Advanced In-Situ Hydraulic Profiler for Optimized Design of Flood Control Structures

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Safety Moment – Hurricane Season is Upon Us

- The best time to prepare for a hurricane is before hurricane season begins on June 1
- It is vital to understand your home's vulnerability to storm surge, flooding, and wind
- Put Together an Emergency Kit
- Write or review your Family Emergency Plan
- Review Your Insurance Policies
- Understand NWS forecast products, especially the meaning of NWS watches and warnings
- Know your zone: Find out if you live in a hurricane evacuation area

What is Coastal Resilience?

“

Coastal Resilience means building the ability of a community to “bounce back” after hazardous events such as hurricanes, coastal storms, and flooding – rather than simply reacting to impacts.

Source: National Ocean Service, NOAA

Role of Geotechnical Engineers

Resilience based designs can prevent hurricanes and other extreme events from becoming catastrophes.

- Analyze and evaluate geotechnical aspects of infrastructure impacted by disasters
- Geotechnical engineers should be an integral part of the team in developing resilience-based frameworks (RBF)
- Integration of innovative tools and documented past cases of success and failures are critical

Storm jetty designed by Fugro to protect coastline from erosion in New Bedford, USA.

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Ground Risks Associated with Design of Flood Control Structures

Typical Ground Risks

- Slope instability
- Piping and scour
- Soil Erosion
- Subsidence
- Dynamic loads
- Ground water quality and seepage
- Cross-contamination
- Dynamic sediment transport
- Saltwater infiltration
- Ground water hydraulics

Impacted Structures

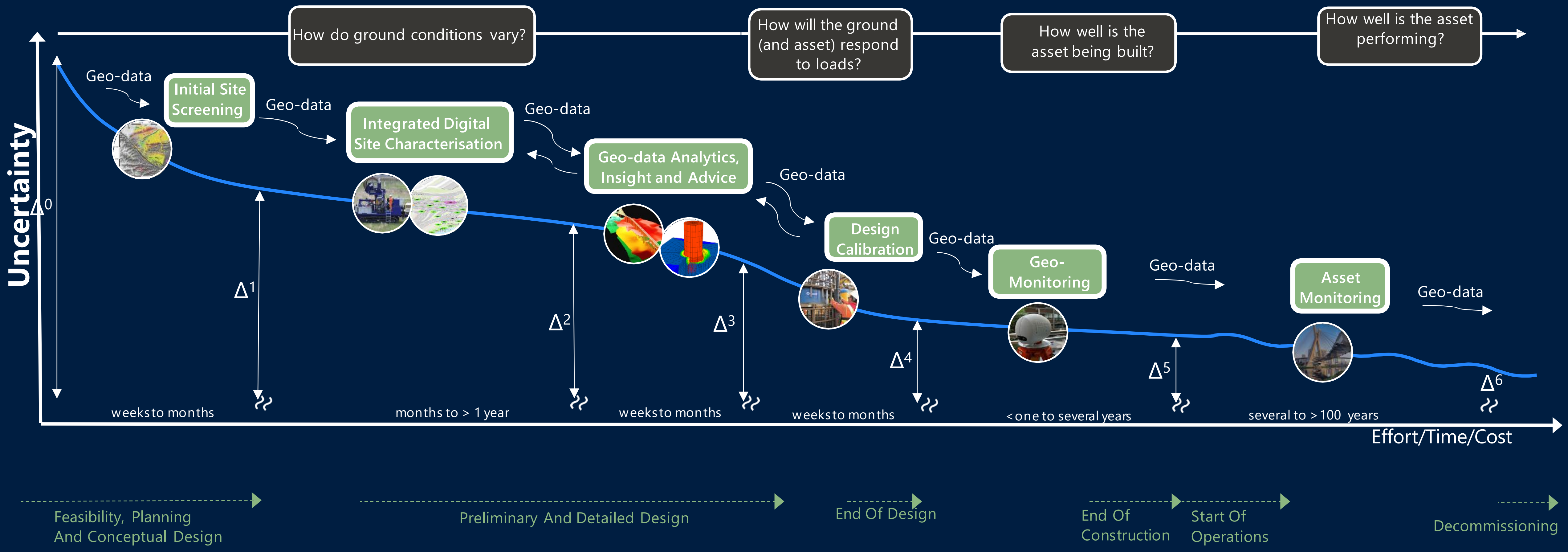
Green infrastructure

- Reefs
- Seagrass
- Marine estate and ocean health
- Natural coastal barriers (Mangroves/ Wetlands)
- Beach replenishment (adaptive)

Grey infrastructure

- Groynes
- Artificial reefs
- Flood (catchment) drainage
- Estuarine barriers
- River levees (estuarine)
- Seawalls
- Land elevations, reclamations
- Linear infrastructure (road/rail/bridges/tunnels)
- Ports
- Landfill and waste management
- Nuclear
- Oil and gas structures
- Airports
- Electricity transformer stations and power

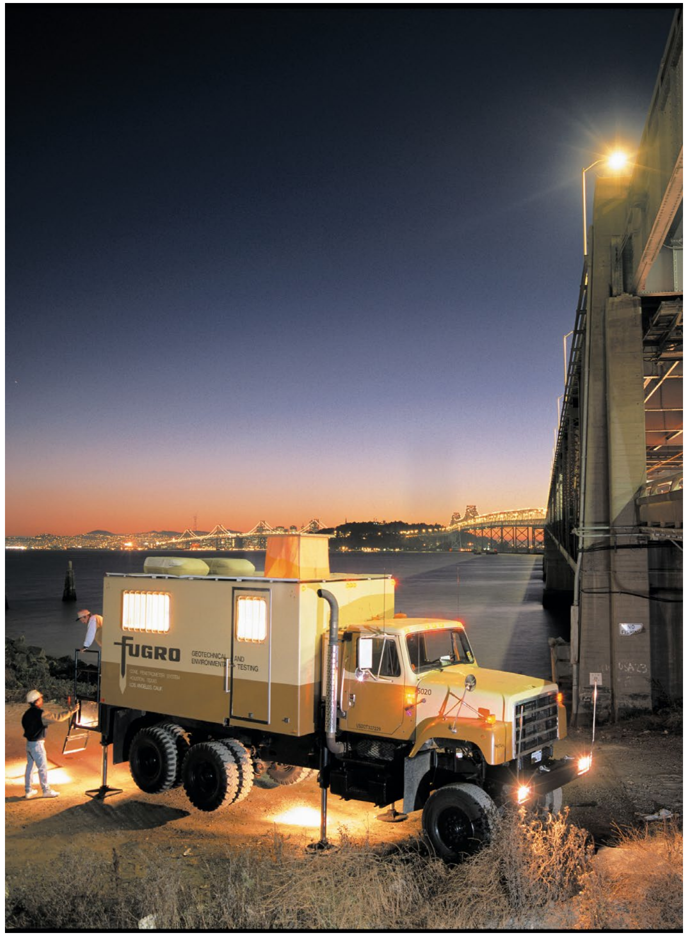
The Ground Risk Management Framework for Coastal Resiliency Projects



Advanced Technologies to Assess Ground Risk

Advanced PCPT Technology (Deployed for USACE New Orleans 2008)

- Measurement of in-situ properties
- Continuous soil stratigraphy
- Identifies thin seams and layers
- Evaluates geotechnical and hydrogeological properties
- Realtime field data acquisition and interpretation
- Safer for environment and crew
- Work in inclement weather
- No drill cuttings
- Identify anomalies



