Eleventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds
Palm Springs, California

Innovation that provides sustainable solutions to complex challenges worldwide

Site Hydrostratigraphy Refinement: Integrated Field Methods for Characterizing a NAPL-Impacted Sedimentary Aquifer in Brazil

April 11th 2018

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Outline

- **Site Description & Goals**
- **Integrated Methods:**
  - **Drilling Methods**
  - **MiHPT profiling**
  - **Natural Gamma logging**
  - **Electric Resistivity Imaging**
- **Updated Site Hydrostratigraphy**
- **Conclusions**

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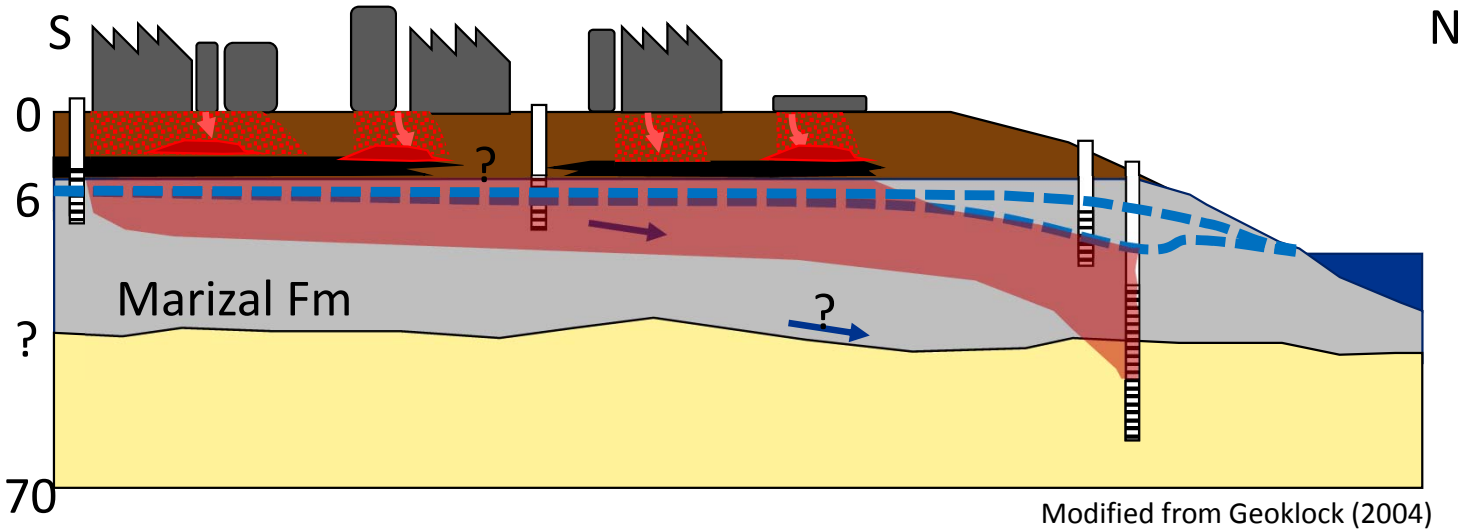
Site Description and Goals

- 1987 plant started
- Nitrated/Chlorinated Benzenes and Anilines (DNAPL mixture)
- Residual NAPL (immobile)



Modified from Geoklock (2004)

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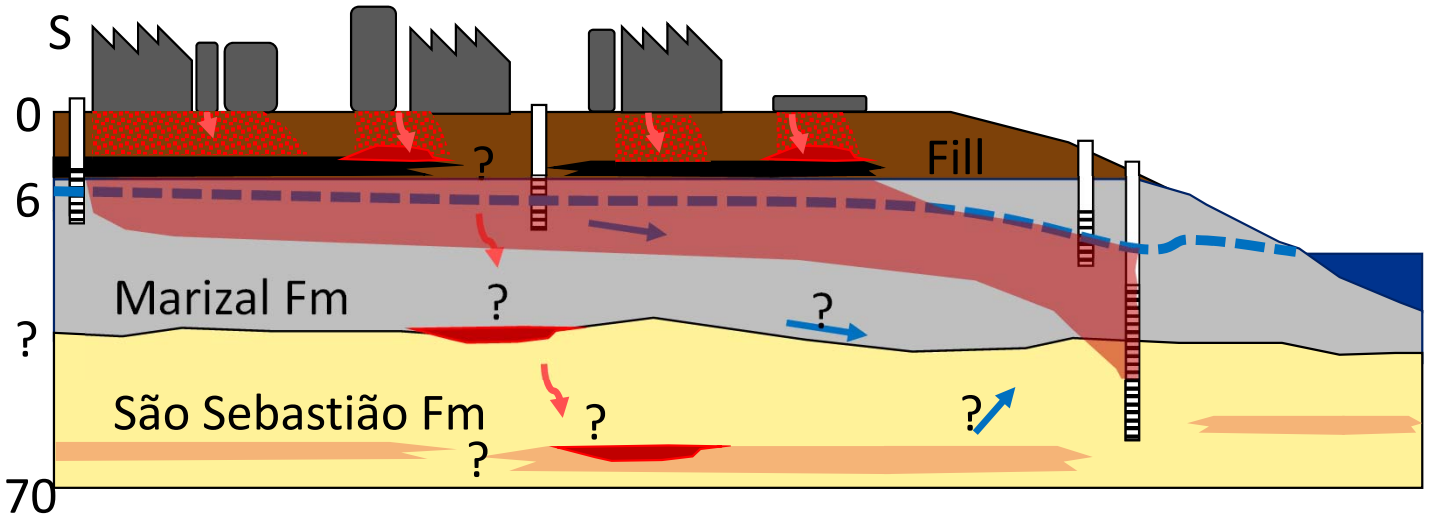
Site Description and Goals

- Identify preferential flow paths
- Support remedial design
- Vertical extent of Hydrostratigraphic Units (HSUs)
- Lateral continuity of aquitards



Highly heterogenous sands, silts, and clays

Fine to medium sands, clay lenses, aquitard?

