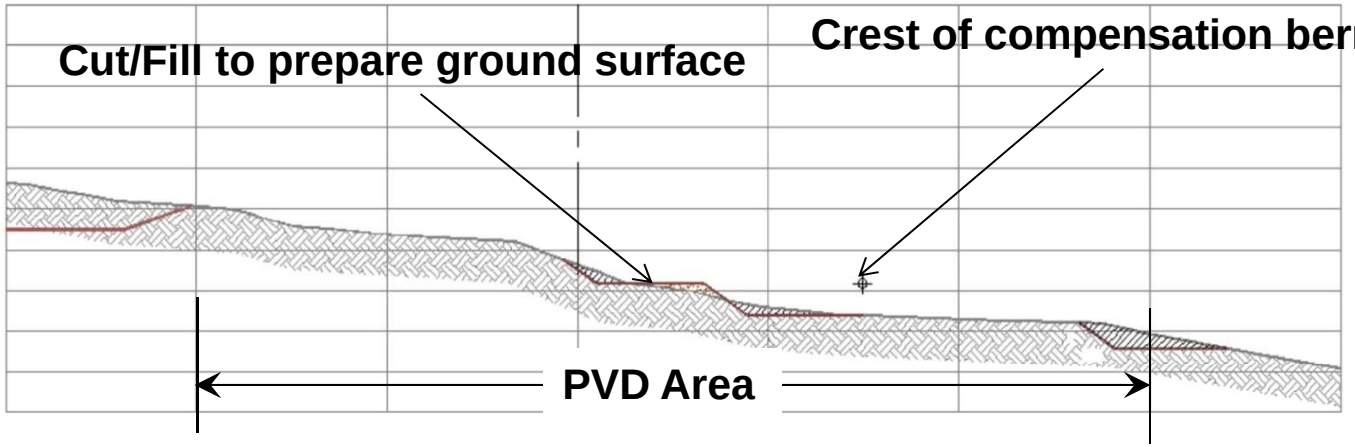
MODEL IMPLEMENTATION IN SLIDE



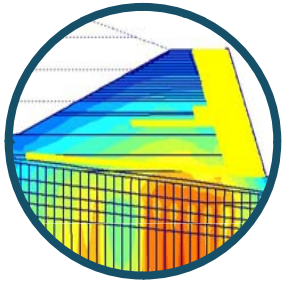


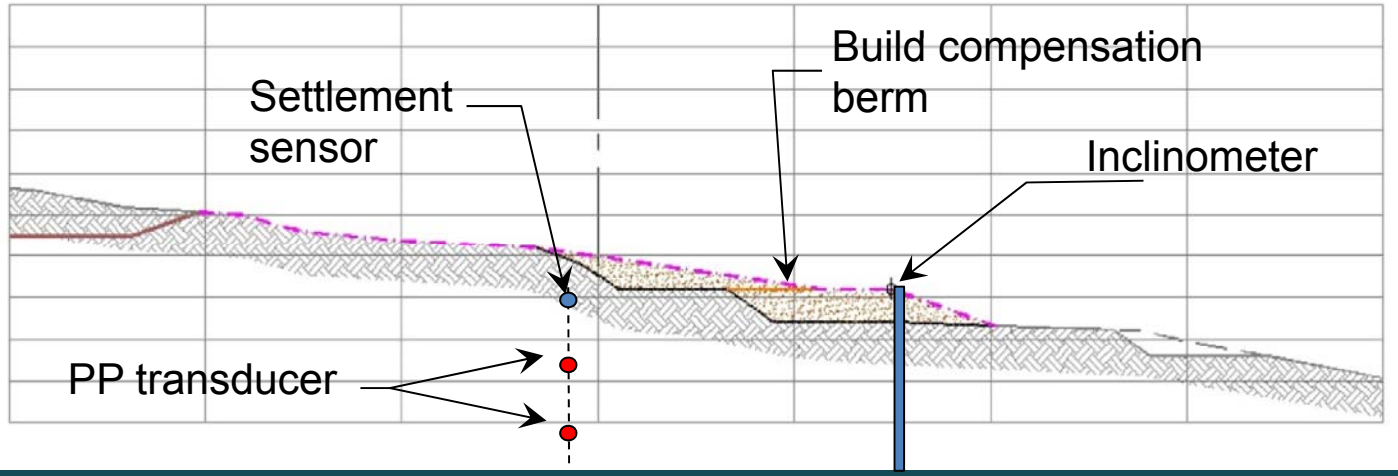
PREP SUBGRADE FOR PVD INSTALLATION



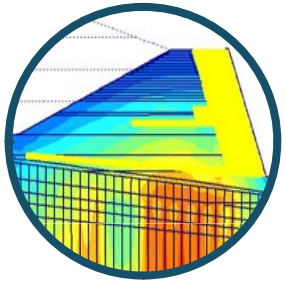