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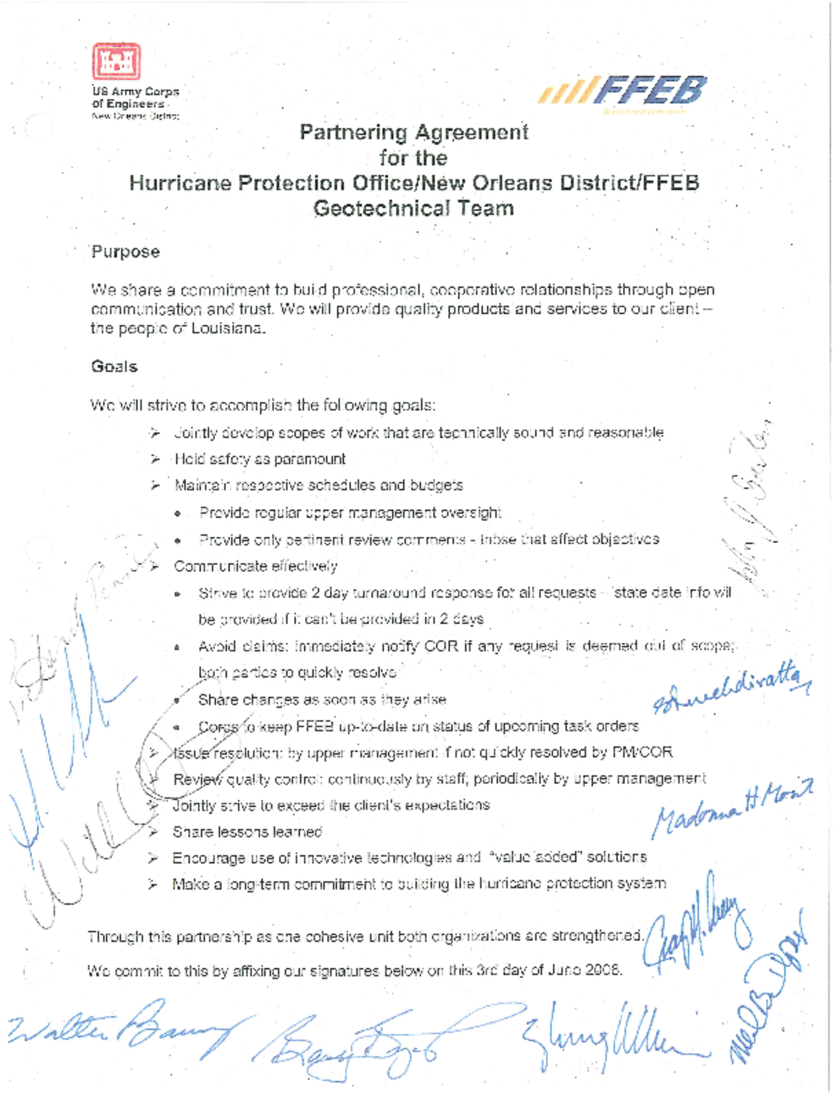
USACE Partnering



US Army Corps of Engineers
New Orleans District

FFEB

Partnering Agreement
for the
Hurricane Protection Office/New Orleans District/FFEB
Geotechnical Team

Purpose

We share a commitment to build professional, cooperative relationships through open communication and trust. We will provide quality products and services to our client – the people of Louisiana.

Goals

We will strive to accomplish the following goals:

- Jointly develop scopes of work that are technically sound and reasonable
- Hold safety as paramount
- Maintain respective schedules and budgets
  - Provide regular upper management oversight
  - Provide only pertinent review comments - those that affect objectives
- Communicate effectively
  - Strive to provide 2 day turnaround response for all requests - state date info will be provided if it can't be provided in 2 days
  - Avoid claims: Immediately notify COR if any request is deemed out of scope; both parties to quickly resolve
  - Share changes as soon as they arise
  - Corps to keep FFEB up-to-date on status of upcoming task orders
- Issue resolution: by upper management if not quickly resolved by PM/COR
- Review quality control: continuously by staff, periodically by upper management
- Jointly strive to exceed the client's expectations
- Share lessons learned
- Encourage use of innovative technologies and "value added" solutions
- Make a long-term commitment to building the hurricane protection system

Through this partnership as one cohesive unit both organizations are strengthened.

We commit to this by affixing our signatures below on this 3rd day of June 2008.

Mr. Walter Baumy (Chief – NOLA)

Honorable John Paul Woodley (Asst. Sec. of Army) and Mr. James Dalton (Chief Engineer – USACE)

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Acceptance of PCPT Technology by USACE

Honorable John Paul Woodley (Asst. Sec. of Army)

General Antwerp (USACE Chief)

Mr. James Dalton (Chief Engineer – USACE)

"As an engineer, this makes me feel a whole lot more comfortable with the design." - Major Mark Jernigan, Deputy District Commander

"You won't find anything else like that in the country." - Dave Pezza, Chief Geotechnical Engineer