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Integrated Methods

Screening

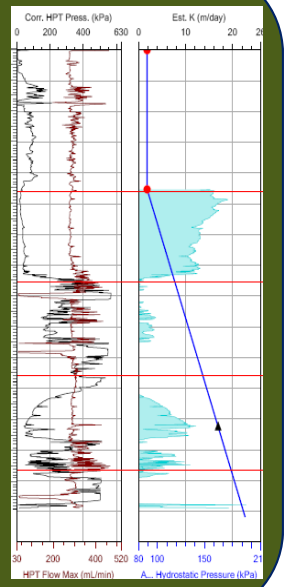
Direct

Drilling; Soil/Rock sampling

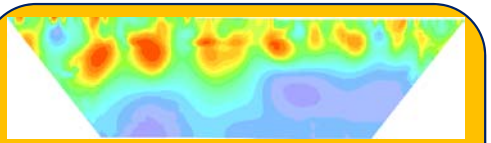
Trenches

MIP
Membrane Interface Probe

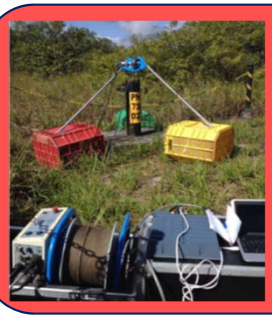
HPT
Hydraulic Profiling Tool



Indirect



Electrical Resistivity Imaging



Natural Gamma Logging

Confirming

Direct

273 Soil samples from confirmatory drilling

69 Groundwater samples from new wells

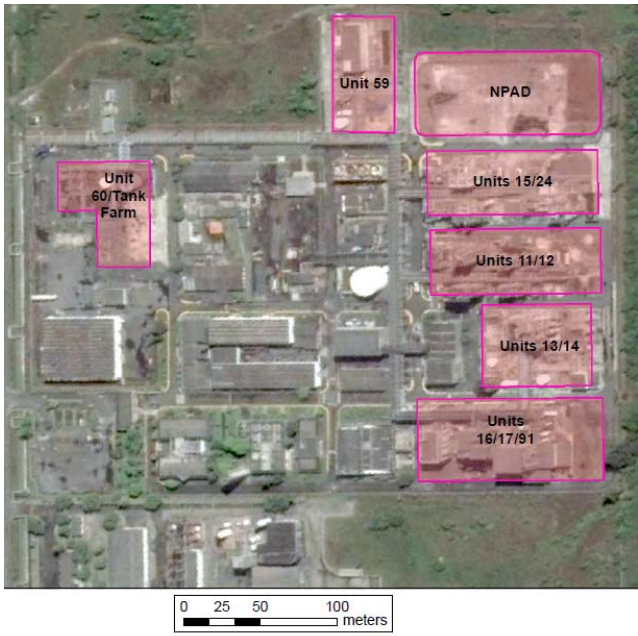
Site Characterization Challenges

Poorly consolidated Cretaceous sedimentary rocks

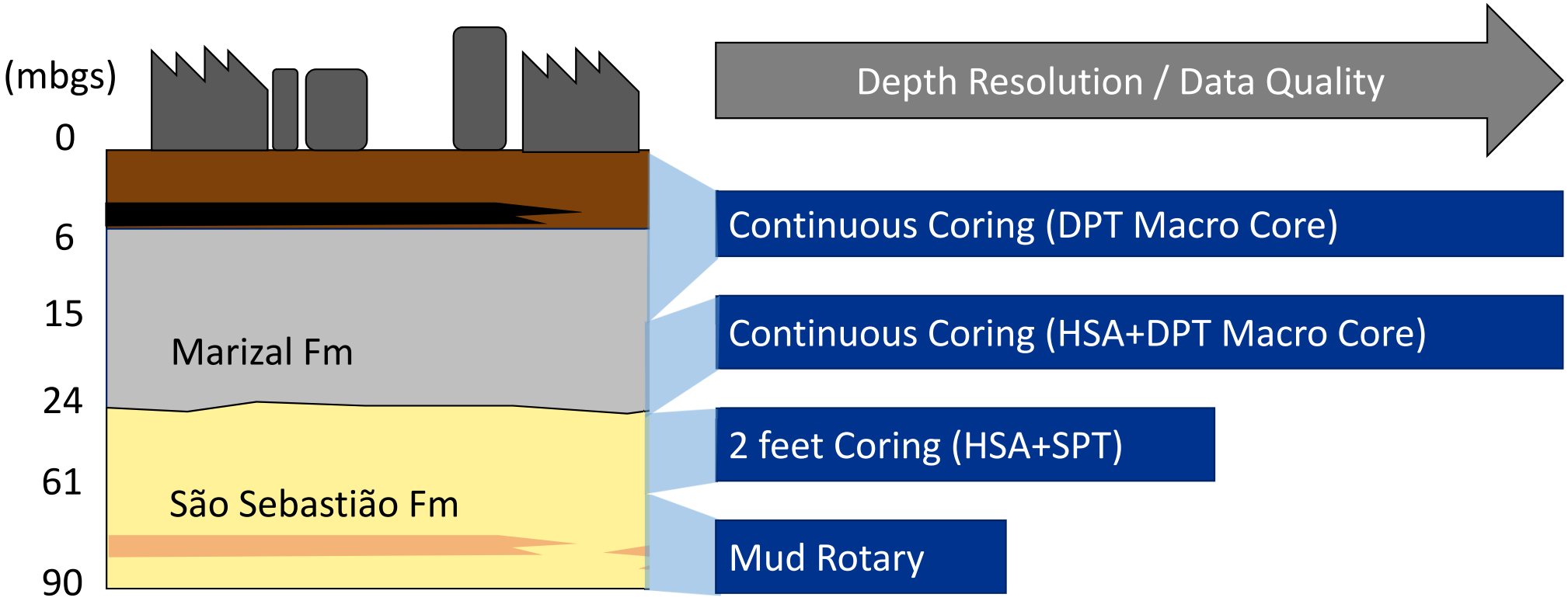
Increasing pore pressure with depth (flowing sands)

Wide range of grain size (clay to cobbles)

Drilling not allowed in former production units



Direct Methods: Drilling and Soil/Rock sampling



DPT = *Direct Push Technology*
HSA = *Hollow Stem Auger* (Trado Helicoidal Oco)
SPT = *Standard Penetration Test*

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MiHPT

Membrane Interface Probe (MIP)

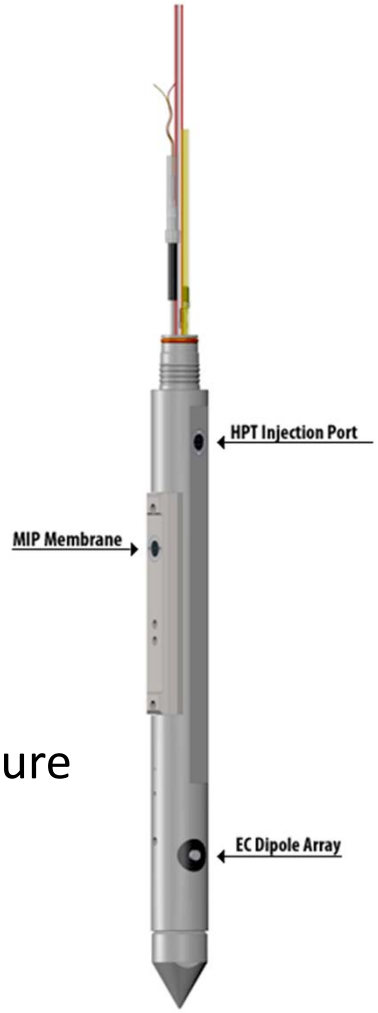
- Heated probe (100 -120°C)
- VOCs diffuse across membrane
- Gases carried to surface for analysis

