

Floodwall and Levee Performance Analysis, Physical Modeling



SCOTT STEEDMAN



Rensselaer



Physical Modeling Team



Michael K. Sharp, PhD, PE
Wipawi Vanadit-Ellis, MS
Wayne Hodo
Henry Blake
David Daily
Dave Carnell



Prof Tarek H. Abdoun, PhD
Prof Thomas F. Zimmie, PhD, PE
Inthuorn Sasanakul, PhD
Javier Ubilla, MS
Marcelo Gonzalez, MS
Hassan Radwan
Alex Sankovich
Dominic Moffitt

SCOTT STEEDMAN

R. Scott Steedman, PhD FREng FICE
Kevin Stone, PhD



Prof Dr Ir Frans Barends
Paul Schaminée, MSc
Adam Bezuijen, MSc



SCOTT STEEDMAN



Physical (Centrifuge) Modeling

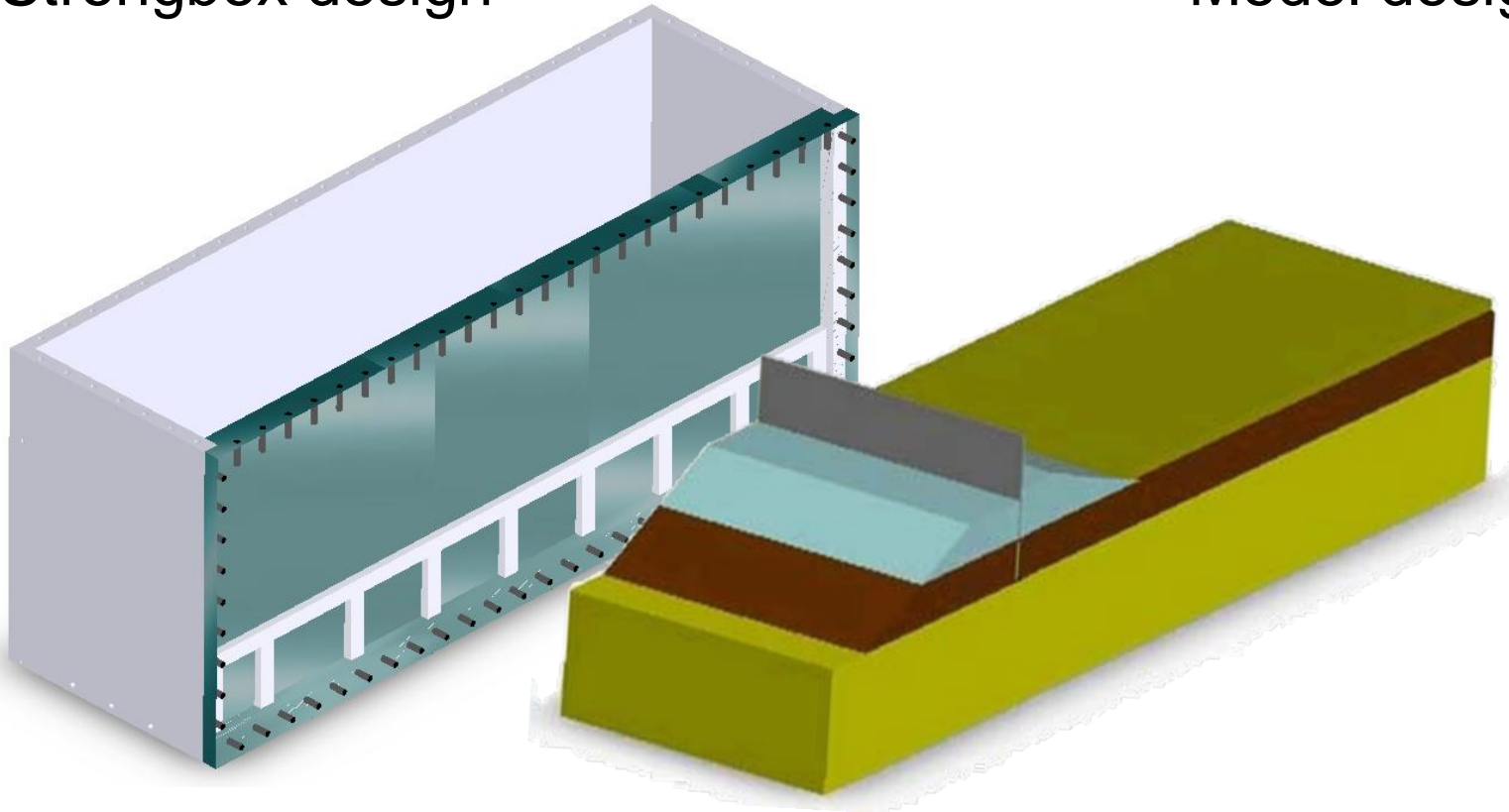
Work Plan

- Use workshops to develop model concept, model design and technical approach ✓
- Obtain block samples of peat layer, test ✓
- Specify materials (clay, sand, flood wall) ✓
- Finalize trial model sections ✓
- Carry out trial models of London North, 17th Street ✓
- Evaluate results from trials and refine plan ←
- Complete full series of model tests, collate and present photo and instrumental data for comparison with numerical modeling

Simulation of Field Conditions

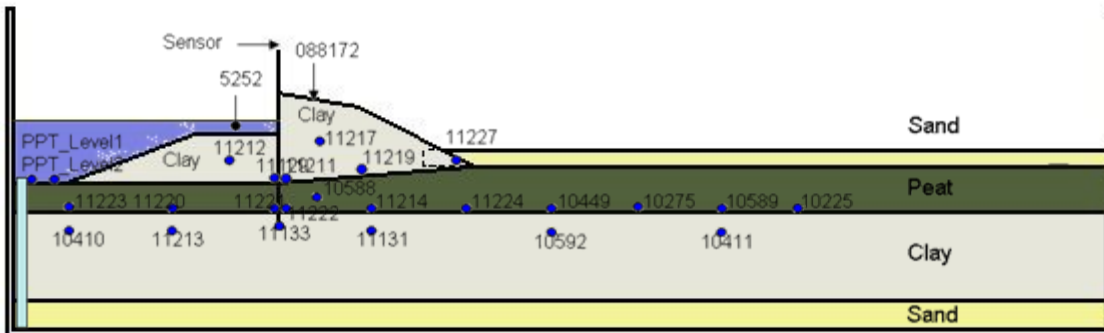
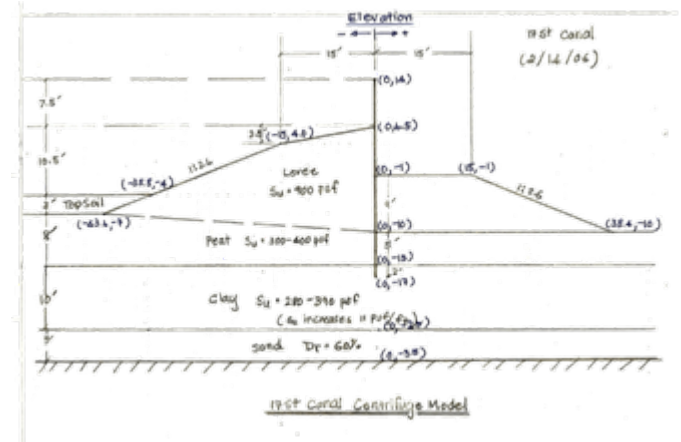
- Strongbox design

- Model design



Design Considerations

- Geometry of the model – soil profile and details of the levee
- Establishing initial conditions
- Instrumentation techniques
- Flood conditions



Material Considerations



- Sand – use a fine Nevada sand, a widely used laboratory sand



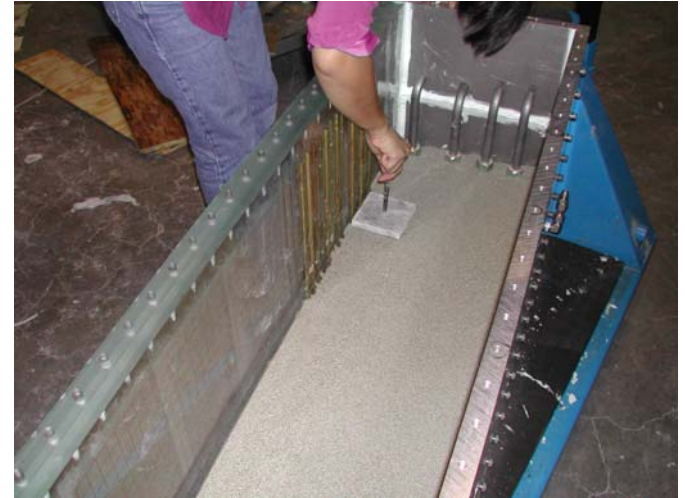
- Flood wall – use steel or aluminium plate, circa 1/4" thick at 1/50 scale



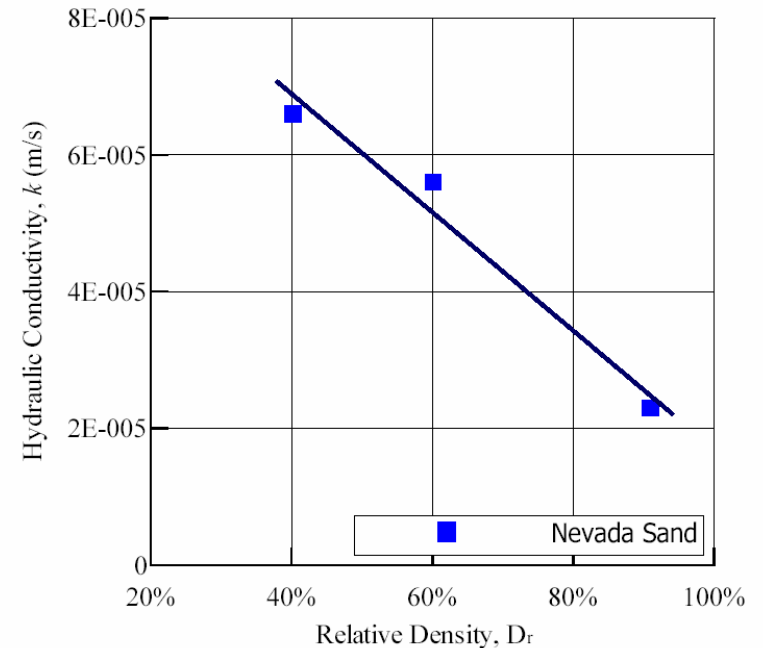
- Peat – use peat cut from block samples recovered from the site
- Clay – use a laboratory kaolin clay, consolidated to the correct strength profile

Sand

- Key material parameters are relative density and permeability



D_{10}	0.08 mm
D_{50}	0.15 mm
Specific gravity, G_s	2.67
Max. void ratio, e_{max}	0.887
Min. void ratio, e_{min}	0.511
Max. dry density	17.33 kN/m ³
Min. dry density	13.87 kN/m ³