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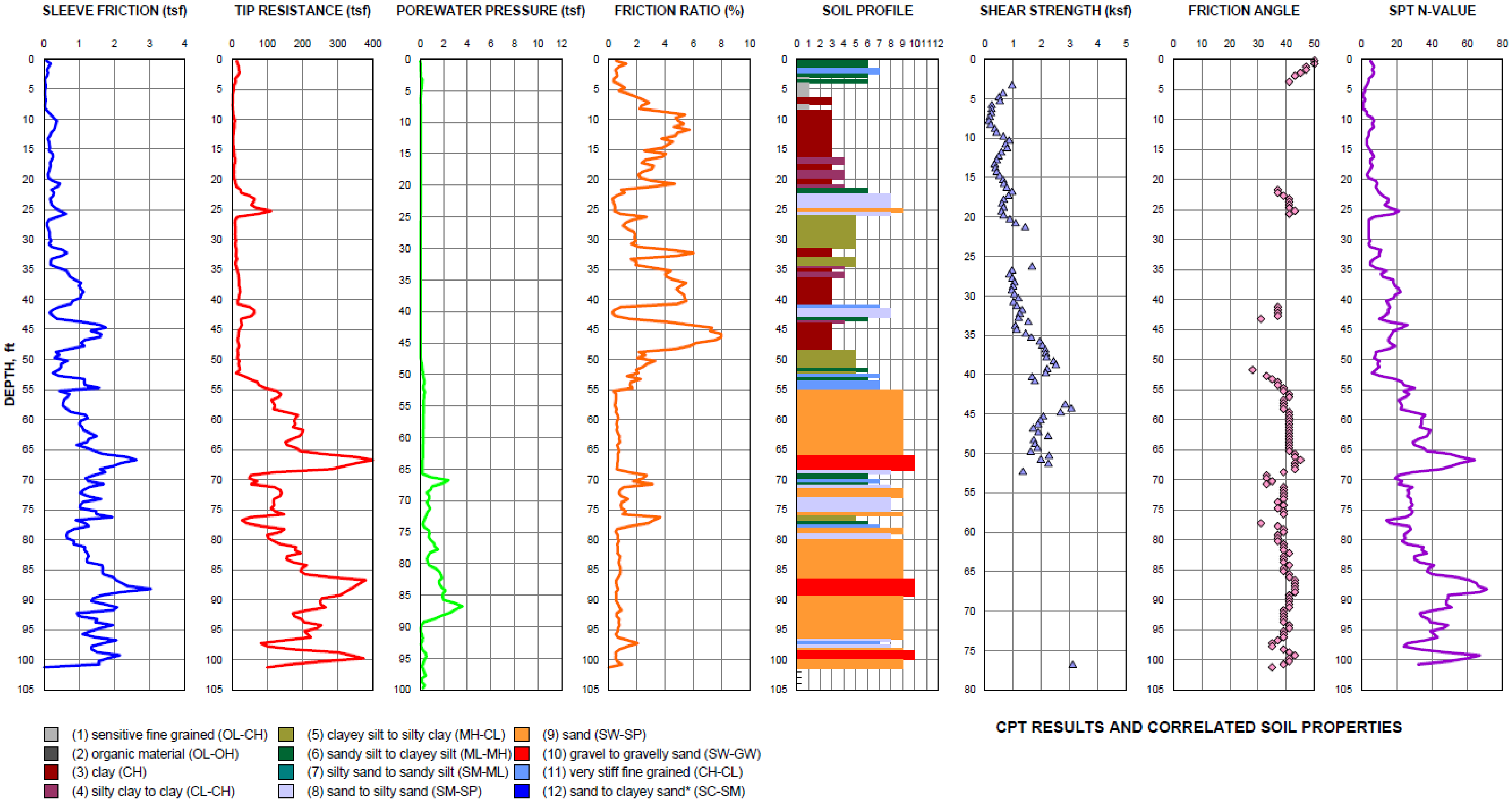
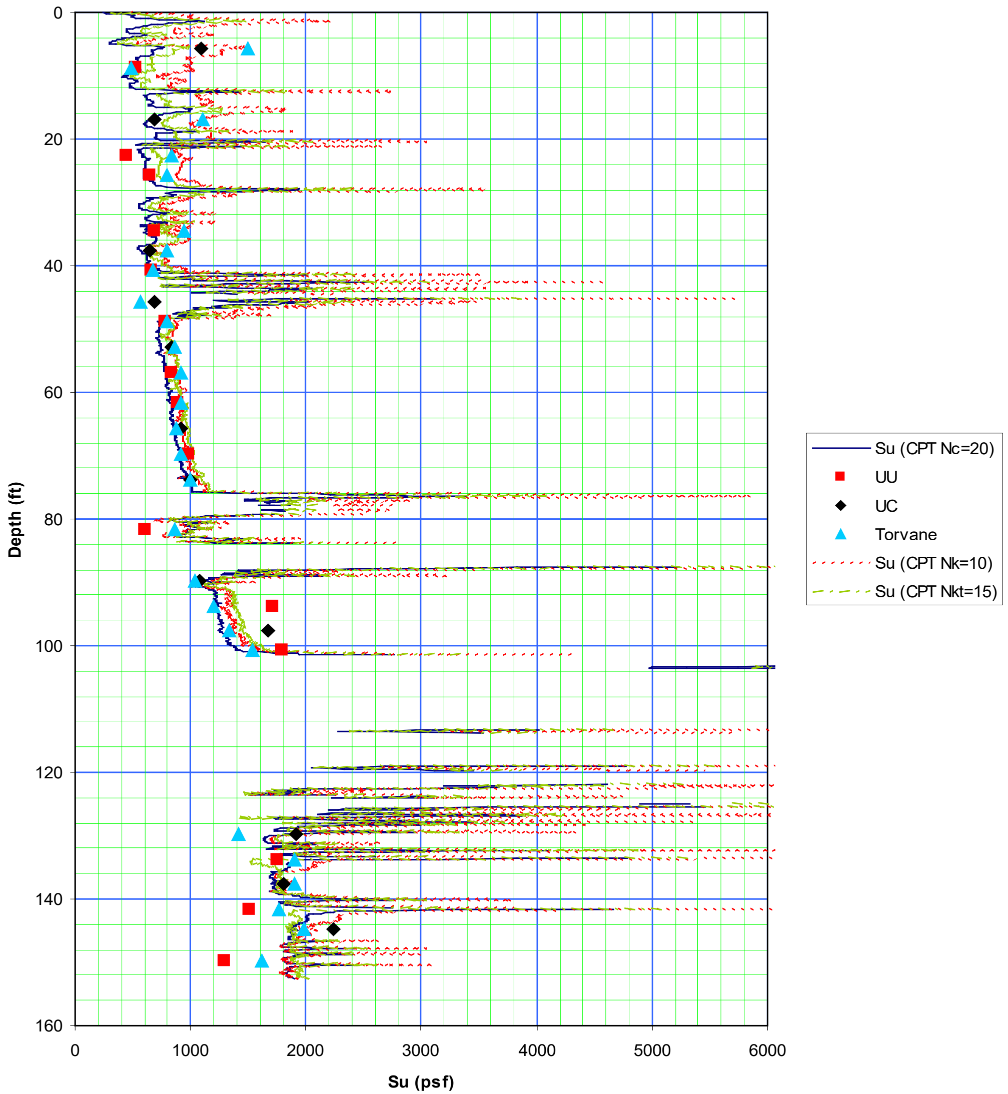
PCPT – Undrained Shear Strength Correlation

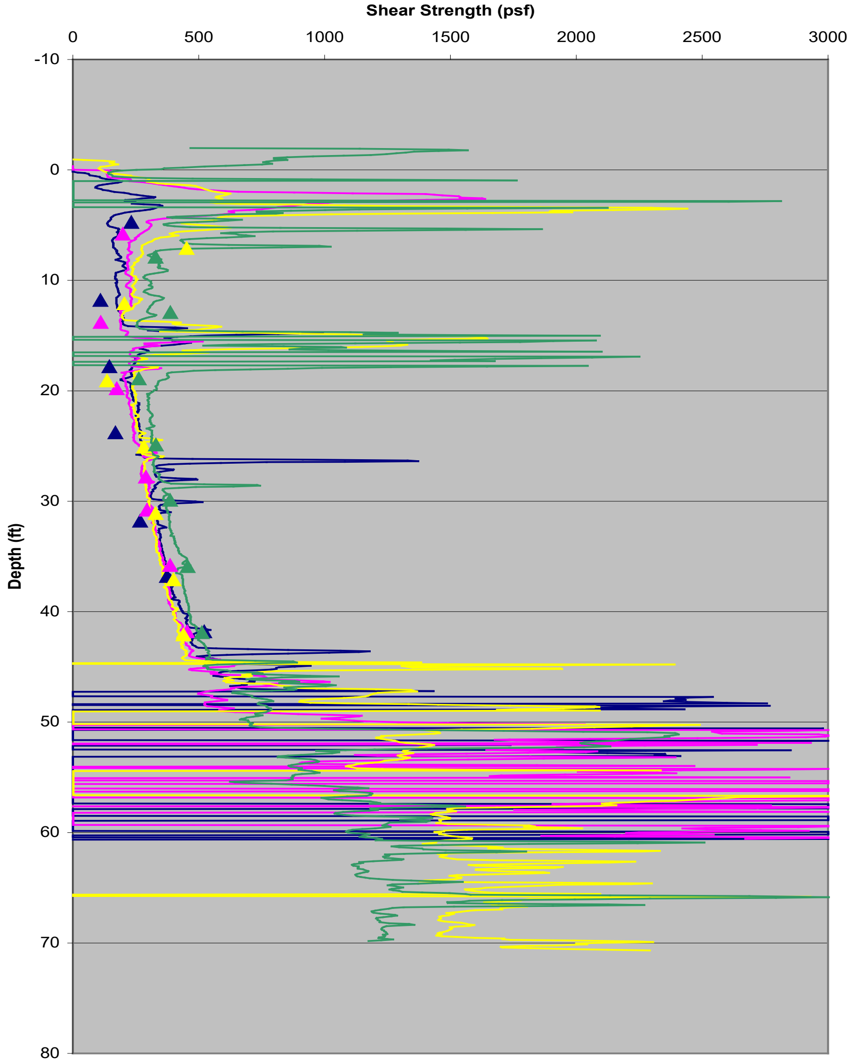


CPT RESULTS AND CORRELATED SOIL PROPERTIES

PCPT – Boring Correlation



PCPT – Vane Shear Strength Correlation



Advanced in-situ hydraulic profiler (HPT-MPT)

Water Innovation Prize Winner (2017)

Awarded by the Union of Water Board – NL in Water Safety Category

Innovative Permeability Probing for Levee Improvements

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Advanced in-situ hydraulic profiler (HPT-MPT)

A single push ground measurement tool improving how we quantify ground water risks to reduce their impact on civil assets.