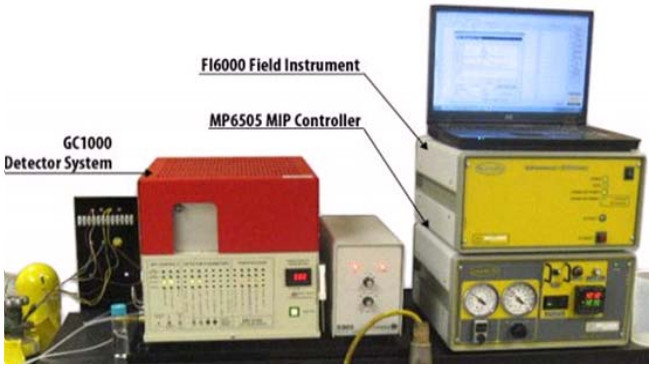
Hydraulic Profiling Tool (HPT)

- Water injection at controlled rate
- Measures pressure required for injection
- Dissipation tests: absolute hydrostatic pressure
- Estimated Hydraulic Conductivity (K)
- EC probe: soil conductance

- Max depth ~15 mbgs; sandy units

Limited effectiveness for some site COIs (SVOCs)





From: Geoprobe

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HPT results

- Shallow Hydrostratigraphy Refinement (0-15 mbgs)

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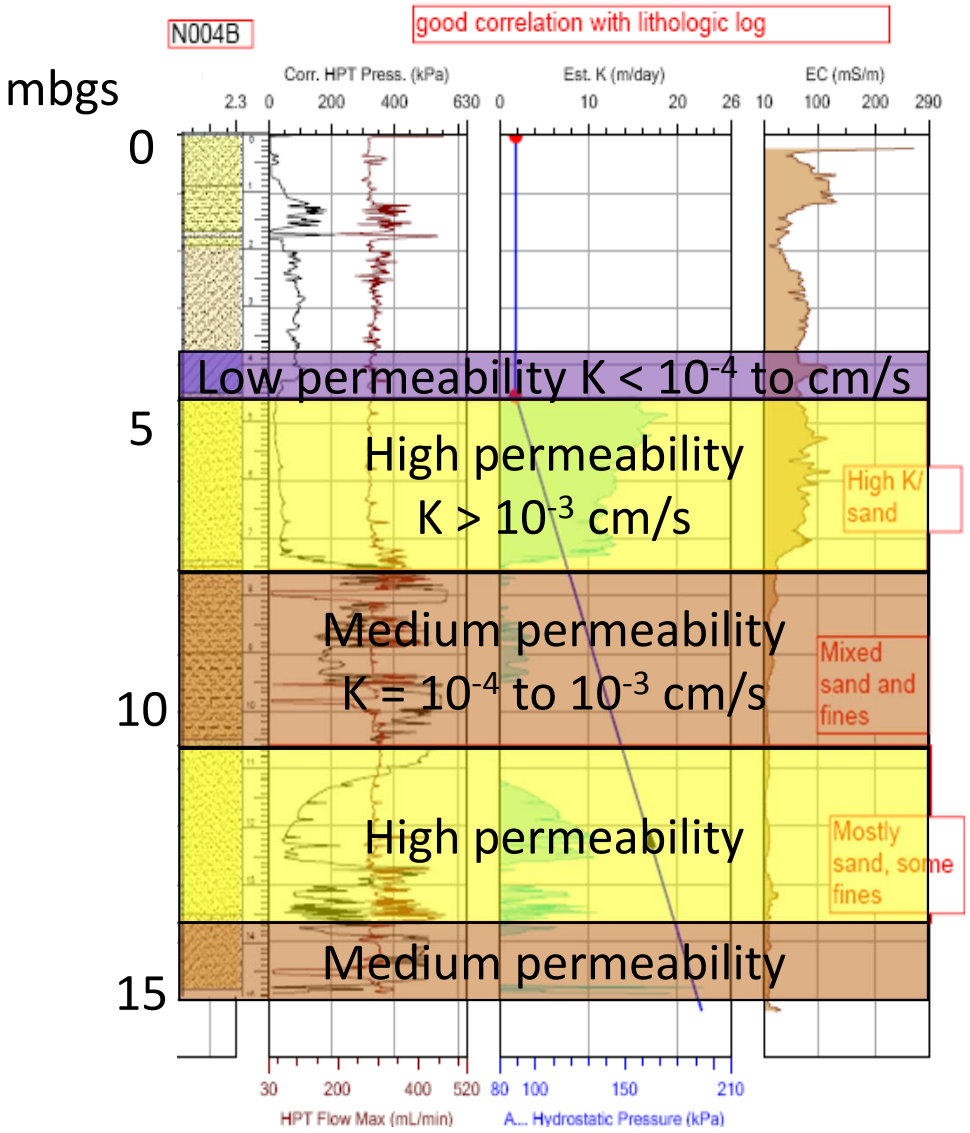
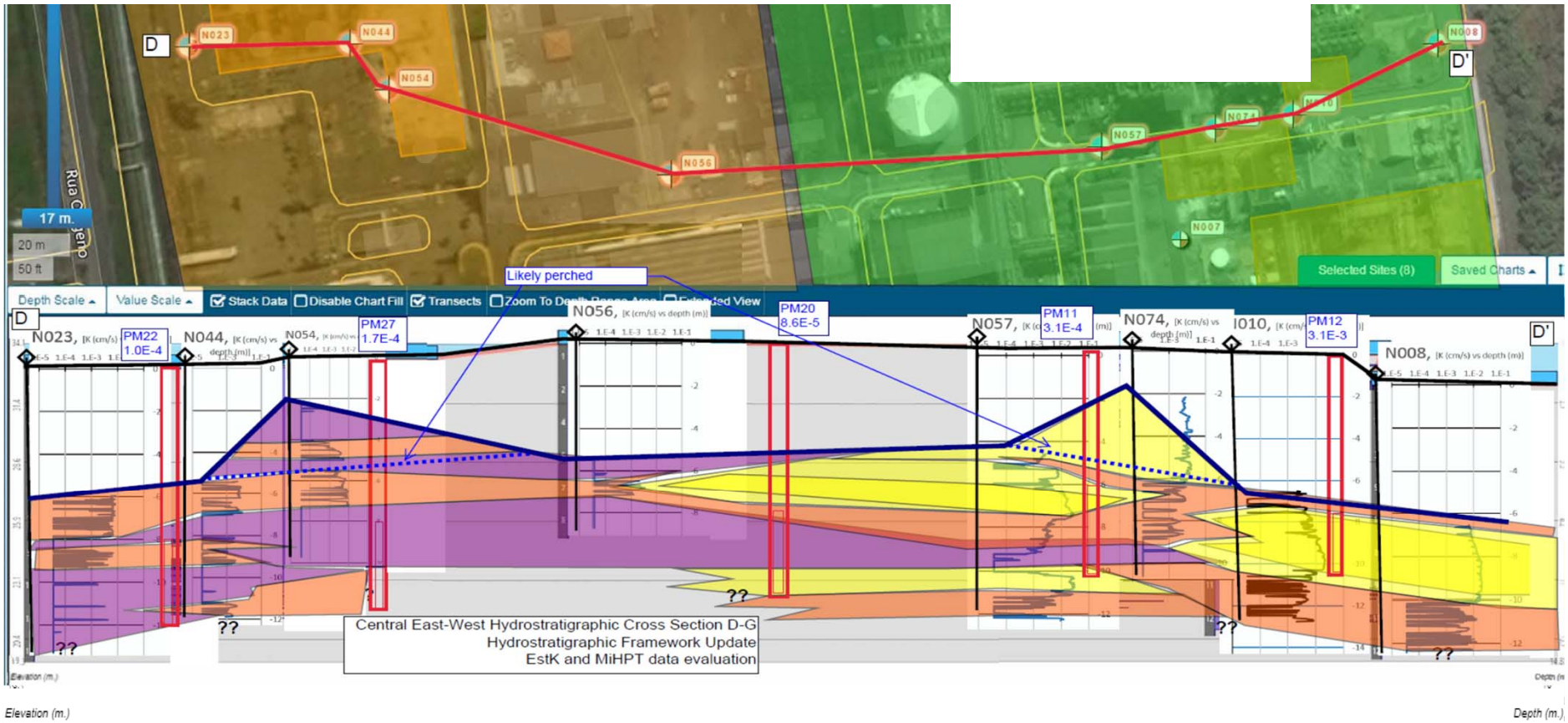
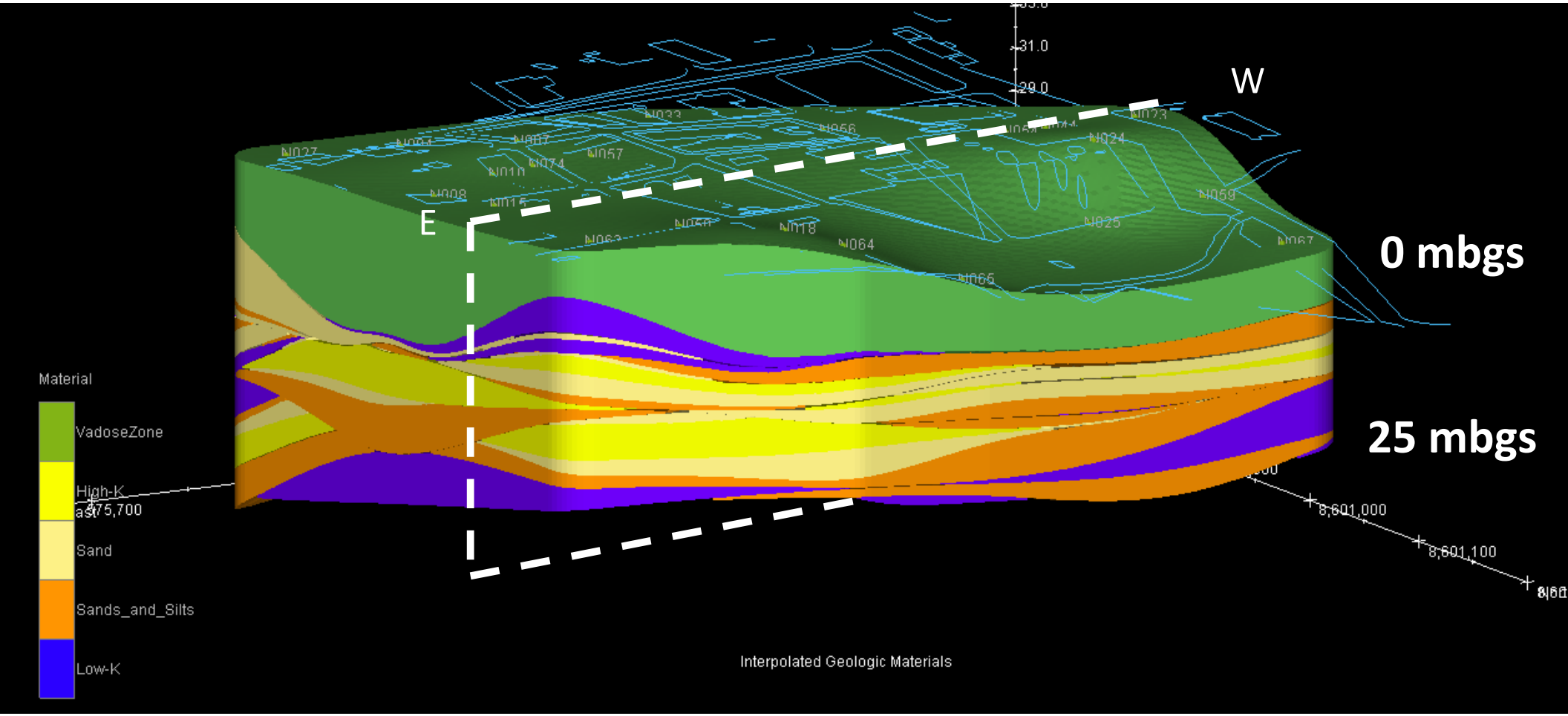