Flood wall

- Use solid plate, in aluminium or steel

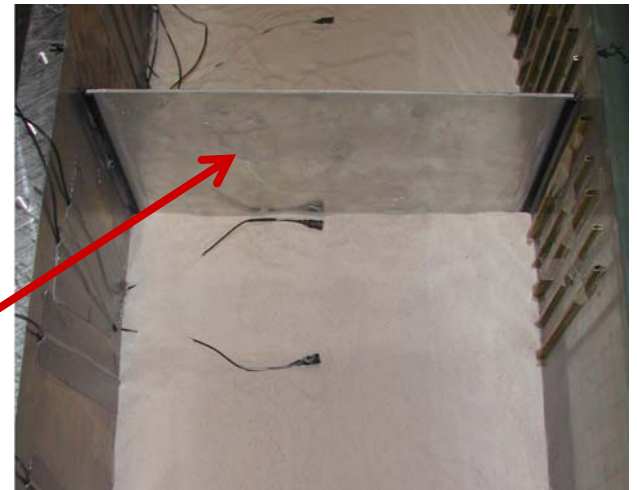
Scaling bending stiffness gives:

$$(EI)_{\text{model}} = (EI)_{\text{field}}/N^3$$

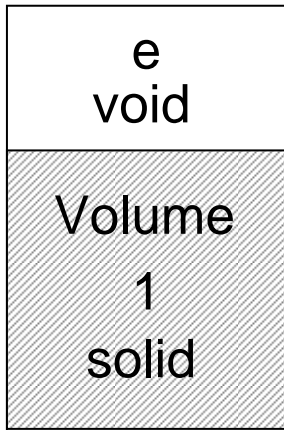
$$N^3 \cdot E_m \cdot d_m^3 / 12 = (EI)_f$$

Sheet piles in the field (Hoesch 12) have $I = 65.4 \text{ in}^4$, hence bending stiffness of $EI = 2 \times 10^9 \text{ psi}$

Model wall in aluminium at 1/50 scale is around $\frac{1}{4}$ " thick.



Initial Conditions for Kaolin

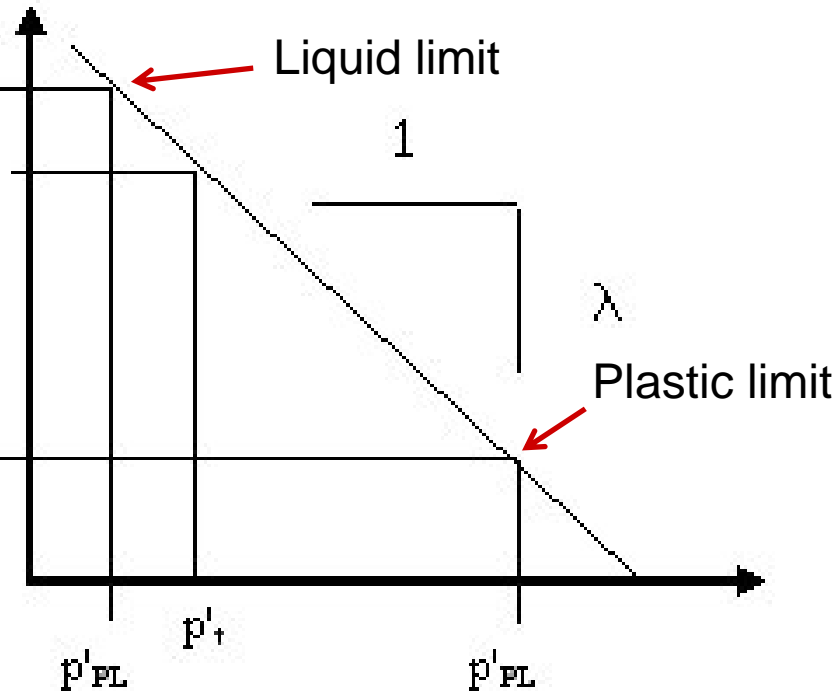


$$V_{LL} = 1 + e_{LL} = 1 + w_{LL} \cdot G_s = 2.5$$

V_{target}

Specific Volume V

$$V_{PL} = 1 + e_{PL} = 1 + w_{PL} \cdot G_s = 1.7$$



Exploiting the Volume – Log p' relationship:

$$p'_{PL} / p'_t = (Su)_{PL} / (Su)_t = \exp [(V_{target} - V_{PL}) / \lambda]$$

effective confining pressure p'

Based on knowledge of the undrained strength S_u :

Undrained strength at Liquid limit $(Su)_{LL} = 1.7 \text{ kPa}$

Undrained strength at Plastic limit $(Su)_{PL} = 170 \text{ kPa}$

Peat

- Cut from block samples excavated from the field
- Key properties strength, stiffness and permeability
- Re-consolidated to original conditions in centrifuge flight



Floodwall and Levee Performance Analysis, Physical Modeling

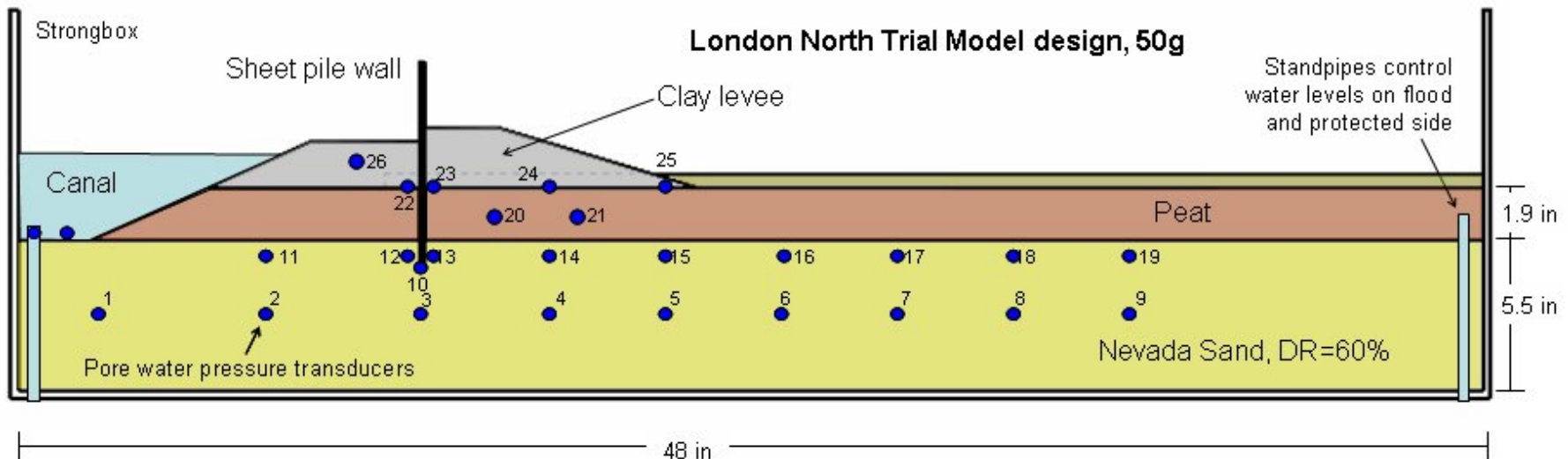
Model Preparation and Preliminary Results

Presentation Outline

- London North Model
 - Model Preparation
 - Preliminary Results
 - Preliminary Observations
- 17th Street
 - Model Preparation
 - Preliminary Results
 - Preliminary Observations

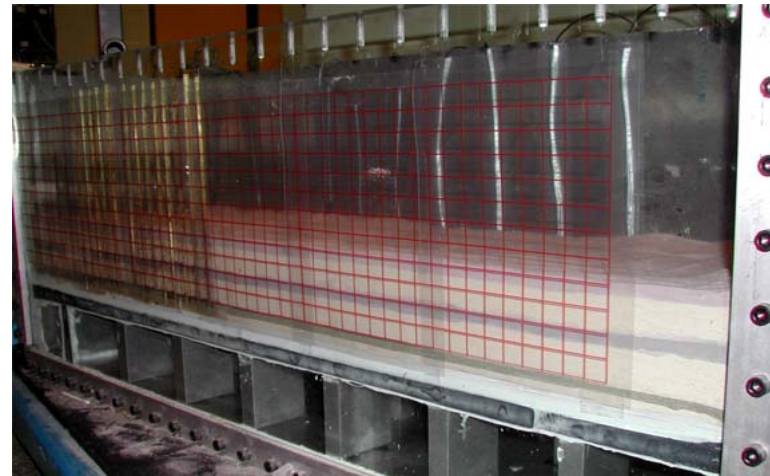
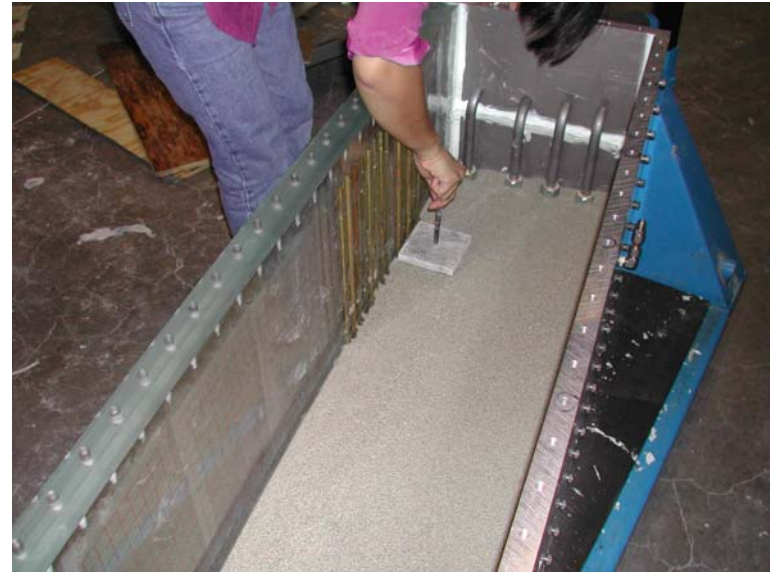
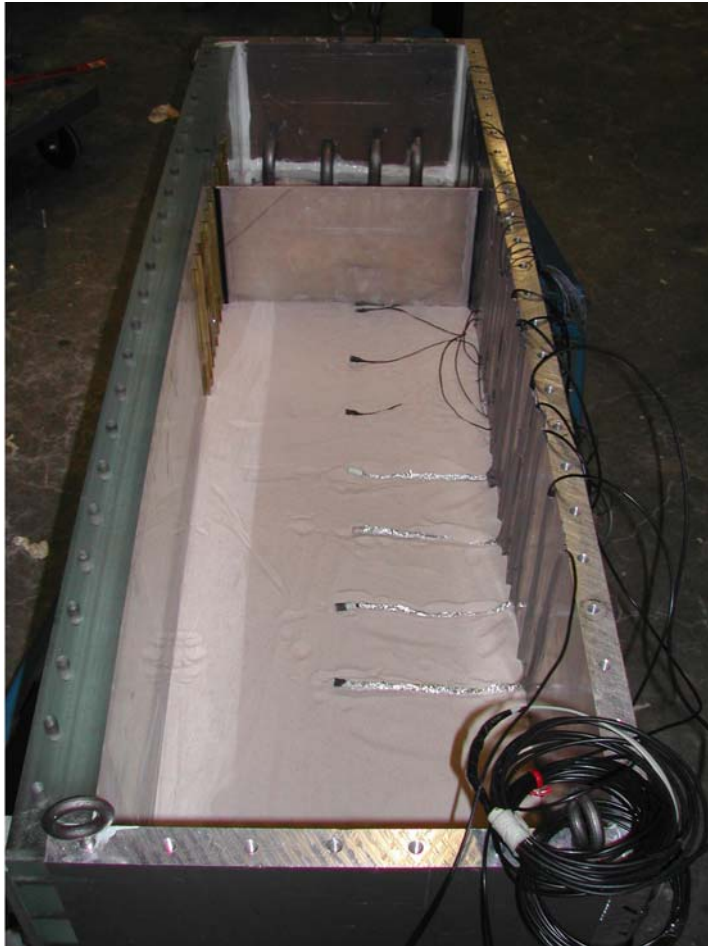
London North: Model Preparation