Improving understanding of hydraulic conductivity in the near subsurface to optimize design of flood control structures.

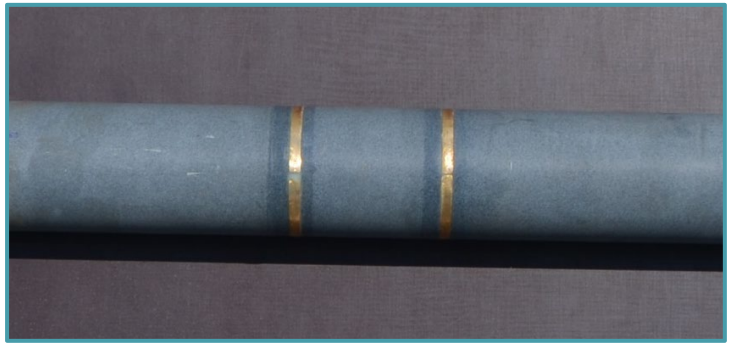
Improving asset design with higher fidelity analysis of hydraulic conductivity in near surface soils (<120 ft)

Single push ground measurement probe delivers targeted in-situ permeability faster

Optimize or eliminate the need for slug and pump tests saving time and money

Less invasive single push design significantly reduces impact in environmentally sensitive or urbanized areas

Advanced in-situ hydraulic profiler cone (HPT-MPT)



- Water pressure (U1, U2 & U3)
- Cone resistance (qc)
- Friction (fs)

- Electrical conductivity (EC)

- Injection Quantity/ Discharge (Q)
- Injection pressure (P)
- Temperature of injected water (T)

How it works

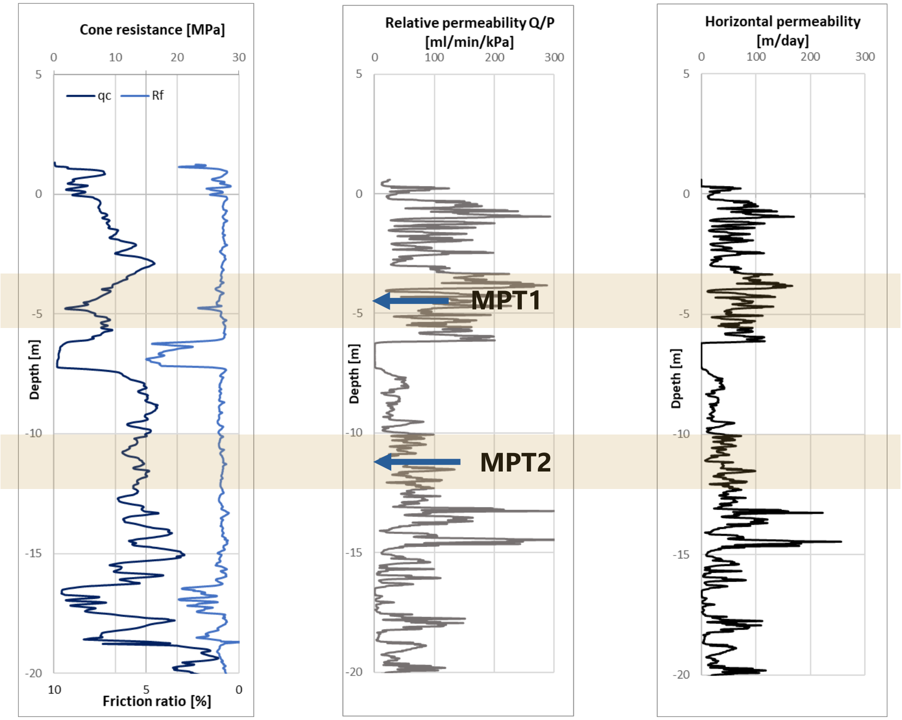
Phase 1

Phase 2

PCPT

HPT

HPT-MPT



Soil Classification

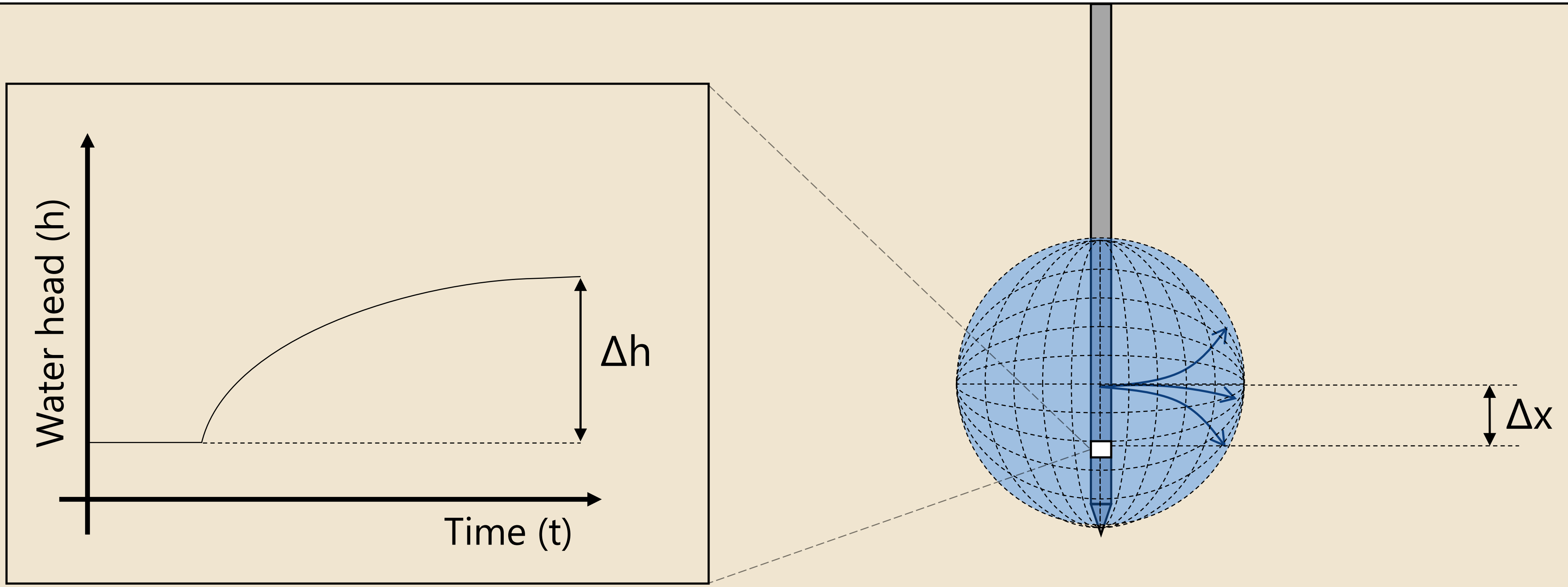
1. Exploration program combines PCPT and HPT tests

2. Real time HPT tests identifies highly permeable zones with a relative permeability profile

3. Permeable zones are targeted with in-situ MPT, calibrating the HPT log to measure absolute hydraulic conductivity profile of the soil