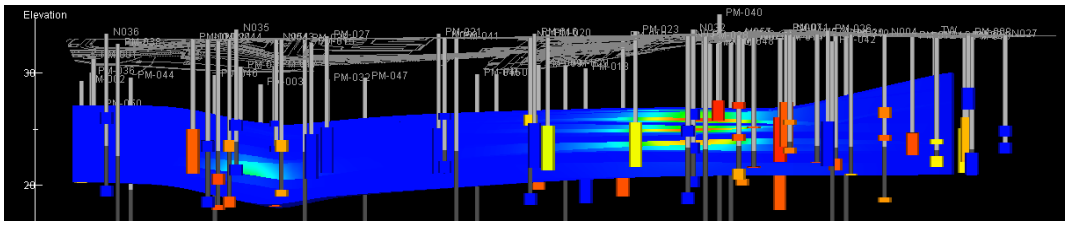
Preferential Flow intervals (0-15 mbgs)





Mass Flux
Chloroanilines HSU II and III

W



E

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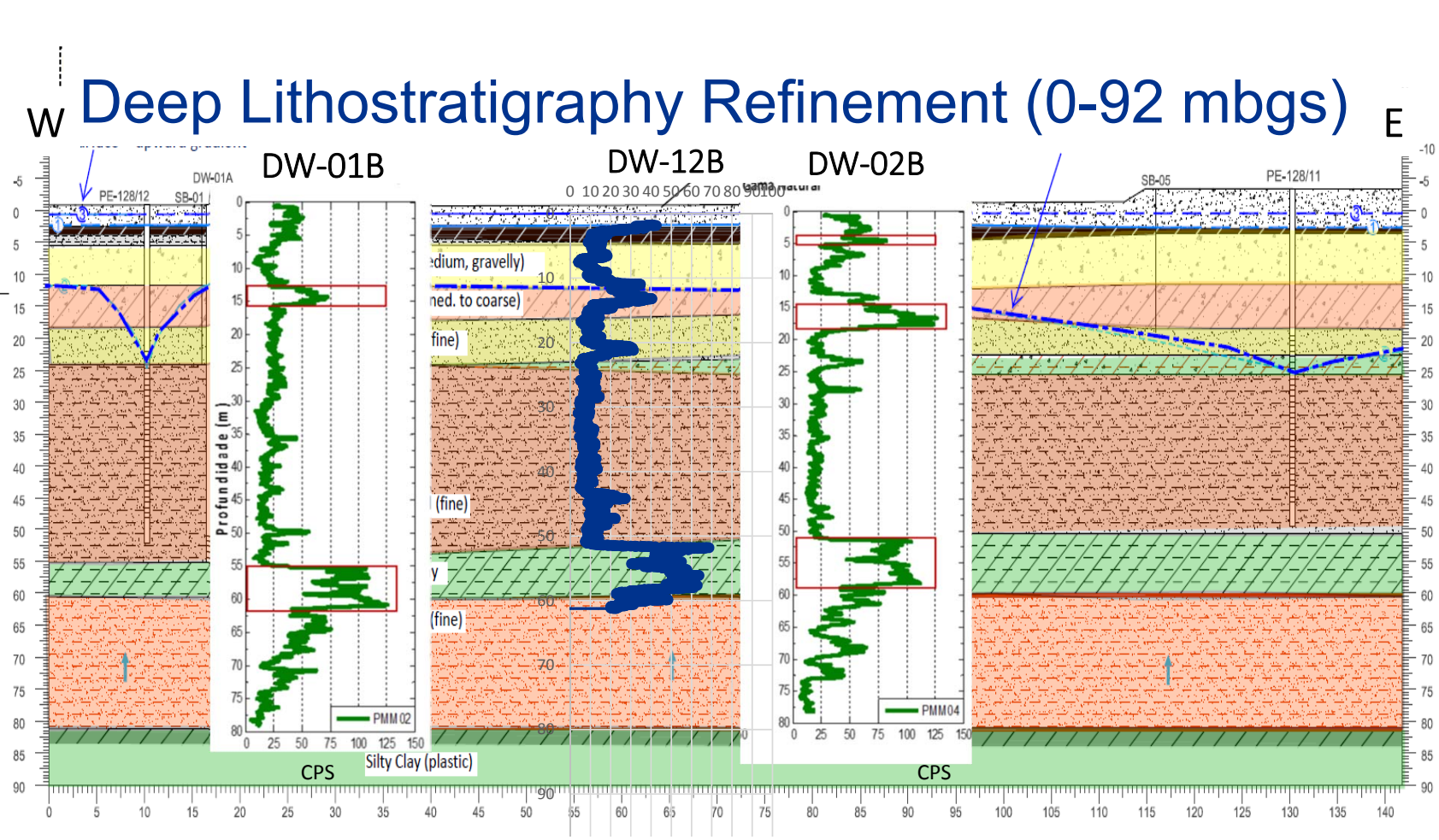
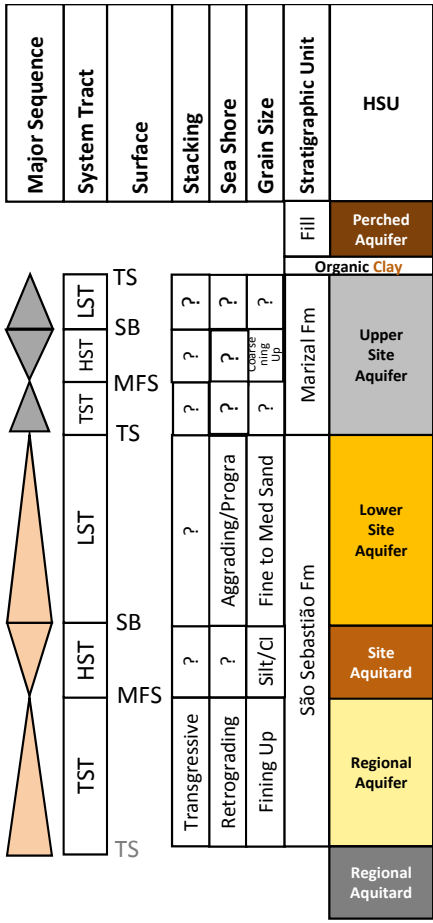
Deep Lithostratigraphy Refinement (0-92 mbgs)

W E





Surfaces:
MFS: Maximum flooding surface
TS: Transgressive Surface
SB: Sequence Boundary

Parasequences:
TST: transgressive system tract
HST: highstand system tract
LST: lowstand system tract