BUILD SETTLEMENT COMPENSATION BERM

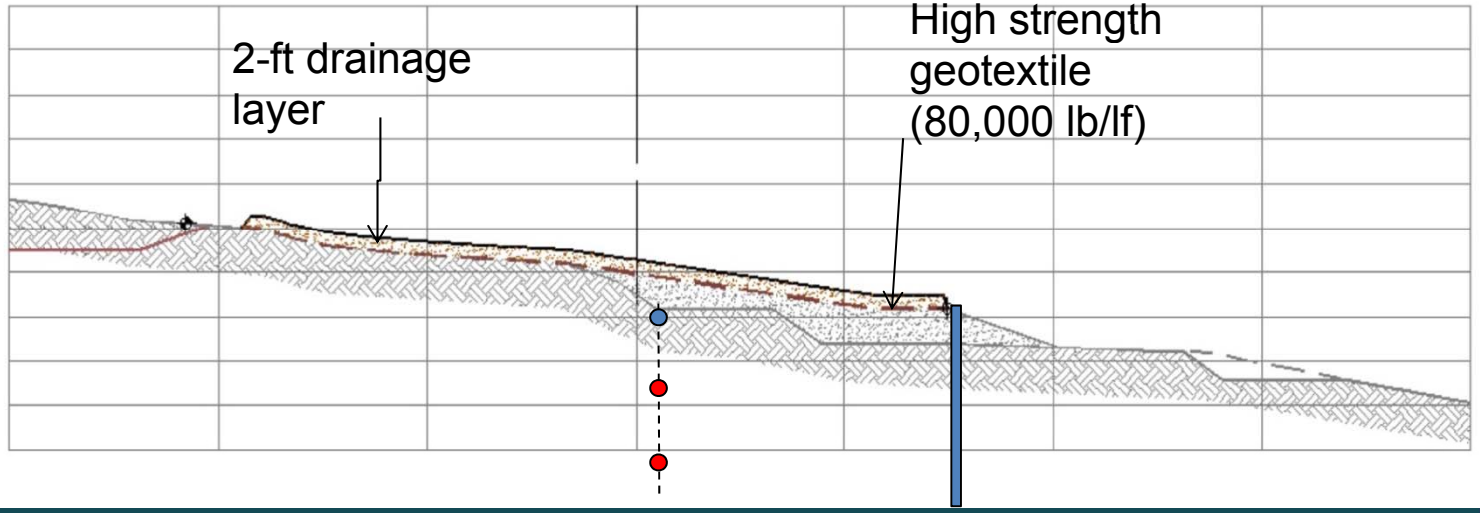




BUILD BASE OF MSE BERM

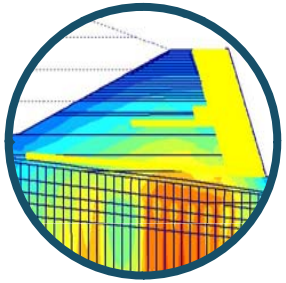


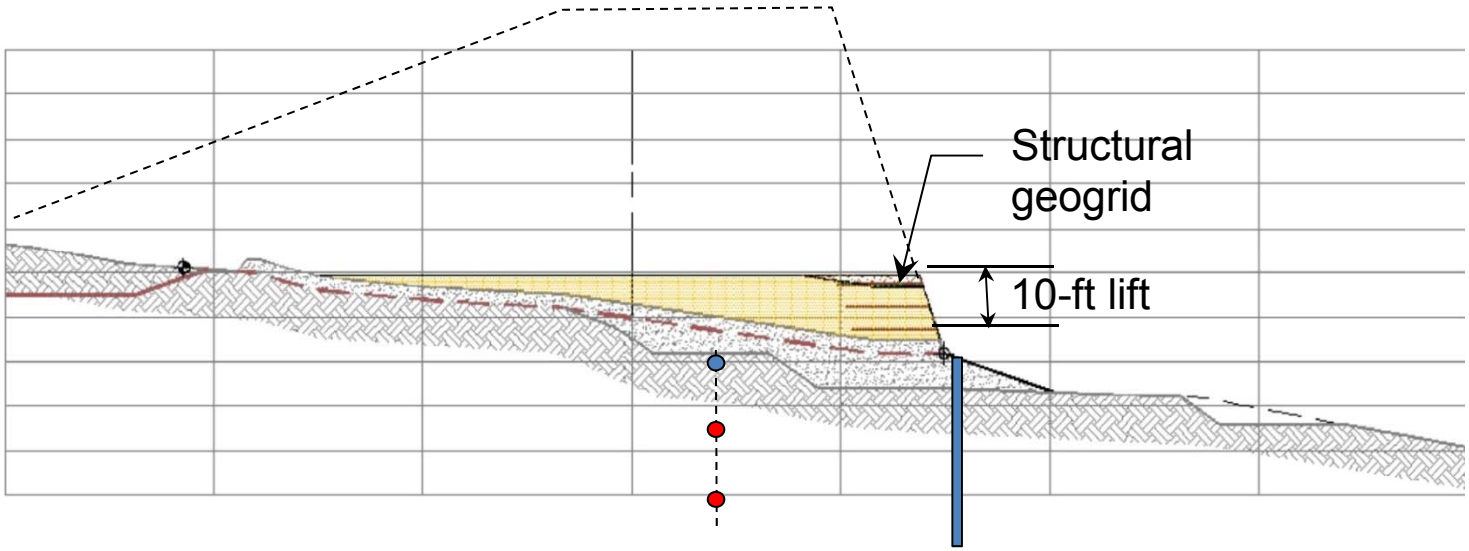
- Install high strength geotextile (140-ft long) followed by a drainage layer



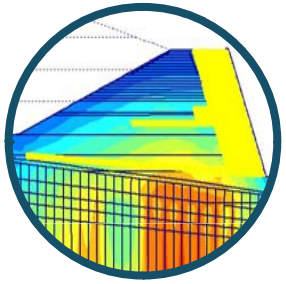
STAGED CONSTRUCTION OF MSE BERM

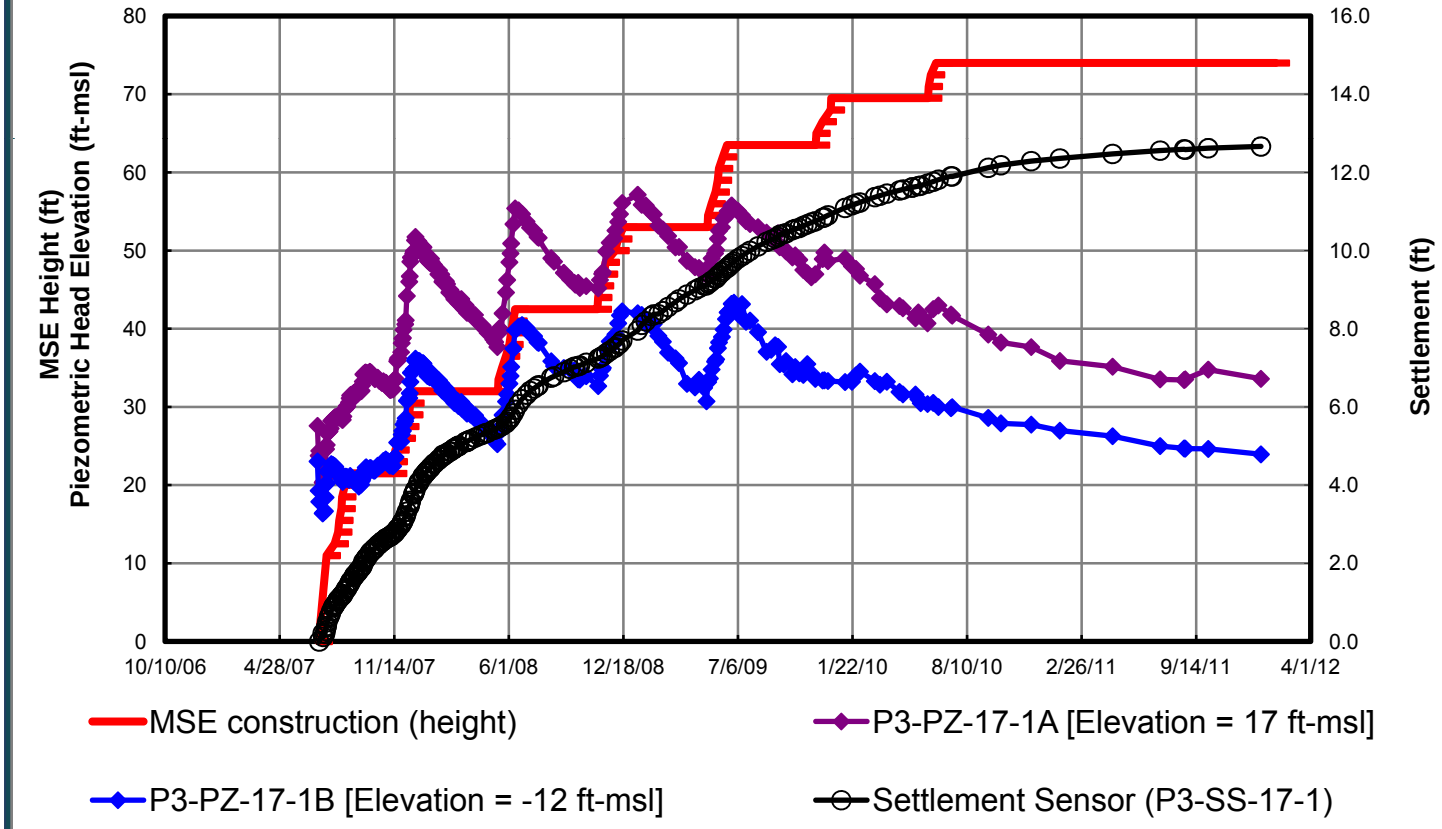
- Build MSE berm in 10-ft high lifts
- Monitor geotechnical instruments