4. The combination of HPT-MPT provides reliable in-situ permeability profile of the subsurface soils

Principle of Mini-Pumping Test (MPT)®



Darcy's law (simplified equation)

$$Q = \boldsymbol{K}\frac{\Delta h}{\Delta x}$$

where,

Q – Injection Quantity/ Discharge
K – Hydraulic Gradient
Δh – Difference in Hydraulic Head
Δx – Flow Length

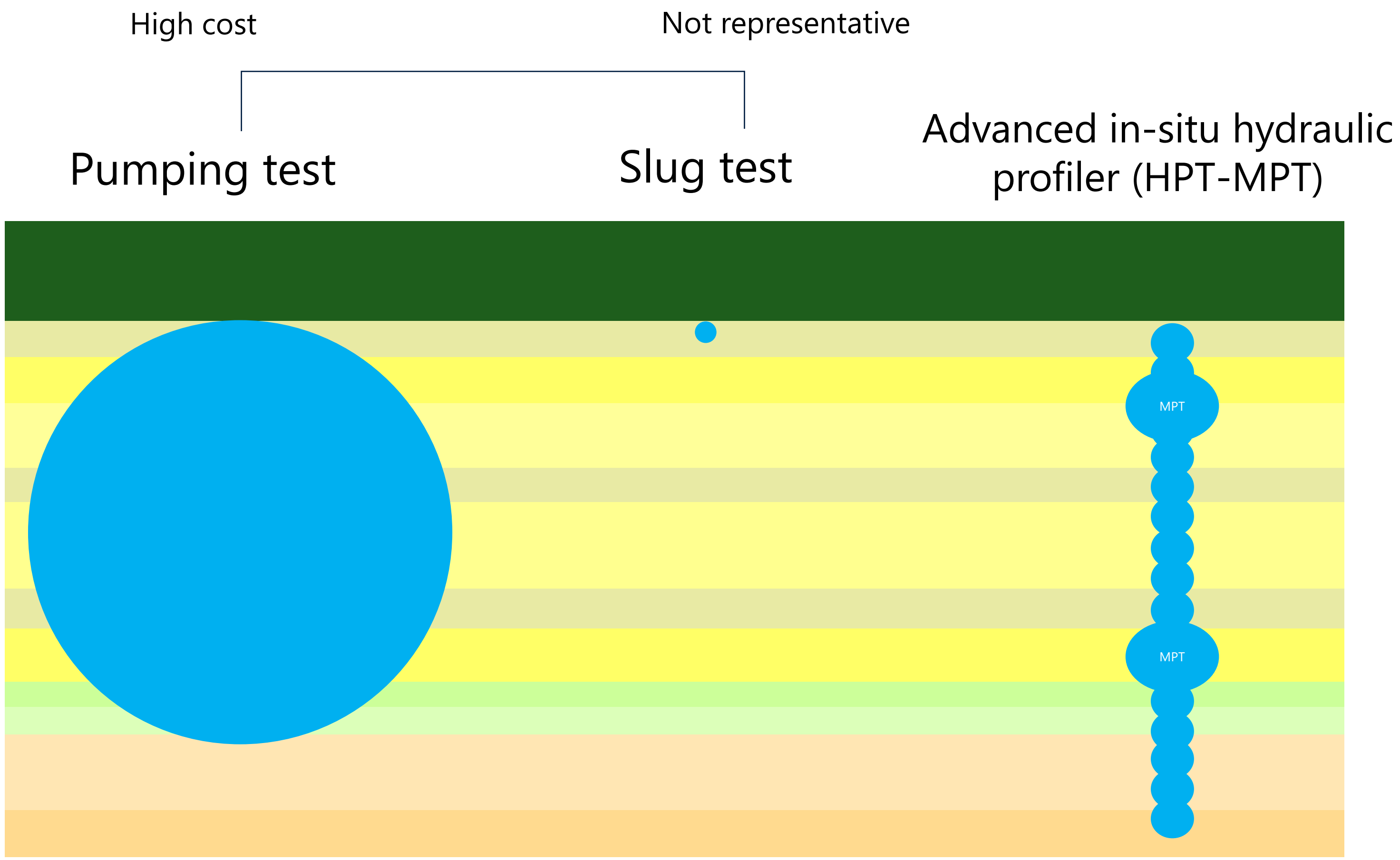
Realtime and Cost Effective Measurement of In-situ Permeability

Targeted, higher fidelity data delivering greater confidence in engineering analysis and design

Simultaneous PCPT/HPT/MPT acquisition provides realtime in-situ permeability of subsurface soils

Up to 24X faster than traditional methods allowing for greater density of data, improving spatial certainty of risk due to ground water seepage/flow

Traditional Methods



Applications of advanced in-situ hydraulic profiler (HPT-MPT)

- Design of Levees
  - Piping failure analysis
  - Slope stability analysis
  - Liquefaction
- Design of Flood Control Structures
  - Retaining Walls/ Sheet Pile Walls
  - Tunnels
  - Cofferdams
- Groundwater/ Hydraulic Flow Calculations
  - Dewatering
  - Infiltration

Benefits of Advanced in-situ hydraulic profiler (HPT-MPT)

- Measurement of in-situ hydraulic properties
- Continuous relative soil permeability (HPT)
- In-situ absolute permeability measurements (MPT)
- Real-time field data acquisition and interpretation
- Significant cost and schedule savings vs. pump tests
- Greater spatial understanding of soil properties
- Safer for environment and crew
- Can perform work in inclement weather
- No drill cuttings
- No cross-contamination of layers

Optimized Levee And Flood Control Structures Design

Case Study 1

Flood Protection
Ooijen-Wanssum (NL)

Purpose

- Evaluate levee failure risks based on new regulatory guidelines

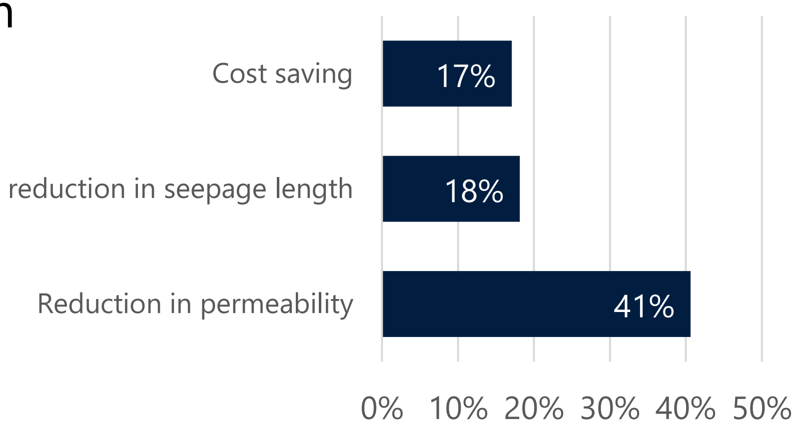
Scope

- Diversion of an old tributary to drain water into the Maas River
- Construction of new levees along the Maas River
- Construction of 5 bridges
- Provincial roads

Cost effective design using HPT-MPT

Benefits derived by using Advanced in-situ hydraulic profiler (HPT-MPT)

- Optimized levee design by 41% reduction in absolute permeability design value
- 18% reduction in required berm width
- 17% cost saving, approx. € 4.9 Million (5.8 Million USD)



Case Study 2

Dike Strengthening Wolferen-Sprok (NL)