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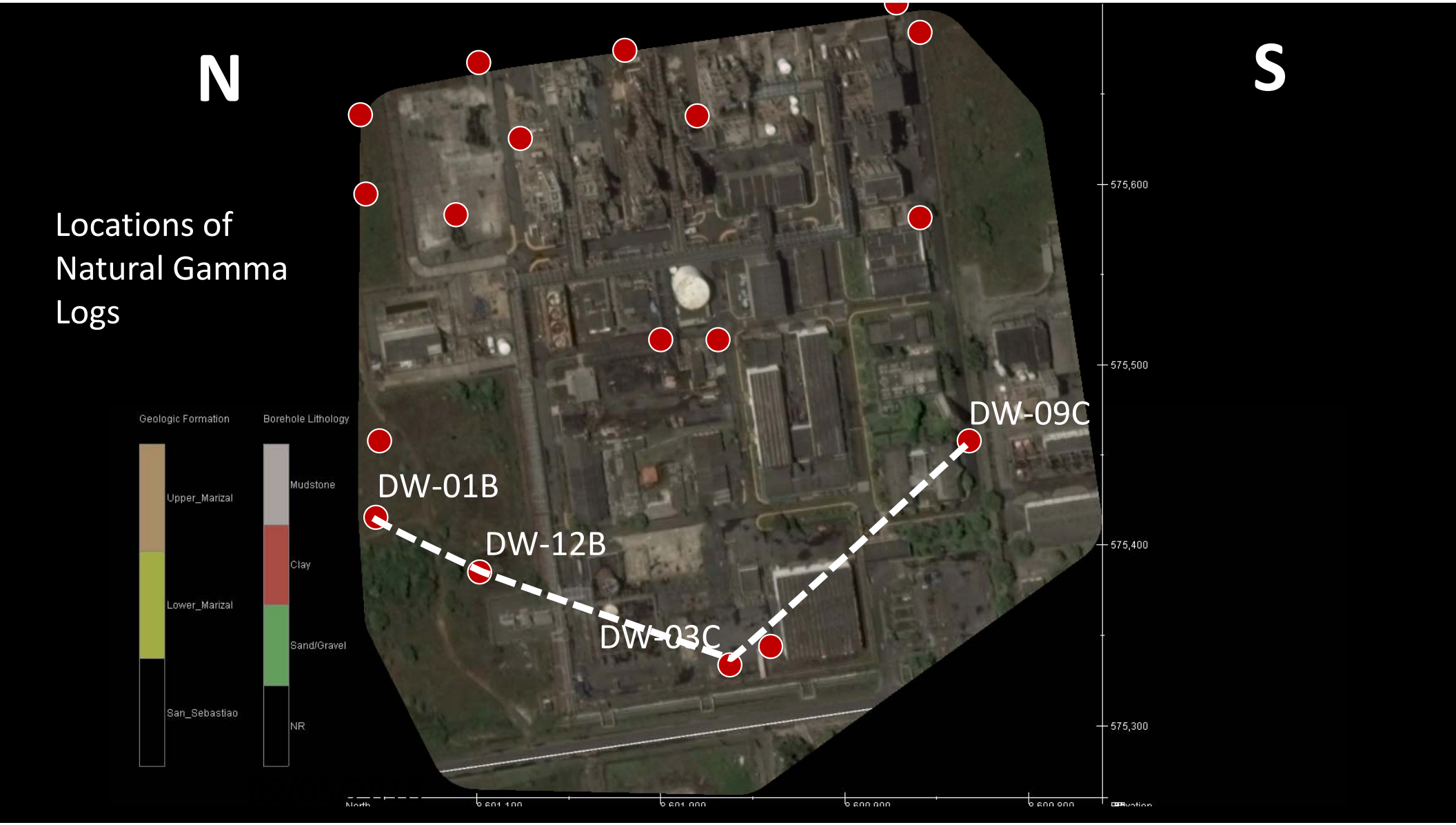
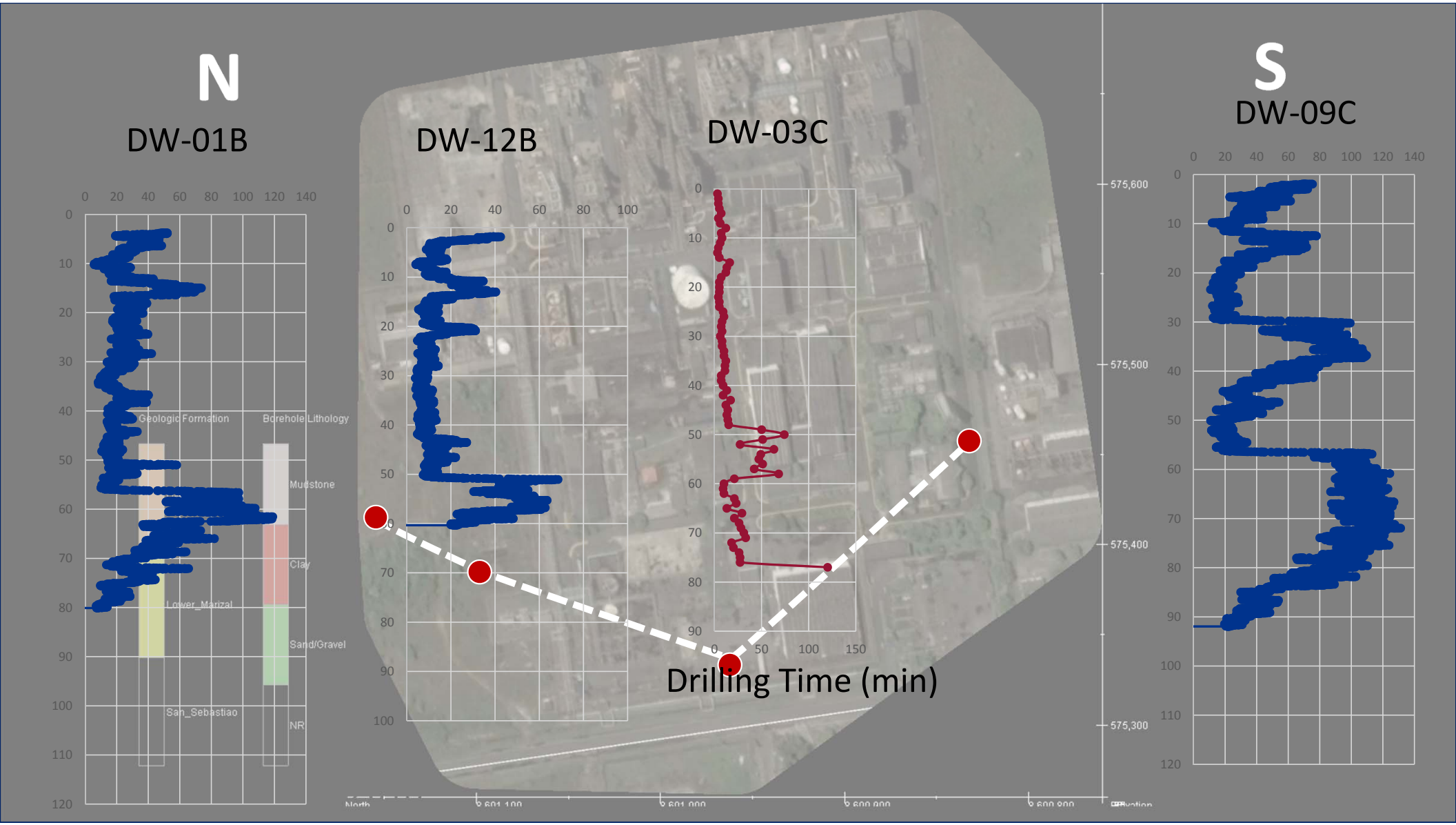
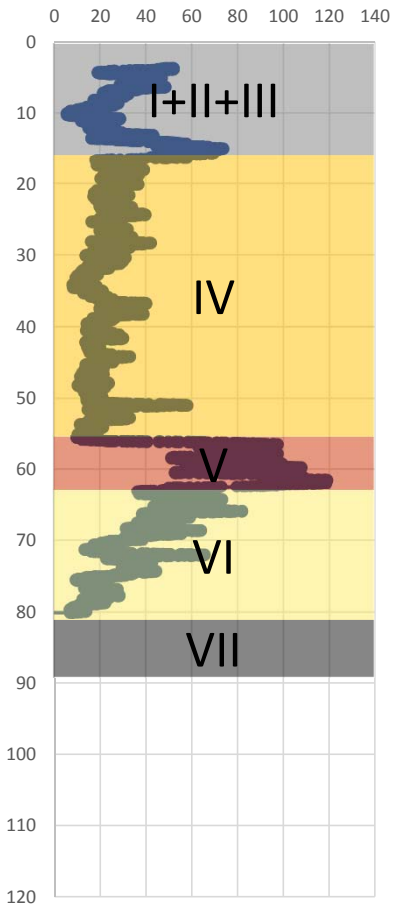

N
S
Locations of Natural Gamma Logs
Geologic Formation
Upper_Marizal
Lower_Marizal
San_Sebastiao
Borehole Lithology
Mudstone
Clay
Sand/Gravel
NR
DW-01B
DW-12B
DW-03C
DW-09C
575,600
575,500
575,400
575,300
North
Elevation