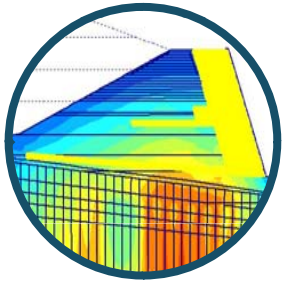


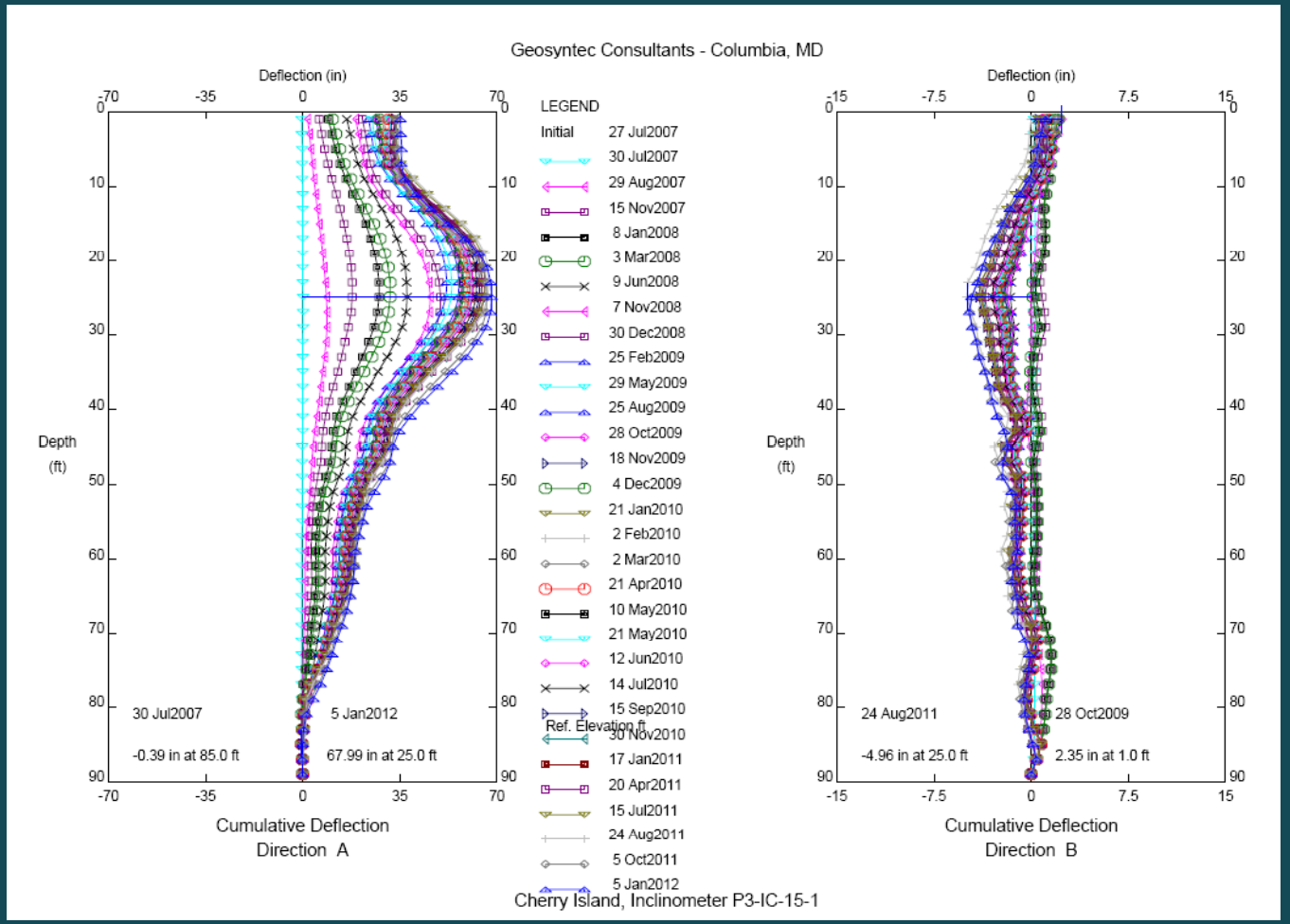
Monitoring During Construction



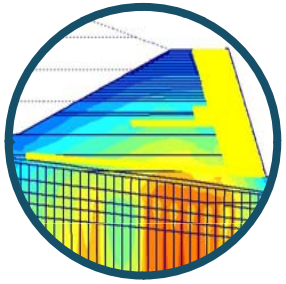


FEM & Monitoring During Construction





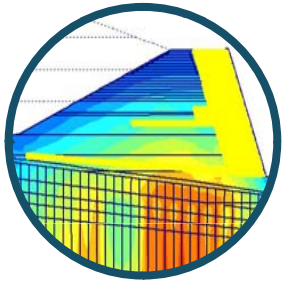
MSE Berm Construction

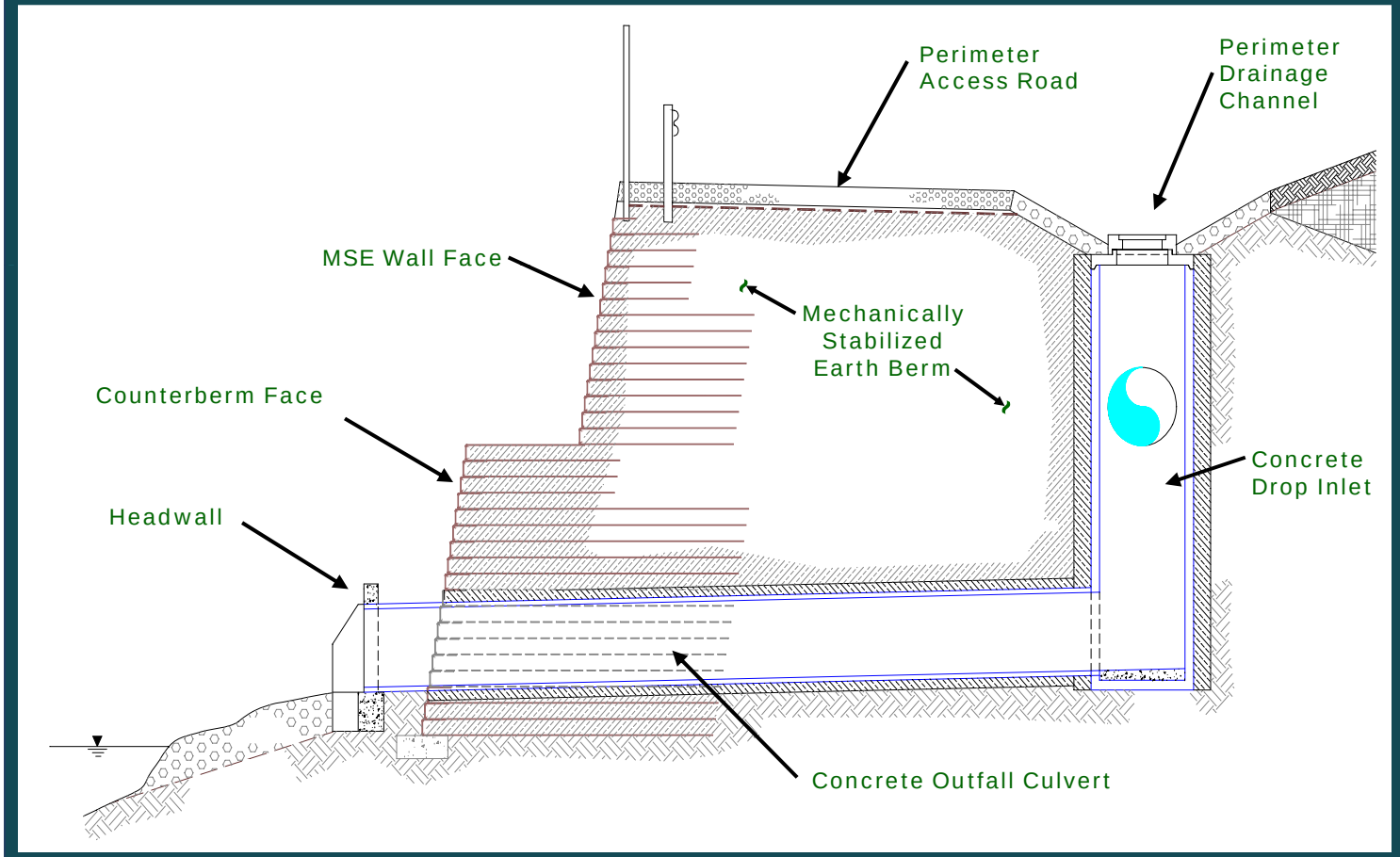


Other topics of concern:

- Coordinating geotechnical review with construction
- Helping the contractor understand the implications of settlement on construction and measurements
- Stormwater control
  - MSE berm fill is very erodible
- Concrete pipe supply

MSE Berm Construction
Permanent Stormwater