- Two trial models were tested one model at each facility (RPI & ERDC)
- Levee: Synthetic clay (match field conditions based on lab test, CPT, etc)
- Swamp/Marsh: Actual field material
- Beach: Fine sand such as Nevada Sand



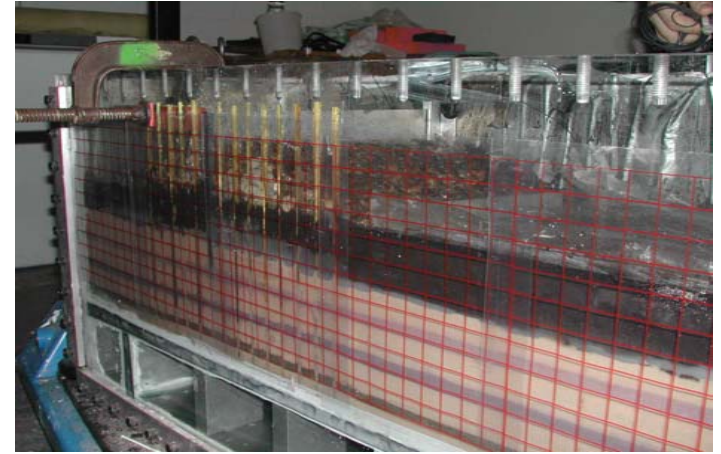
London North: Model Preparation

Sand Placement

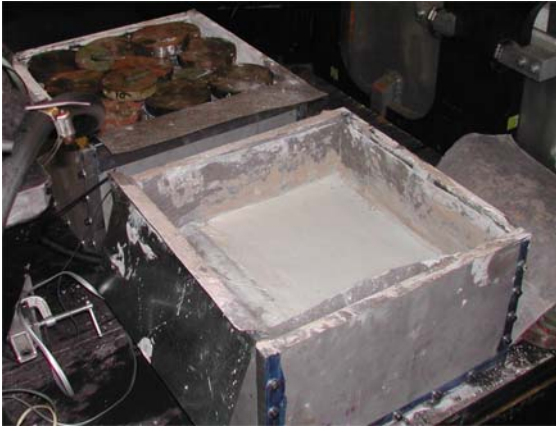


London North: Model Preparation

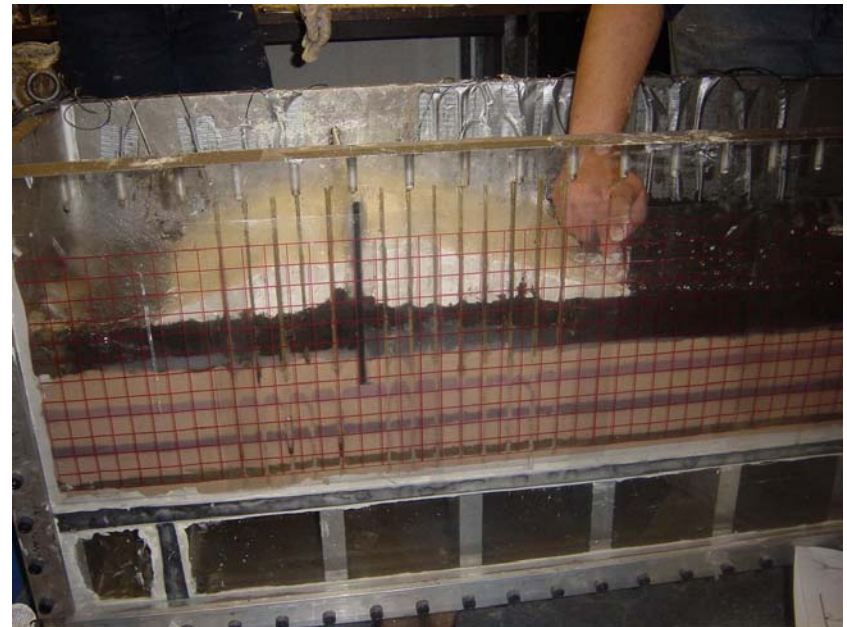
Peat Placement



London North: Model Preparation



Clay Levee Placement



London North: Preliminary Results

New Orleans Levee Centrifuge Models
London North Test



Rensselaer Polytechnic Institute
CEES Center

<http://nees.rpi.edu/>

London North: Preliminary Results

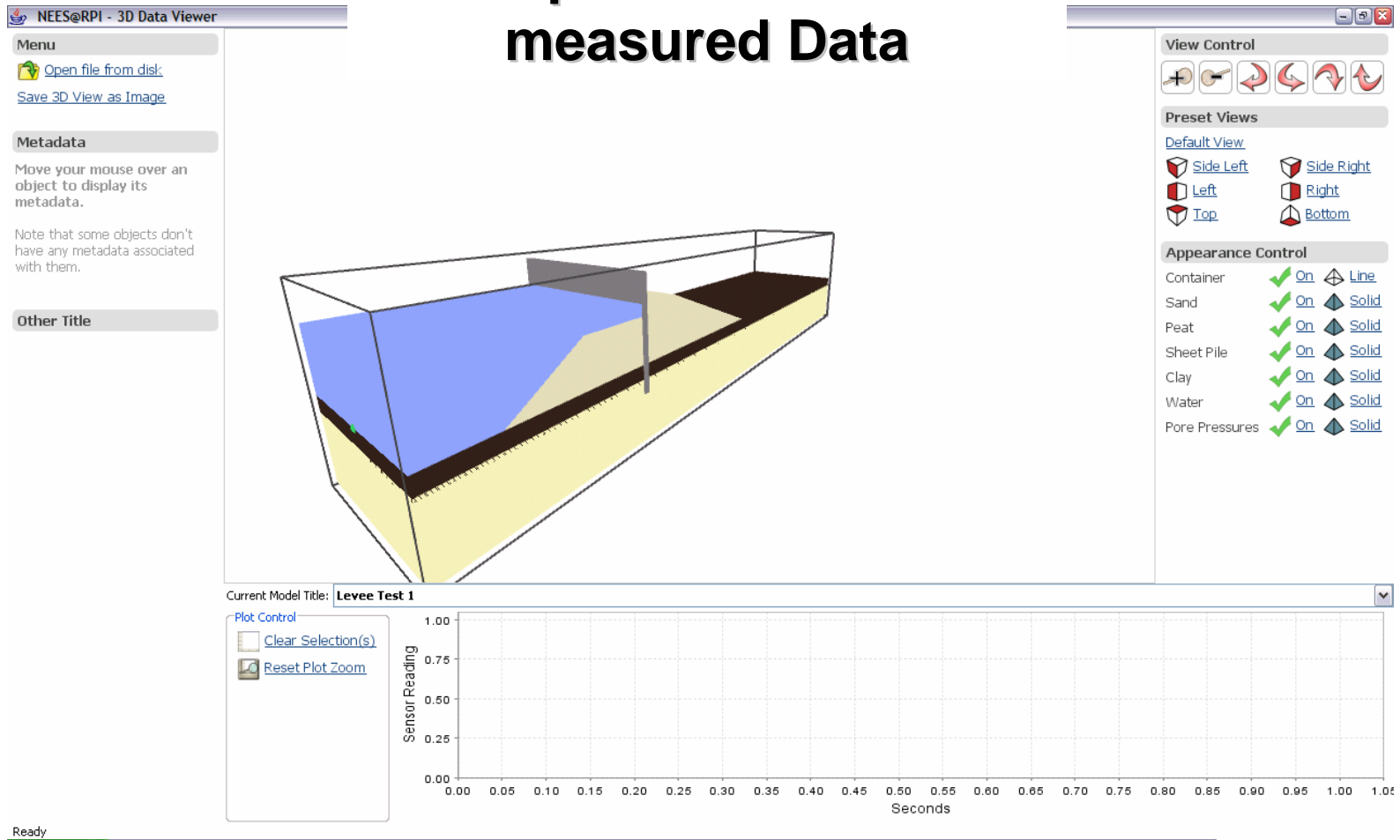
New Orleans Levee Centrifuge Models
London North Test