Purpose

- Dike rehabilitation to meet minimum factor of safety requirements

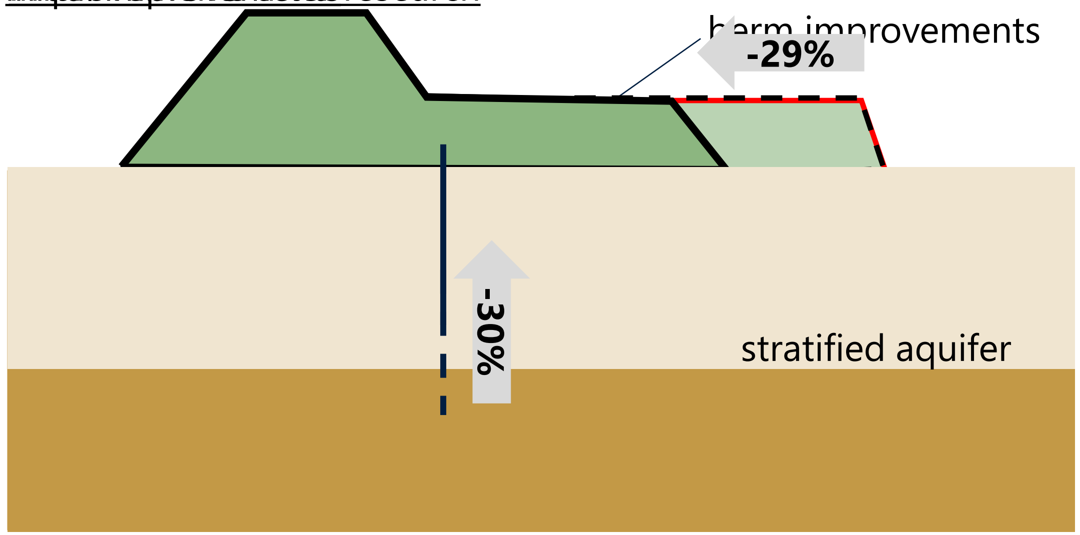
Scope

- Conducted 66 HPT-MPTs along the dike alignment
- Evaluated **piping** risk by determining the variation in permeability used in numerical piping analysis
- Optimized the sheet pile length and berm width

Cost effective design using HPT-MPT

Sheet pile/berm improvement was not needed along 25% of the dike alignment

29% reduction in required berm width or a 30% reduction in sheet pile length



Case Study 3

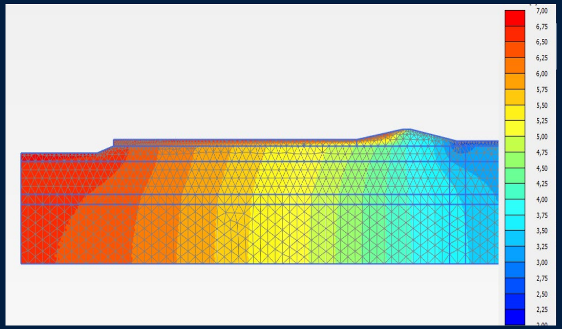
Dike Strengthening Culemborgse Veer – Beatrixsluis (NL)

Purpose

- Evaluate levee failure risks based on new regulatory guidelines (developed due to levee failure during hurricane Katrina)

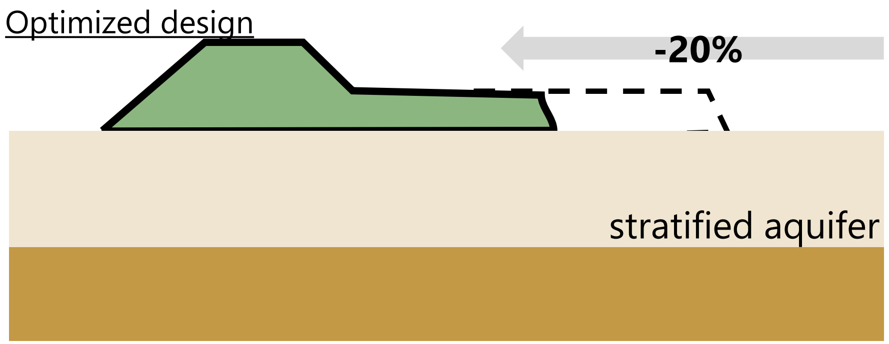
Scope

- Conducted 31 HPT-MPTs divided over 3 dike sections
- Refined the **piping** risk by determining the variation in permeability in combination with numerical analysis

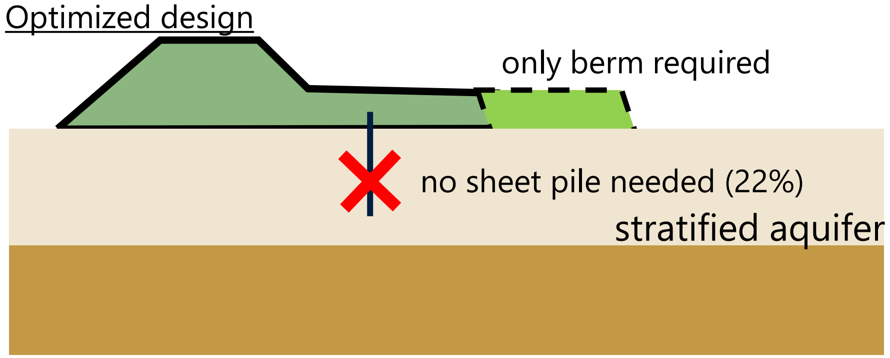


Cost effective design using HPT-MPT

20% reduction in berm width



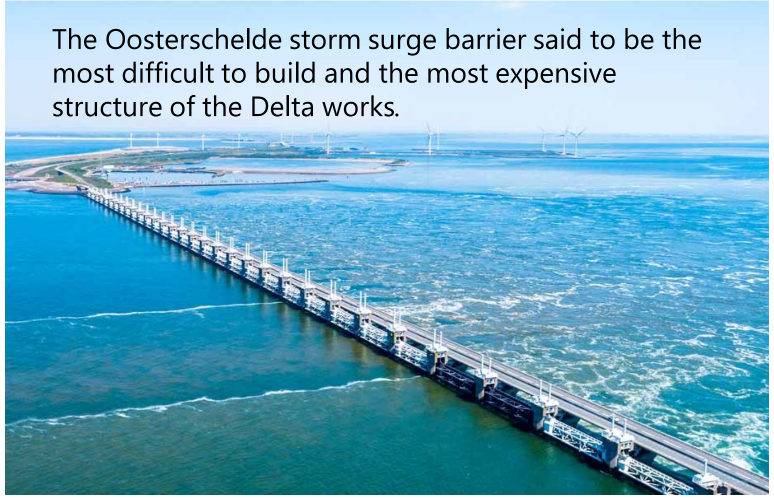
22% of the dike section was reinforced by berm vs. sheet piles resulting in significant construction cost savings

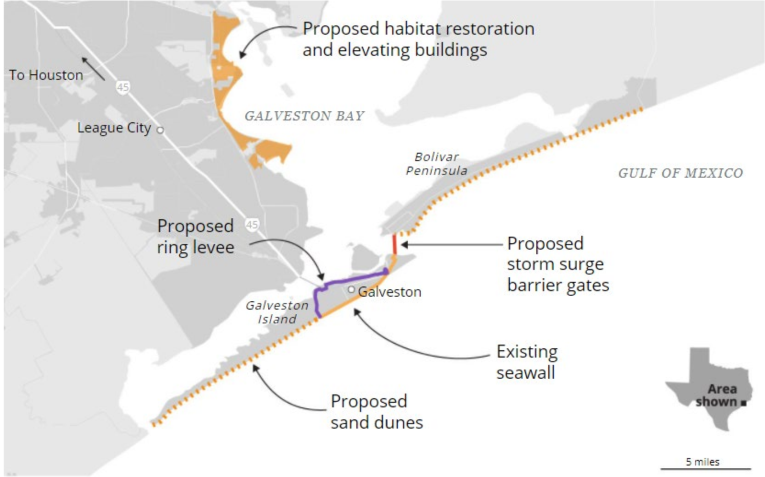


Relevance to Proposed Ike Dike Project

- One of the flood protection concepts (Ike Dike) is based on the Delta Works project located in the Netherlands.
- Delta Works is considered one of the seven wonders of the modern world.
- Fugro has been involved in the site investigation and engg analysis associated with Delta Works from the 70’s and in the safety assessment of the levees since the 90’s.
- Ike Dike – Design concept includes miles of levees, barriers and large floating sector gates.