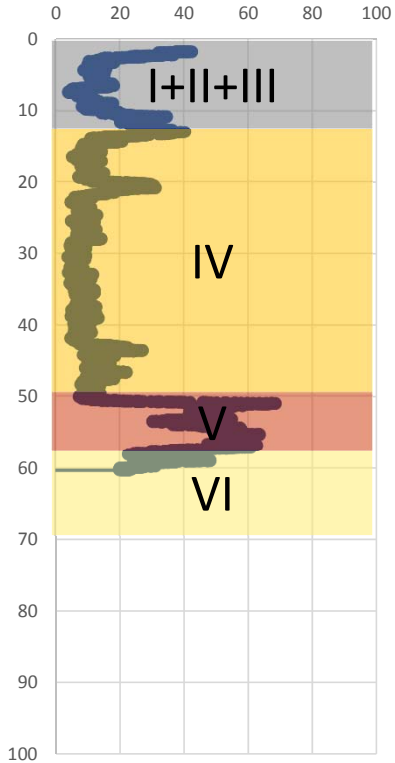

N
DW-01B
DW-12B
DW-03C
S
DW-09C
Geologic Formation
Borehole Lithology
Mudstone
Clay
Lower_Marizal
Sand/Gravel
San_Sebastiao
NR
Drilling Time (min)
575,600
575,500
575,400
575,300

N

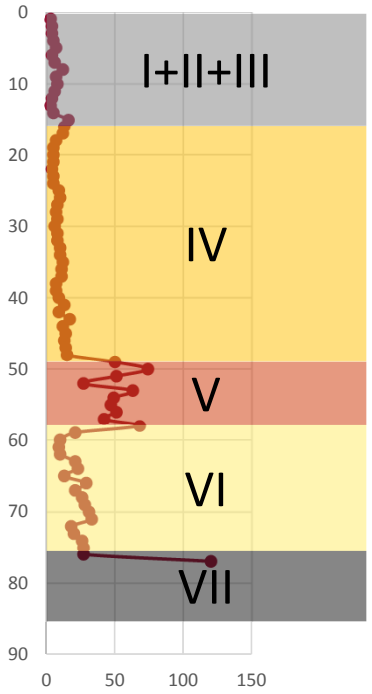
DW-01B



DW-12B



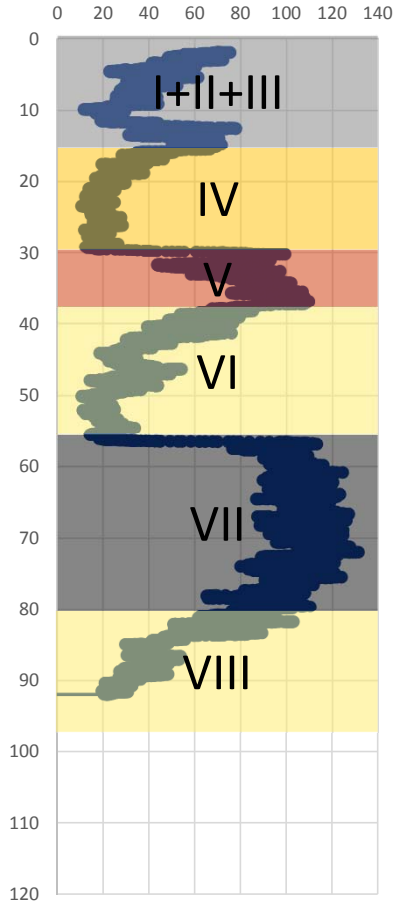
DW-03C



Drilling Time (min)