US Army
Engineer Research and Development Center

London North: Preliminary Results

3D presentation of measured Data



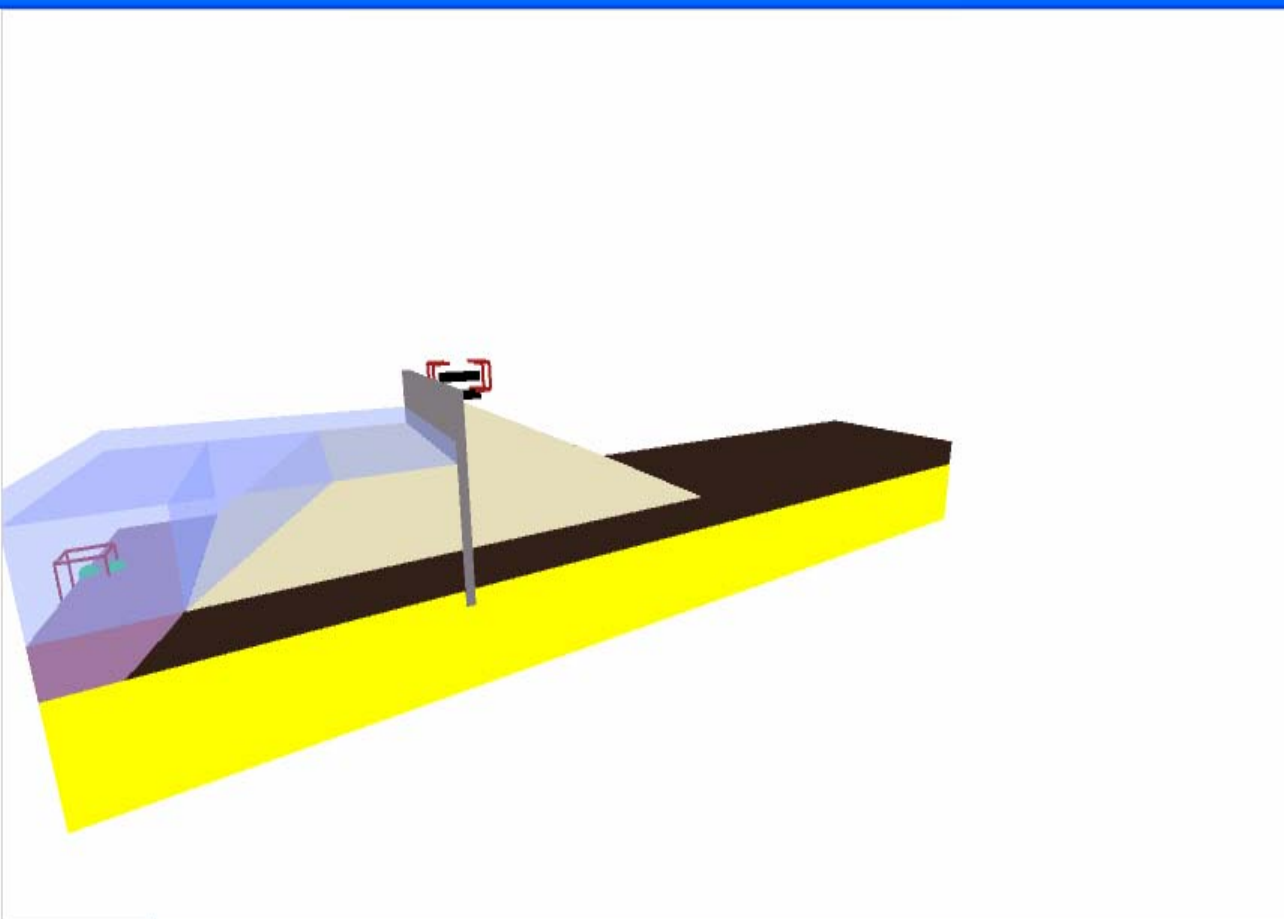
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

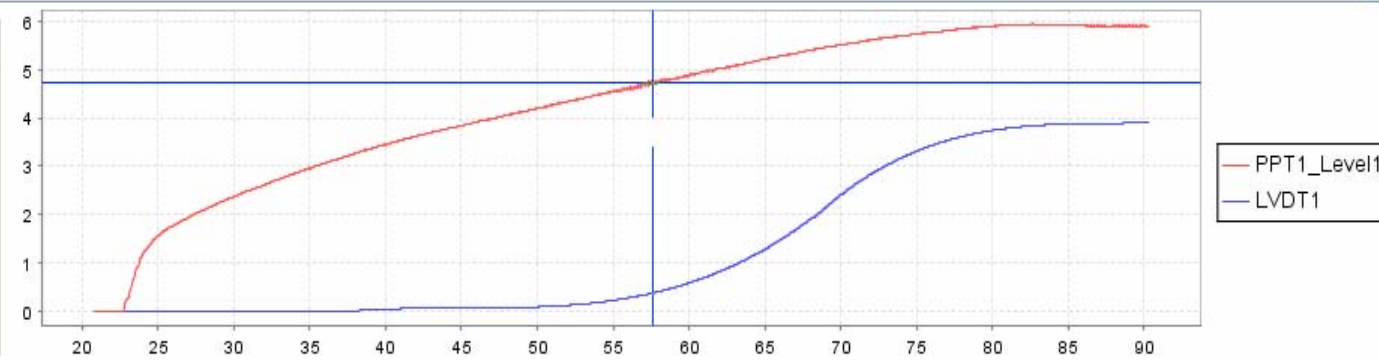
Appearance Control

- Sand: On Solid
- Peat: On Solid
- Gravel: On Solid
- Levee: On Solid
- Sheet Pile: On Solid
- Water: On Trans.
- LVDTs: On Solid
- Pore Pressures: On Solid
- Container: Off Line

Current Model Title: New Orleans Levee Tests - London North

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



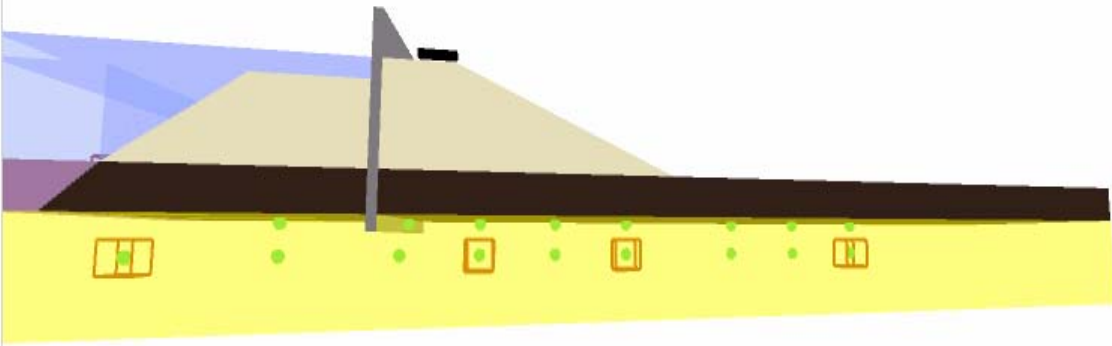
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

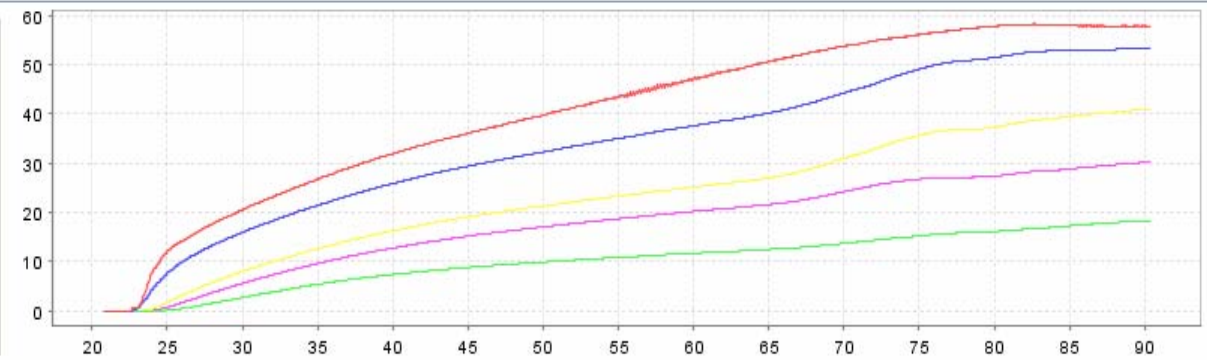
Appearance Control

- Sand: On, Trans.
- Peat: On, Solid
- Gravel: On, Solid
- Levee: On, Solid
- Sheet Pile: On, Solid
- Water: On, Trans.
- LVDTs: On, Solid
- Pore Pressures: On, Solid
- Container: Off, Line

Current Model Title: New Orleans Levee Tests - London North

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



Legend for Plot:

- PPT2_Level2
- 1
- 9
- 4
- 6

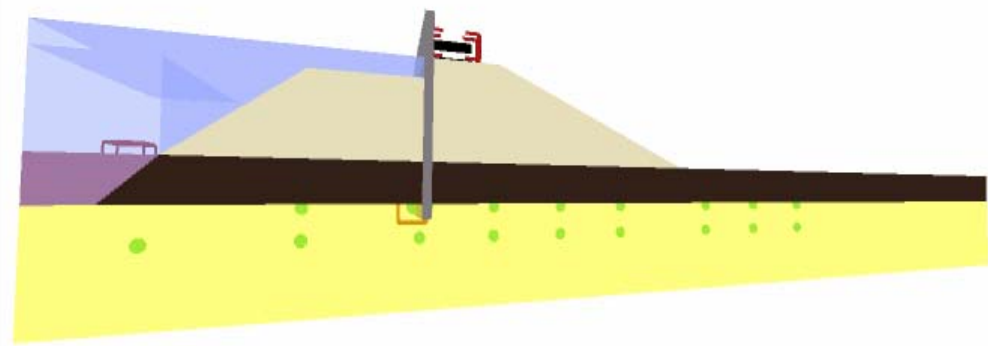
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

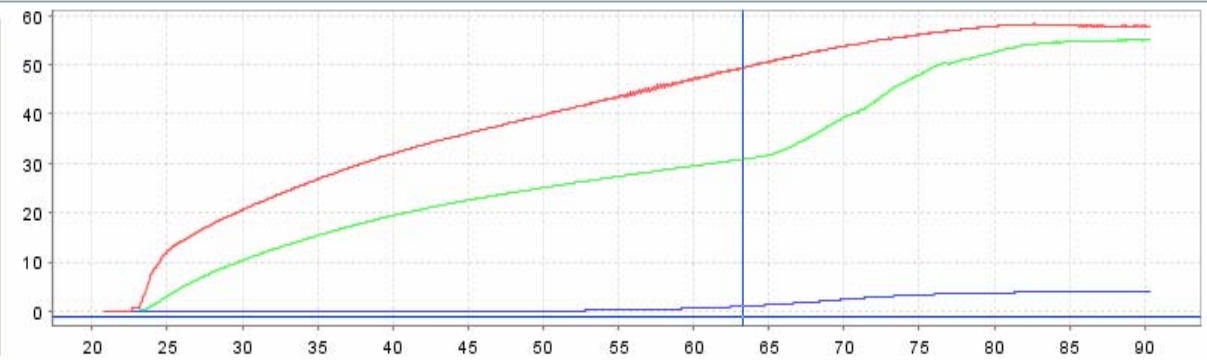
Appearance Control

- Sand: On Trans.
- Peat: On Solid
- Gravel: On Solid
- Levee: On Solid
- Sheet Pile: On Solid
- Water: On Trans.
- LVDTs: On Solid
- Pore Pressures: On Solid
- Container: Off Line

Current Model Title: **New Orleans Levee Tests - London North**

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



Legend:

- PPT2_Level2
- LVDT1
- 12

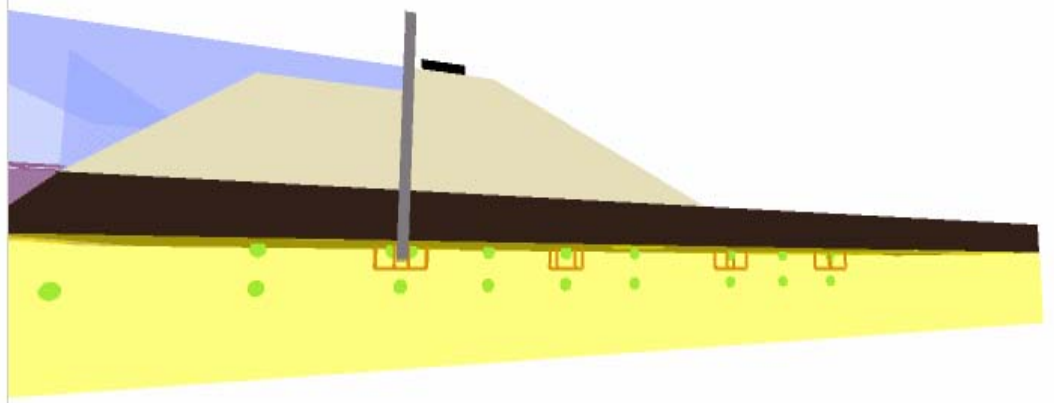
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

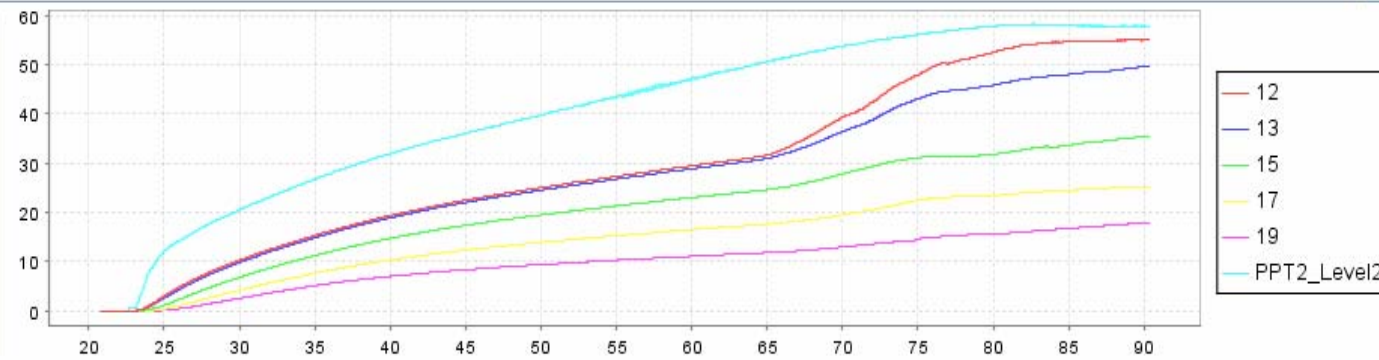
Appearance Control

- Sand: On, Trans.
- Peat: On, Solid
- Gravel: On, Solid
- Levee: On, Solid
- Sheet Pile: On, Solid
- Water: On, Trans.
- LVDTs: On, Solid
- Pore Pressures: On, Solid
- Container: Off, Line

Current Model Title: New Orleans Levee Tests - London North

Plot Control

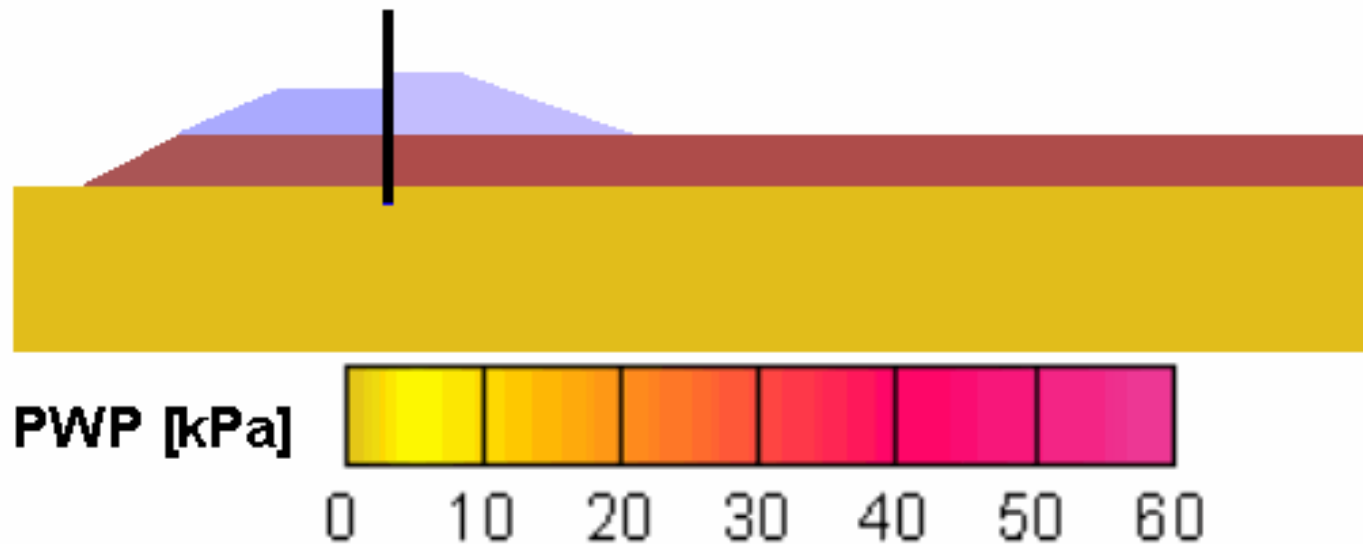
- Clear Selection(s)
- Reset Plot Zoom



London North: Preliminary Results

Frame 001 | 06 Mar 2006 | New Dataset

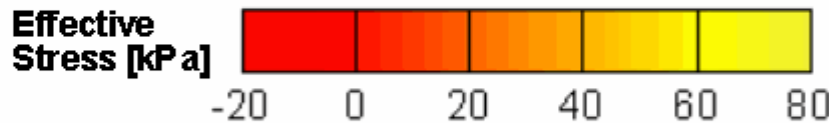
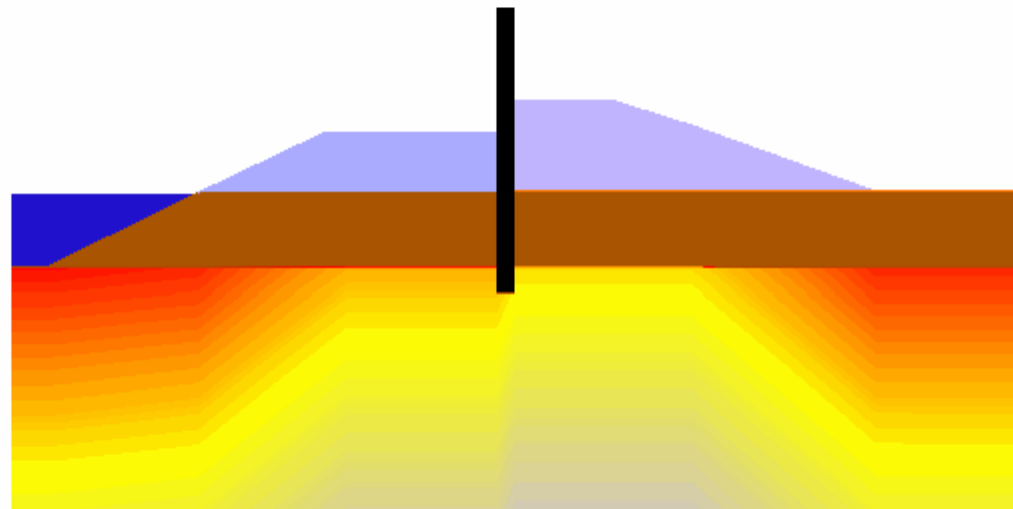
New Orleans Levees Project Physical Model of Failure at London North



London North: Preliminary Results

Frame 001 | 07 Mar 2006 | New Dataset

New Orleans Levees Project Physical Model of Failure at London North

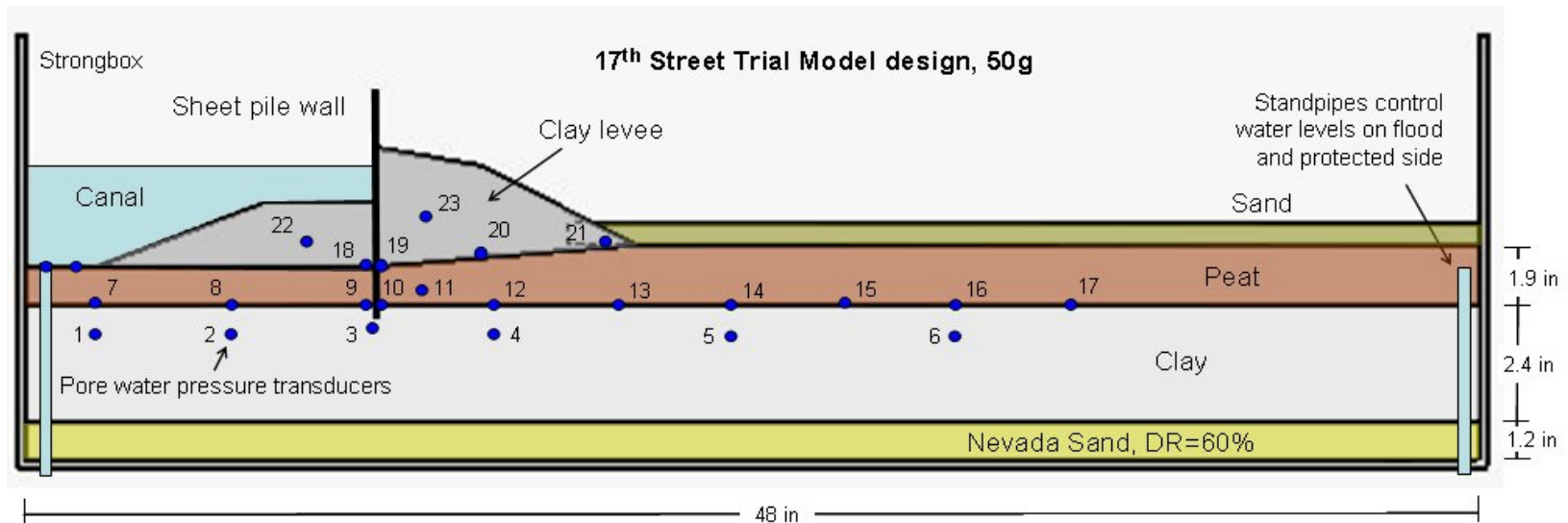


London North: Preliminary Observations

- Similar model responses are recorded in both the RPI & ERDC models confirming the repeatability of the physical models.
- As the water level rose to flood levels, a crack formed down the front of the wall.
- Failure of the wall is associated with an increase in the hydrostatic pressure (uplift) under the downstream levee.