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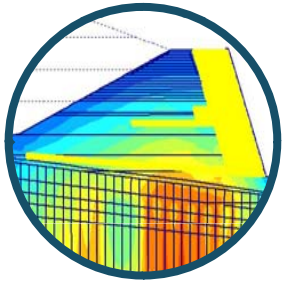

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MSE Berm Construction

Concrete Pipe Installation

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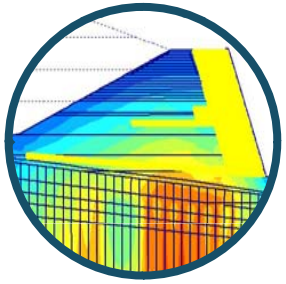

STGEC 2012

MSE Berm Construction

Mirafi 20 XT geogrid

Mirafi Mesh facing

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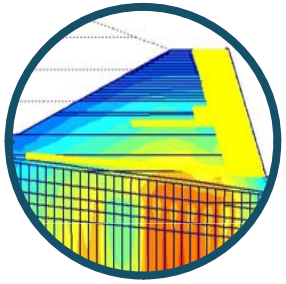
MSE Berm Construction



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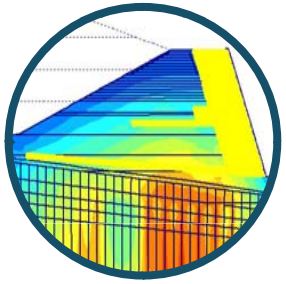

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CONCLUSIONS

- Basics
- Subsurface Information
  - Key to project success
- Understanding of analytical tools strengths/shortcomings
- FEM model and Field Monitoring
  - Predictions allowed faster construction
  - Response guided decisions
- Communication
  - Client, contractor, engineer
- Engineering and Onsite CQA - $10 million
- Construction - $96 million

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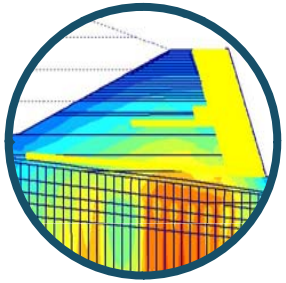

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CONCLUSIONS

- $ 11 million foundation improvement

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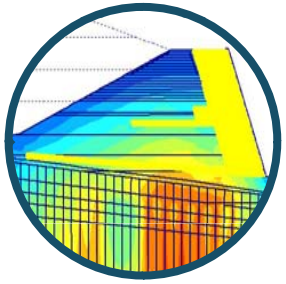

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QUESTIONS ?