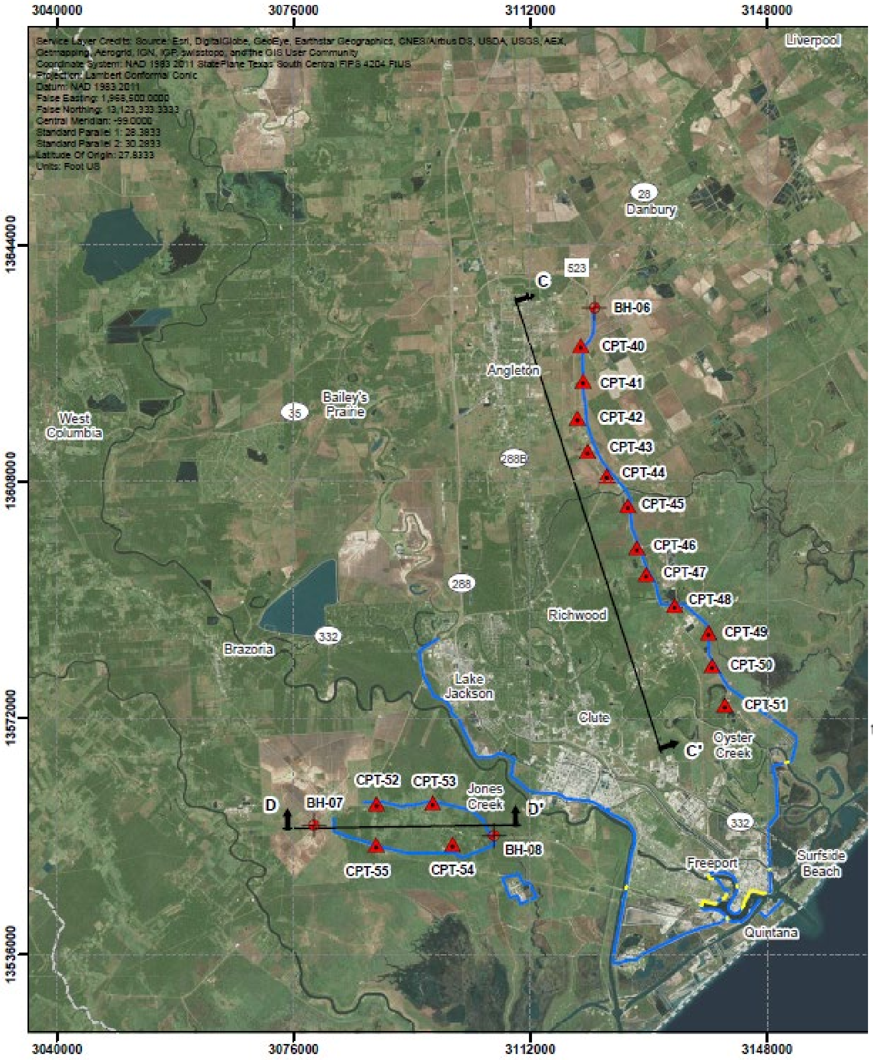
Flood protection systems in Netherlands are typically designed to withstand a 1 in 10,000-year event.

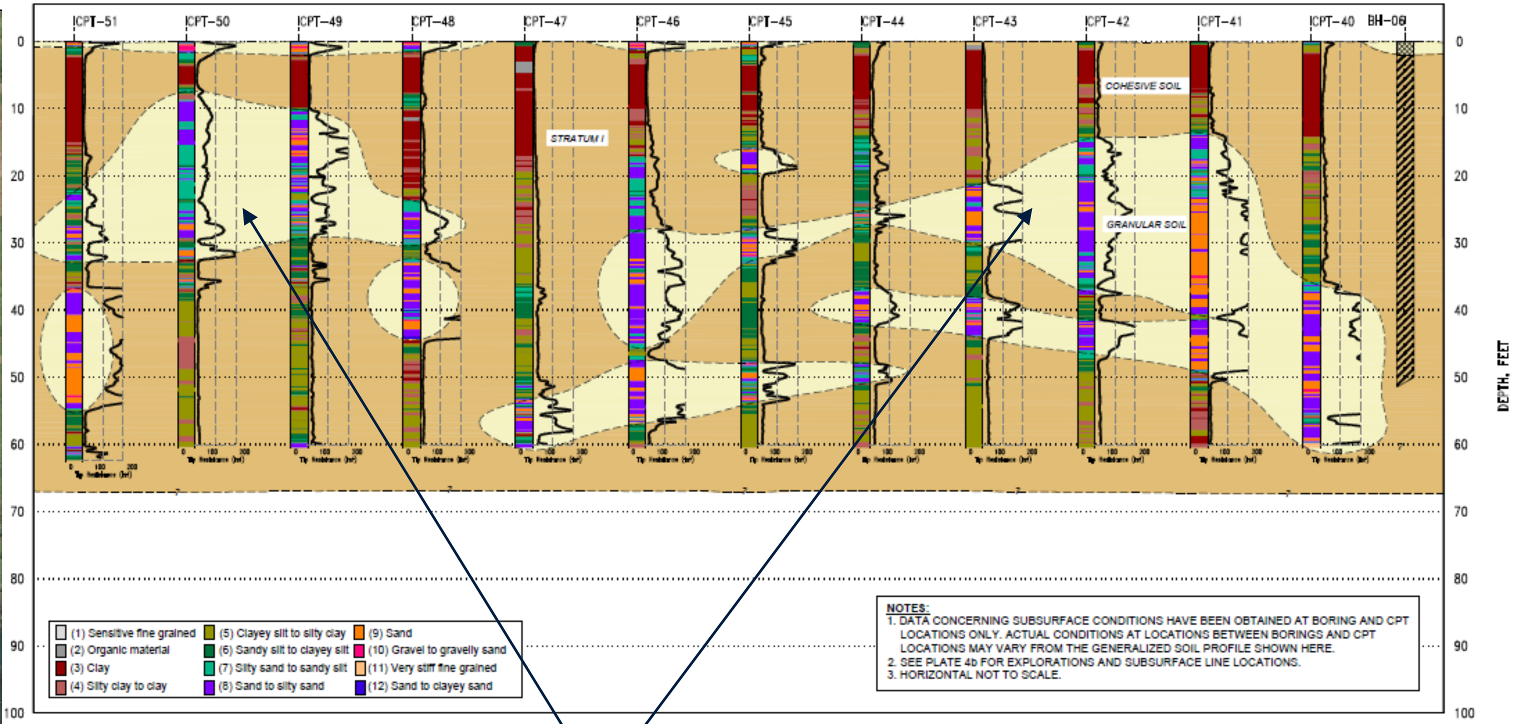

The Oosterschelde storm surge barrier said to be the most difficult to build and the most expensive structure of the Delta works.