17th Street: Model Preparation

- One trial model was tested at RPI. A second model is under construction at ERDC
- Levee: Synthetic clay (match field conditions based on lab test, CPT, etc)
- Swamp/Marsh: Actual field material
- Lacustrine: Synthetic clay (match field conditions)
- Beach: Fine sand such as Nevada Sand



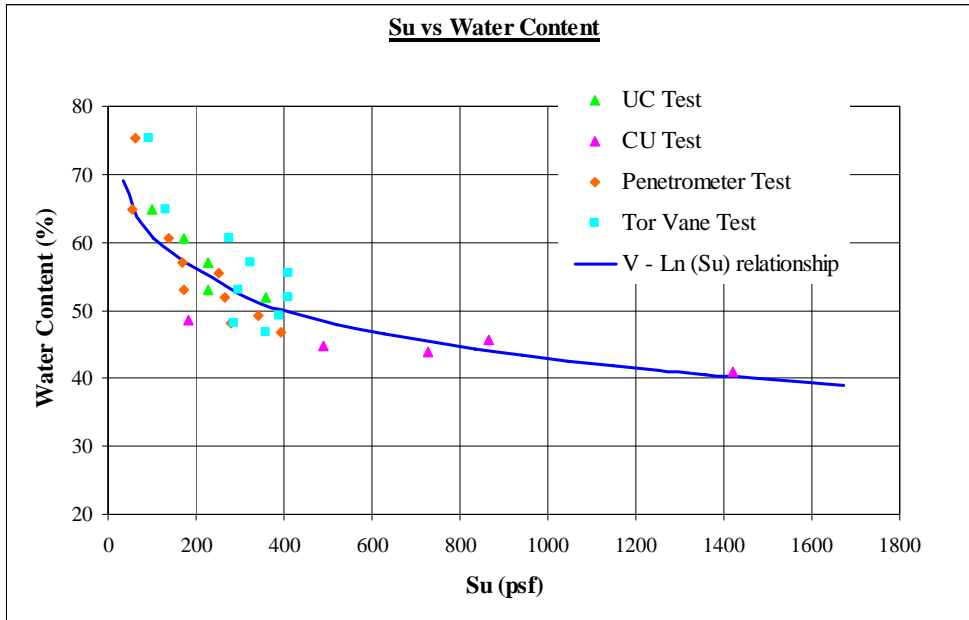
17th Street: Model Preparation

Clay Placement



17th Street: Model Preparation

Clay Placement



Shear Strength Estimation of Clay Layer @17th street

Location	Water Content (%)	Estimate S_u (kPa)	Estimate S_u (psf)
Surface (after Consol.)	75	3-5	70-110
Surface (after Testing)	64	5-7	110-140
Middle (after Testing)	59	9-12	200-250
Bottom (after Testing)	57	12-15	250-310

17th Street: Model Preparation

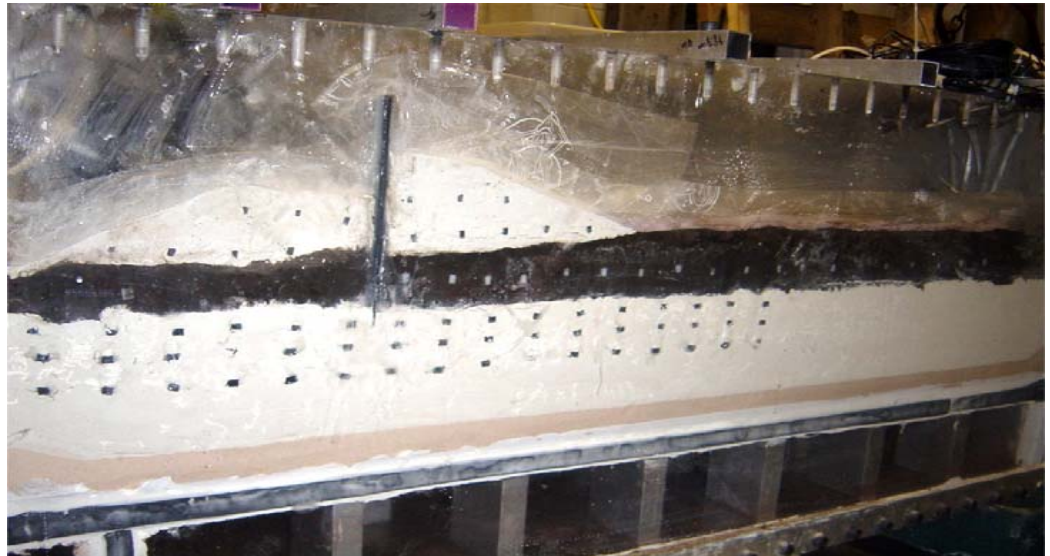
Peat Placement



17th Street: Model Preparation



Clay Levee Placement



17th Street: Preliminary Results

New Orleans Levee Centrifuge Models
17th Street Test

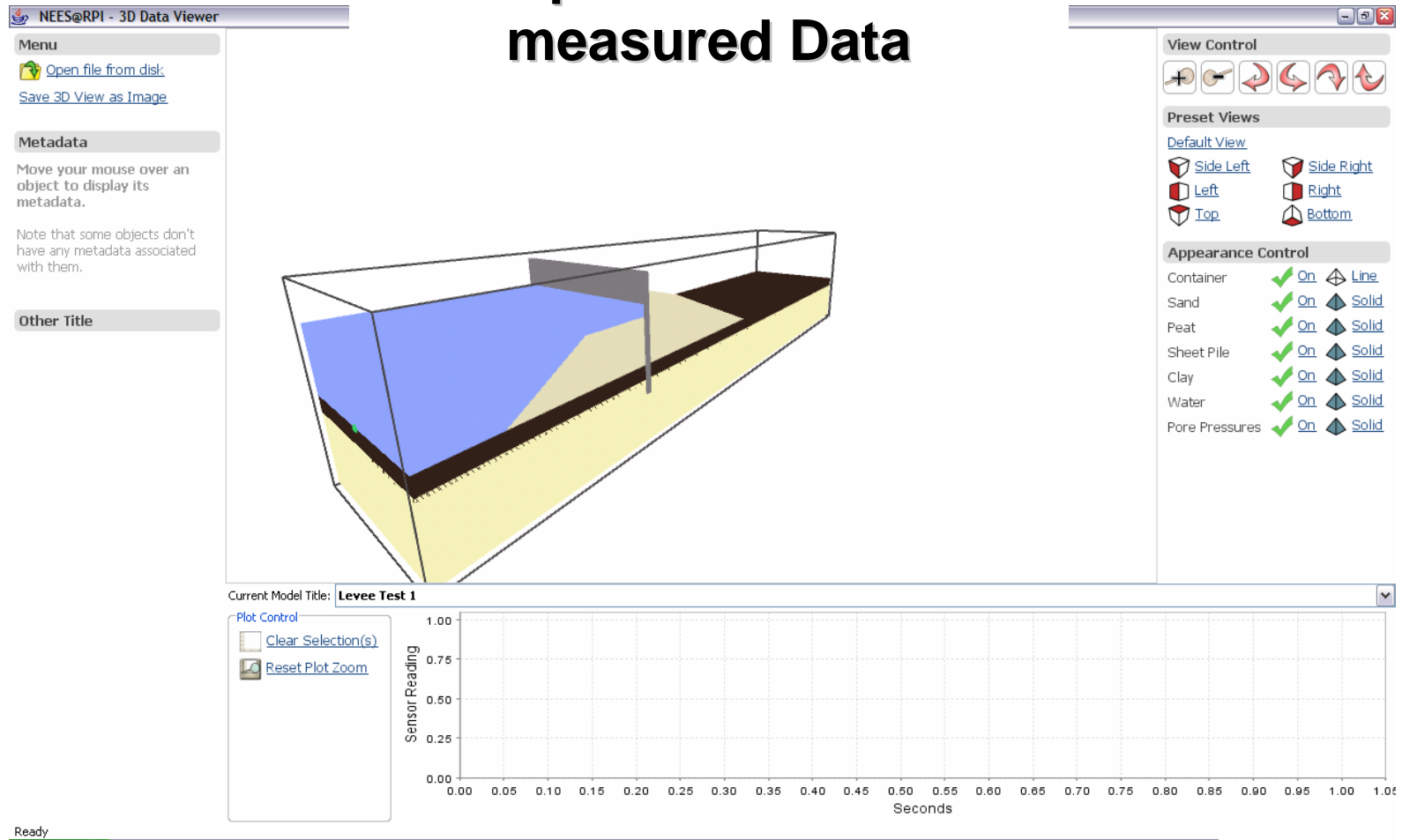


Rensselaer Polytechnic Institute
CEES Center

<http://nees.rpi.edu/>

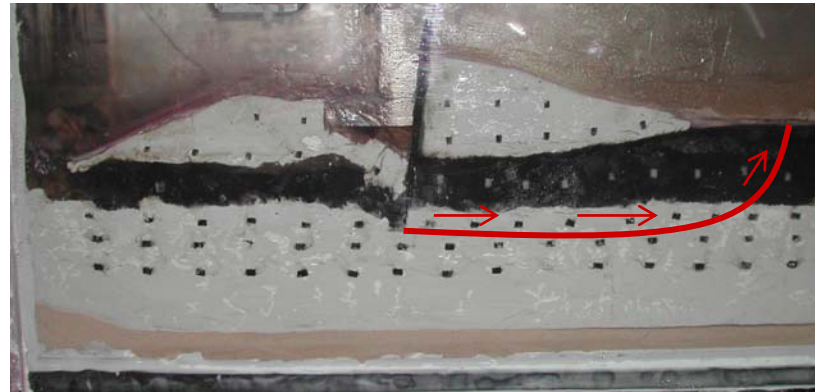
17th Street: Preliminary Results

3D presentation of measured Data



17th Street: Preliminary Observations

- The wall experienced limited tilt and limited increase in the hydrostatic pressure under the downstream levee.
- Shear failure occurred in the clay layer comparable to the field observation.