Source: Coastal Texas Protection and Restoration Feasibility Study, Texas General Land Office

Relevance to Proposed Ike Dike Project – Southern Region (Freeport)

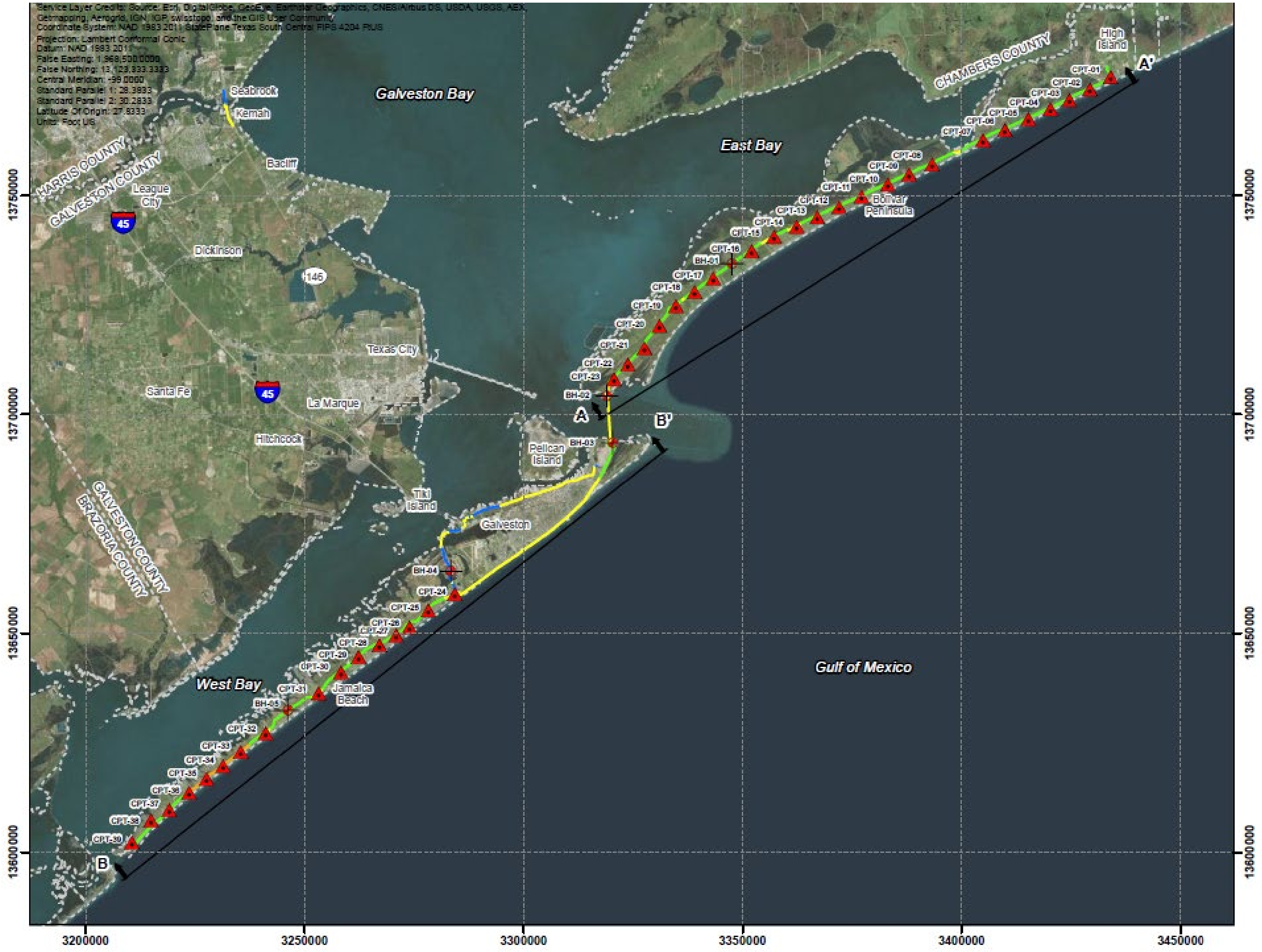




Critical to determine the hydraulic conductivity of permeable zones to evaluate piping risk for the proposed levees

Drawings taken from Fugro report performed as part of the GCCPRD project conducted for Dannenbaum Engineering Corp. and General Land Office (GLO).

Relevance to Proposed Ike Dike Project – Central Region (Galveston)



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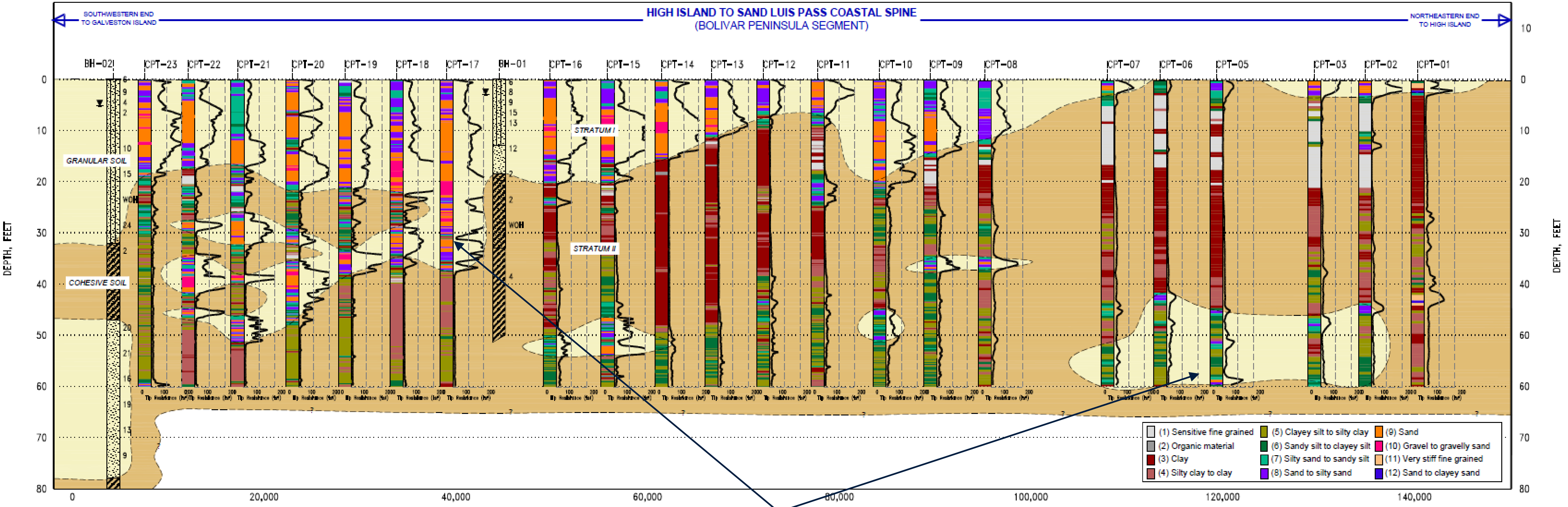
Relevance to Proposed Ike Dike Project – Central Region (Galveston)



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Concluding Remarks

- HPT provides continuous relative permeability
- MPT calibrates relative permeability to provide in-situ permeability within zones of interest
- Direct application to proposed projects such as Ike Dike which includes levees and flood control structures.
- Presented case histories showcase considerable cost and schedule savings by optimized design
- Equipment available in US in Summer 2021
- Field demonstration can be arranged for USACE and its consultants

GIWW West Closure Aerial Photo Dec 2010

Belle Chase Jan 18 2011

Optimized design using PCPT/HPT-MPT leads to significant cost and schedule savings for flood control structures

Together we create a safe and liveable world

THANK YOU

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