Future Plans

- To fully understand the failure mechanisms
- To integrate the physical model results with the overall performance assessment of the levees
- Provide practical insights to Task Force Guardian

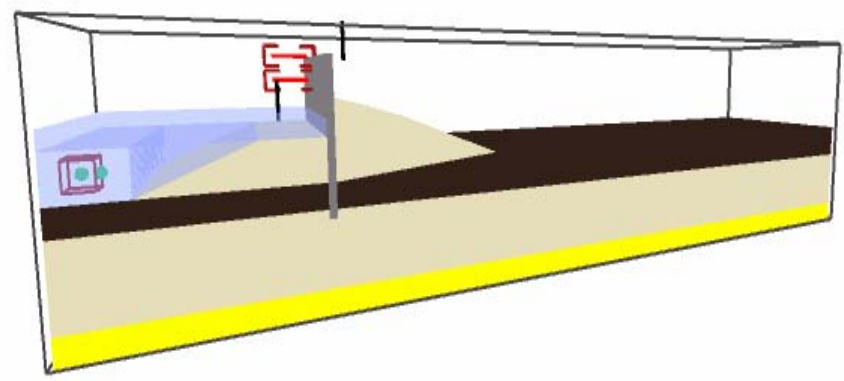
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

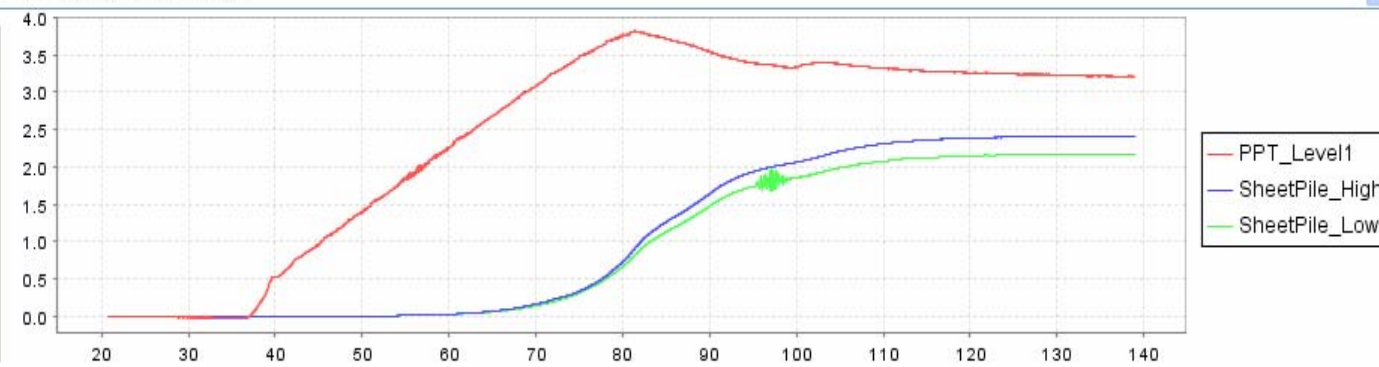
Appearance Control

- Sand On Solid
- Clay On Solid
- Peat On Solid
- Levee On Solid
- Sheet Pile On Solid
- Water On Trans.
- LVDTs On Solid
- Lasers On Solid
- Pore Pressures On Solid
- Container On Line

Current Model Title: **New Orleans Levee Tests - 17th Street**

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



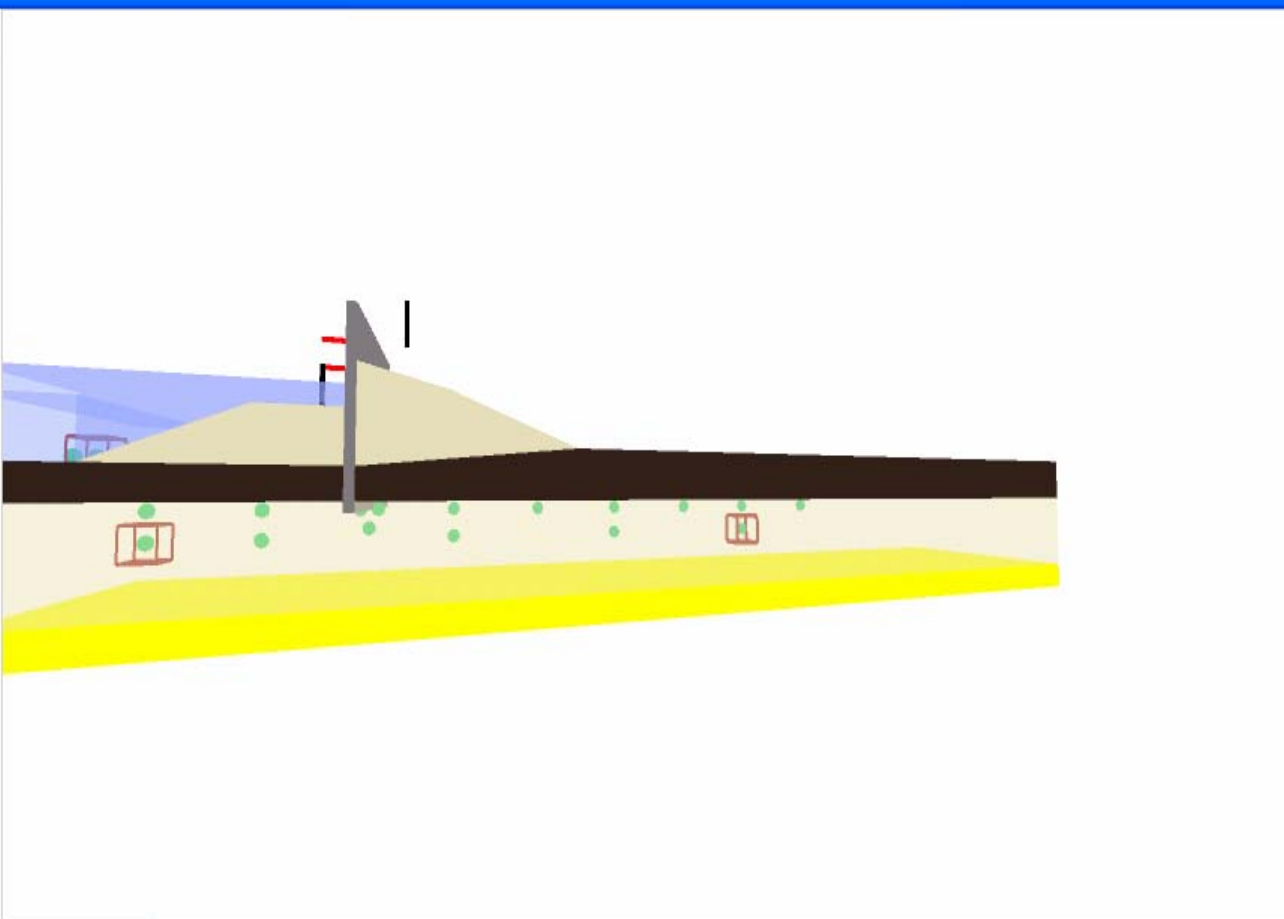
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

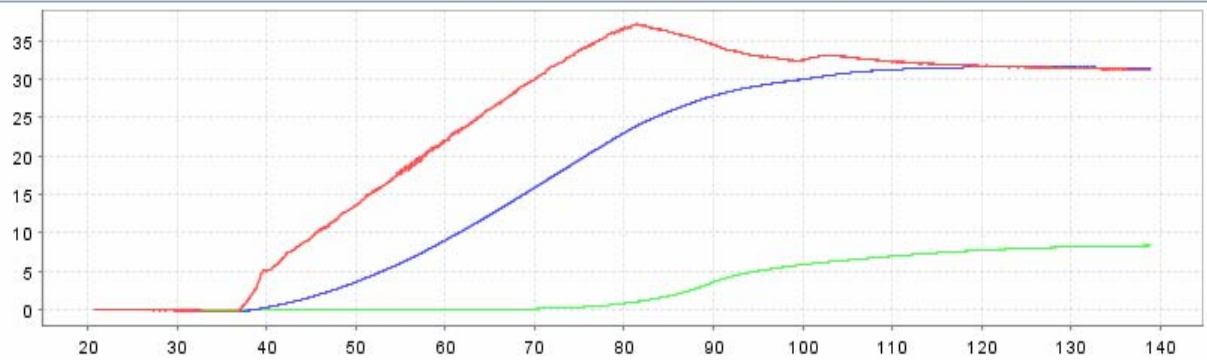
Appearance Control

- Sand: On Solid
- Clay: On Trans.
- Peat: On Solid
- Levee: On Solid
- Sheet Pile: On Solid
- Water: On Trans.
- LVDTs: On Solid
- Lasers: On Solid
- Pore Pressures: On Solid
- Container: Off Line

Current Model Title: New Orleans Levee Tests - 17th Street

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



- PPT_Level2
- PPT1
- PPT6

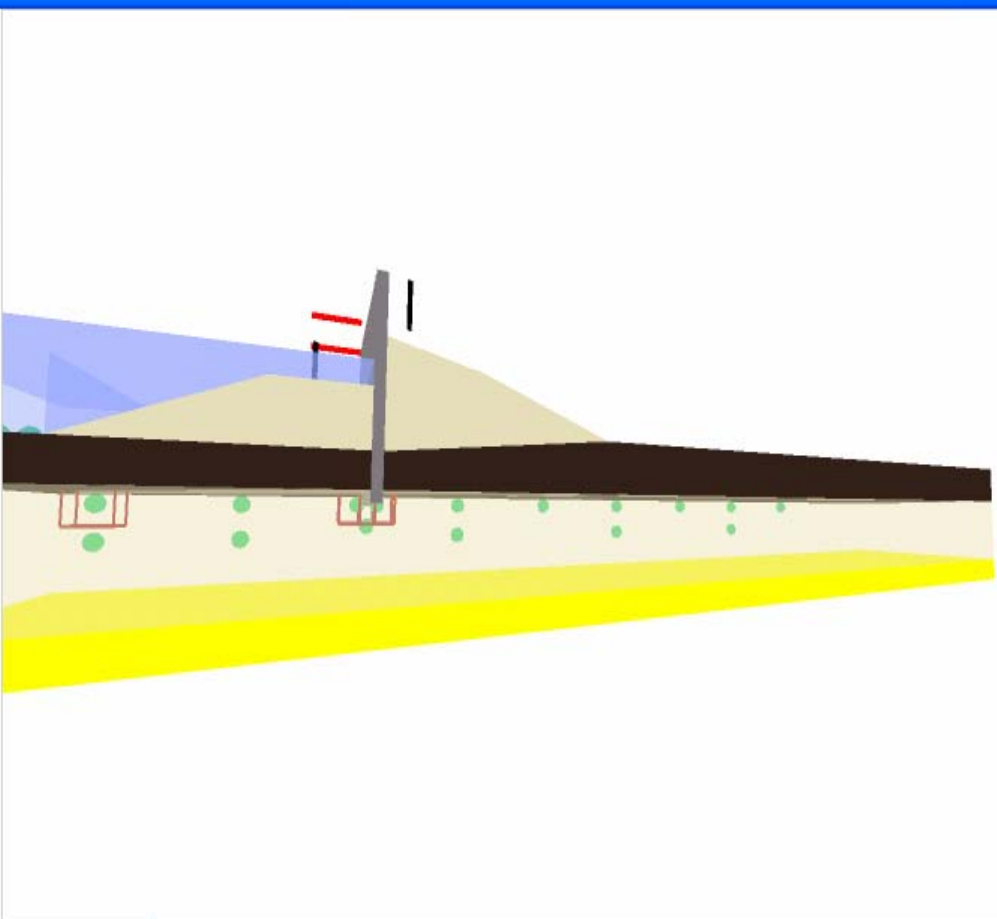
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

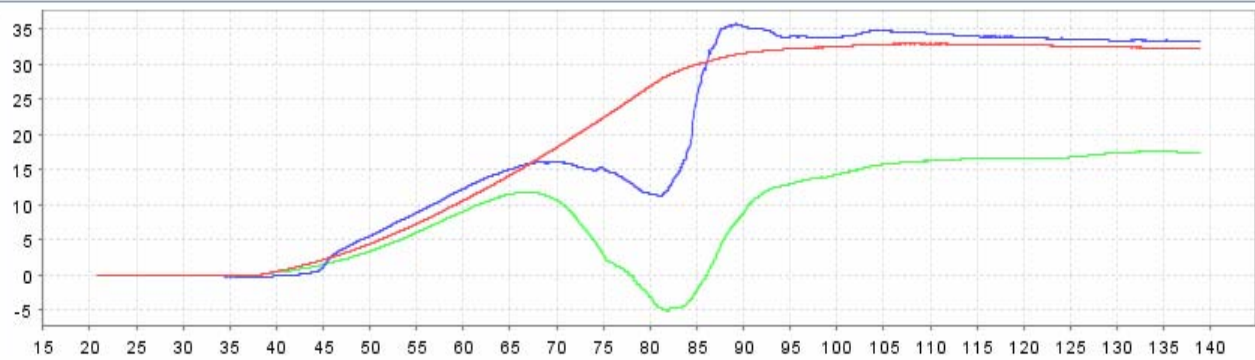
Appearance Control

- Sand: On Solid
- Clay: On Trans.
- Peat: On Solid
- Levee: On Solid
- Sheet Pile: On Solid
- Water: On Trans.
- LVDTs: On Solid
- Lasers: On Solid
- Pore Pressures: On Solid
- Container: Off Line

Current Model Title: New Orleans Levee Tests - 17th Street

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



Legend

- PPT7
- PPT9
- PPT10

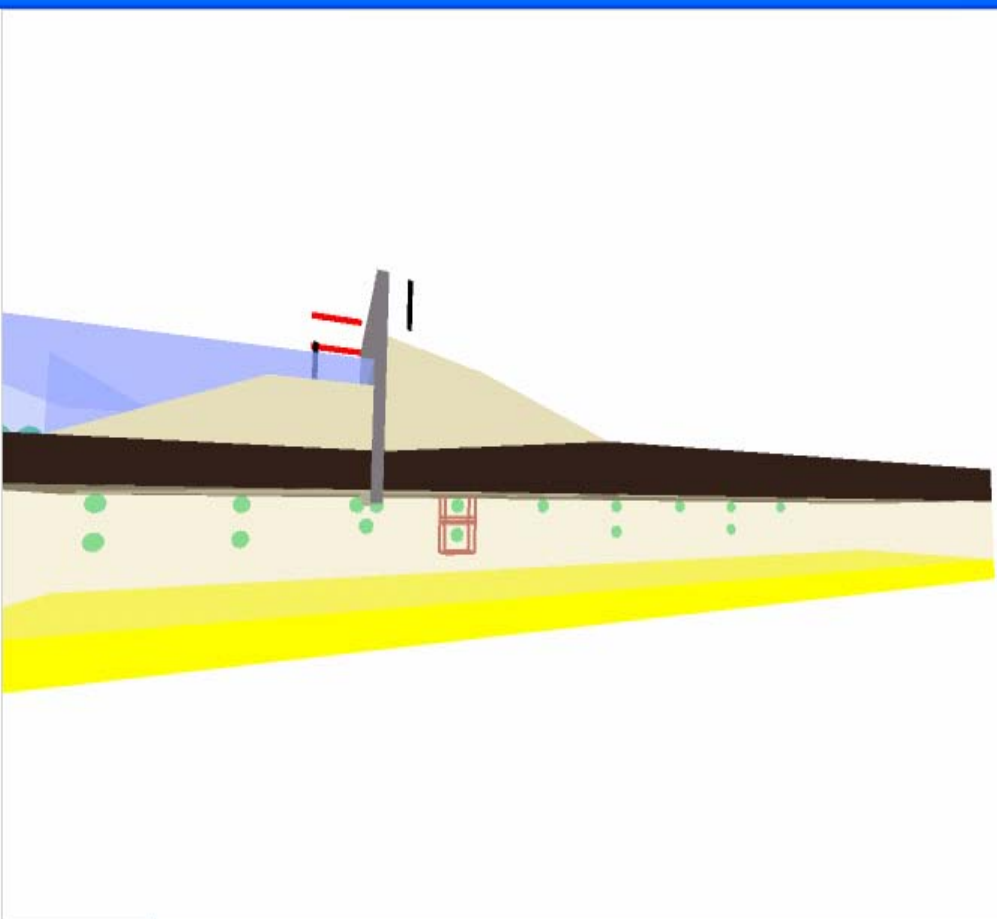
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

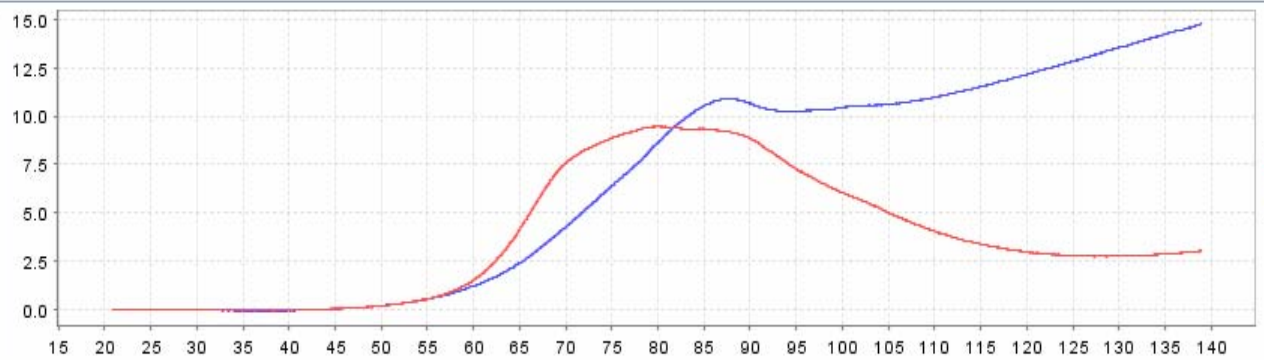
Appearance Control

- Sand: On Solid
- Clay: On Trans.
- Peat: On Solid
- Levee: On Solid
- Sheet Pile: On Solid
- Water: On Trans.
- LVDTs: On Solid
- Lasers: On Solid
- Pore Pressures: On Solid
- Container: Off Line

Current Model Title: **New Orleans Levee Tests - 17th Street**

Plot Control

- Clear Selection(s)
- Reset Plot Zoom



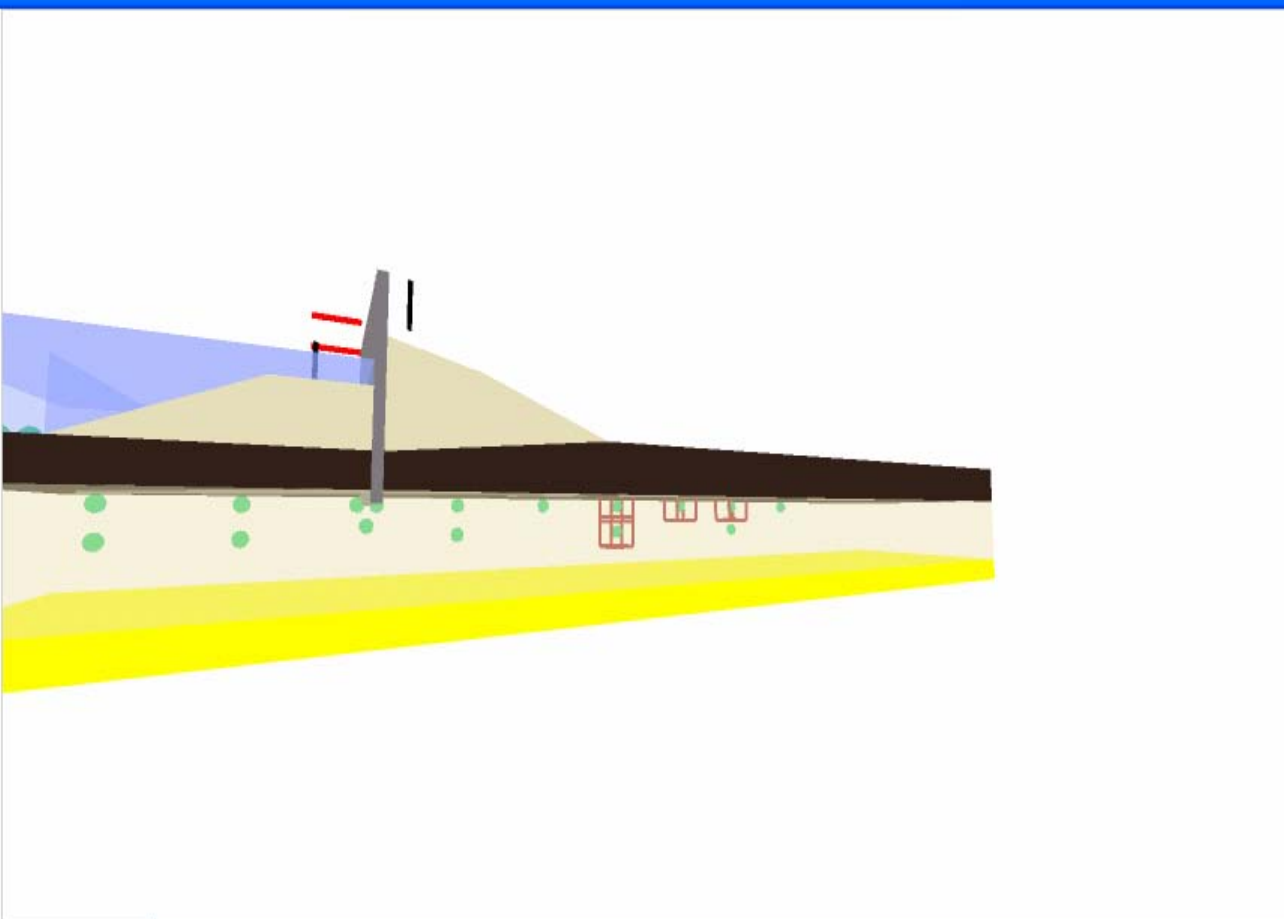
Menu

- Open file from disk
- Save 3D View as Image

Metadata

Move your mouse over an object to display its metadata.

Note that some objects don't have any metadata associated with them.



View Control



Preset Views

- Default View
- Side Left
 - Side Right
 - Left
 - Right
 - Top
 - Bottom

Appearance Control

- Sand: On Solid
- Clay: On Trans.
- Peat: On Solid
- Levee: On Solid
- Sheet Pile: On Solid
- Water: On Trans.
- LVDTs: On Solid
- Lasers: On Solid
- Pore Pressures: On Solid
- Container: Off Line

Current Model Title: **New Orleans Levee Tests - 17th Street**

Plot Control

- Clear Selection(s)
- Reset Plot Zoom