S

DW-09C



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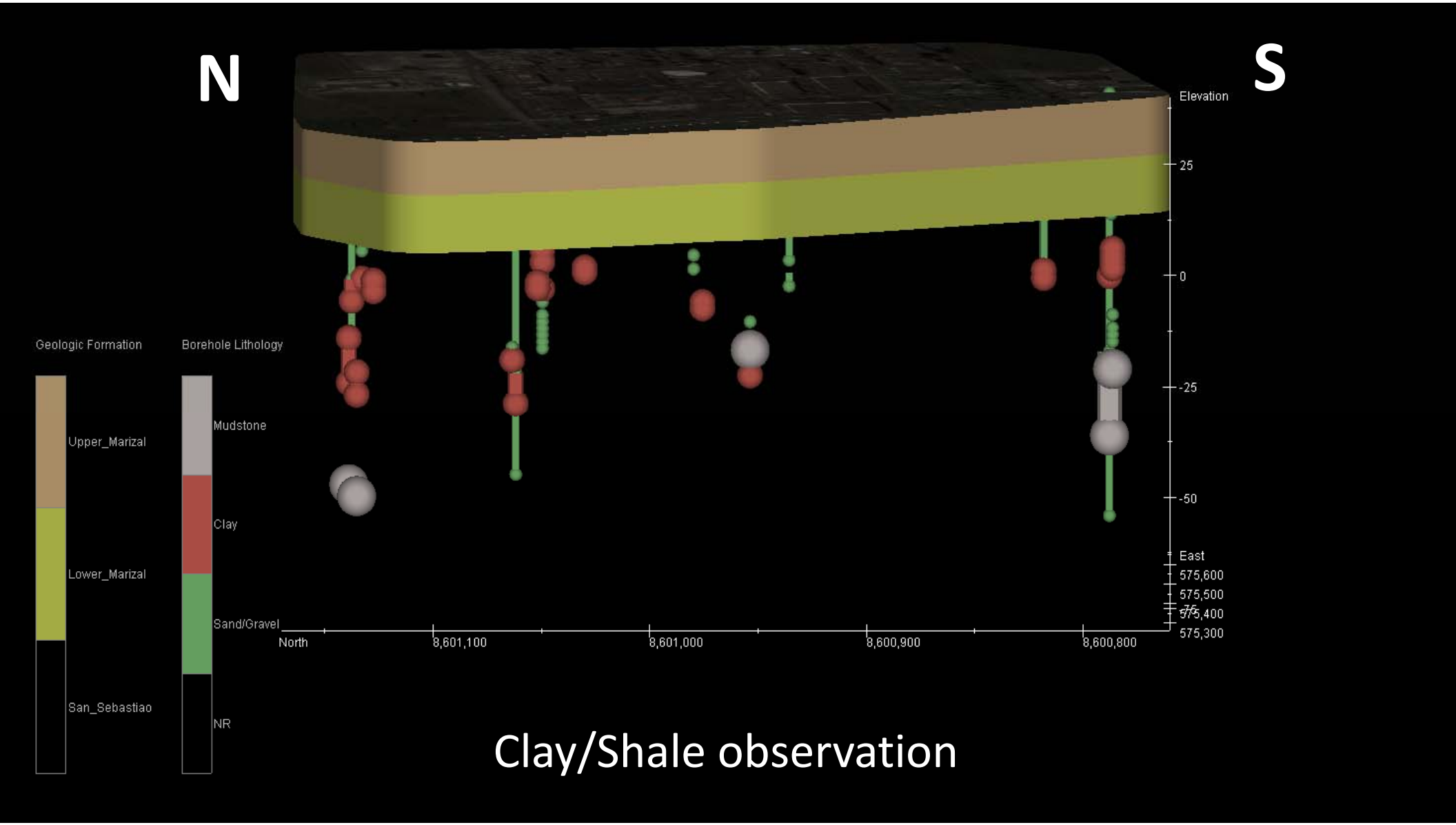
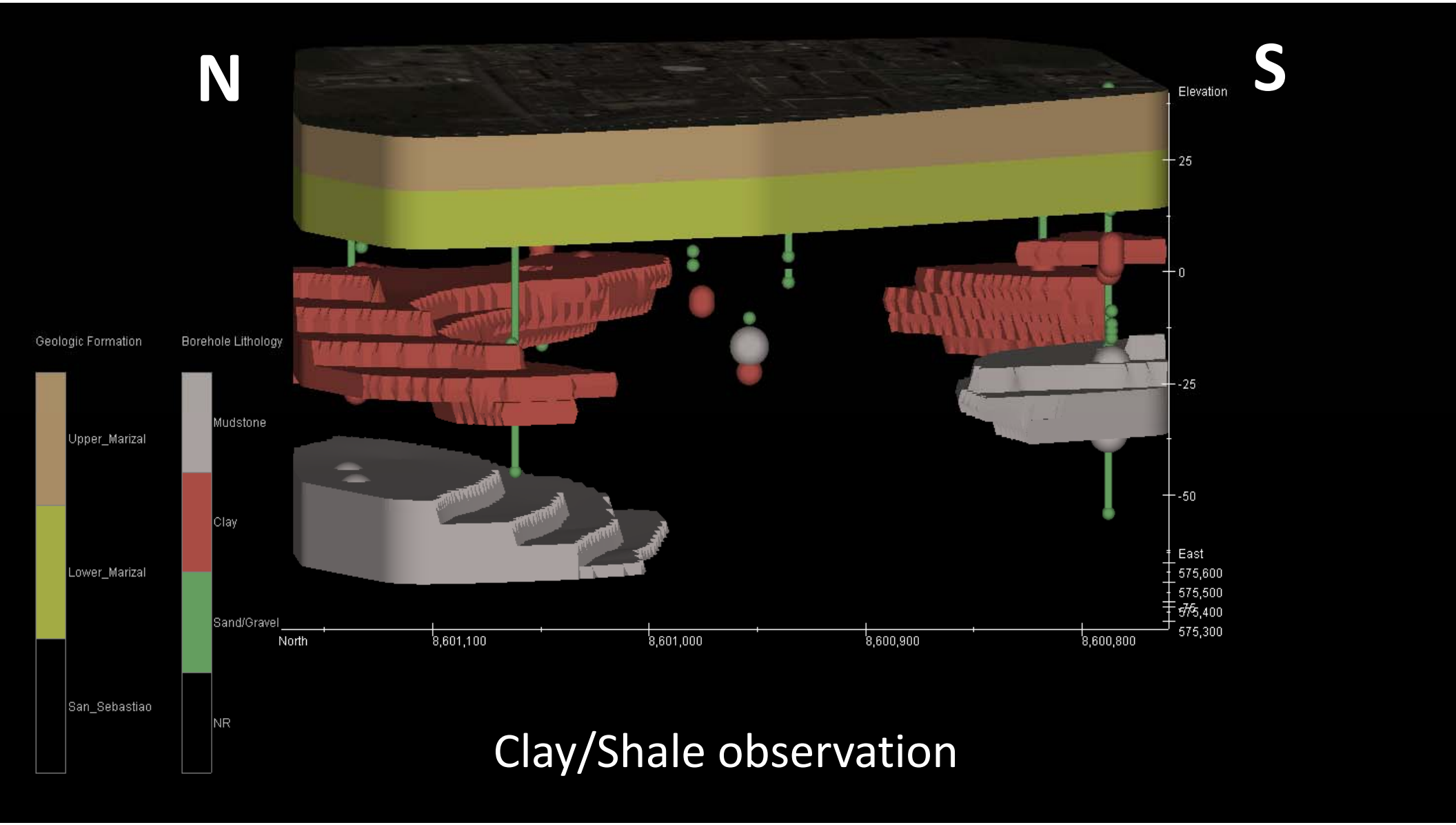
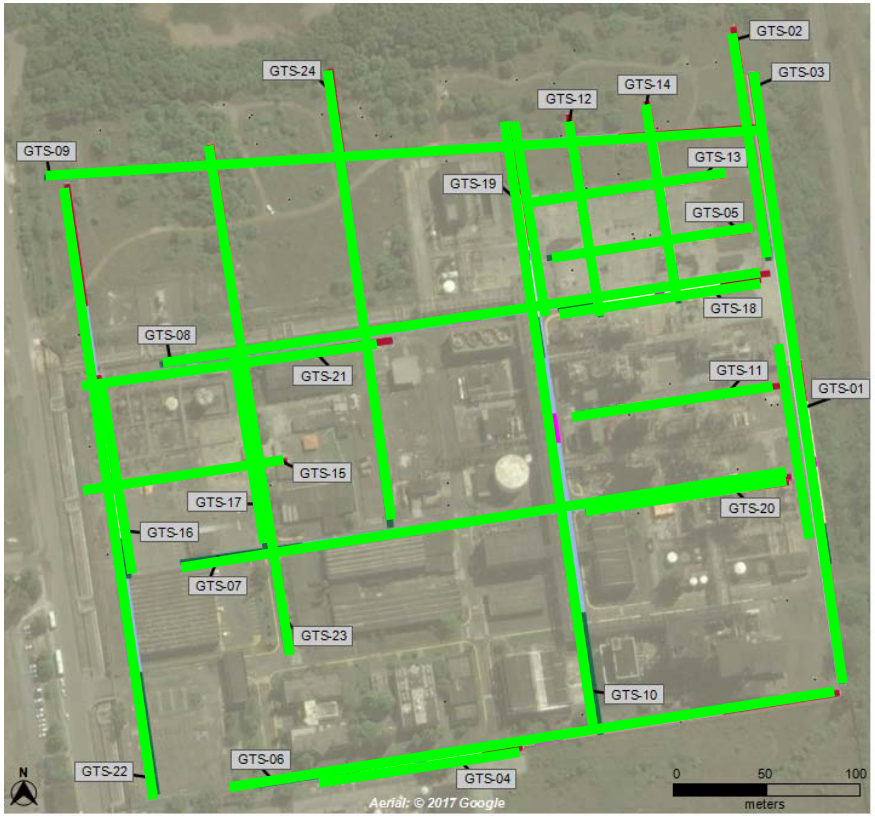


Clay/Shale observation



Clay/Shale observation

Electric Resistivity Imaging
Surface Geophysics



LEGEND:

GeoTrax Survey™ Orientation and Designation

Electrode 1 — Electrode 56

GTS-01 — **2.0 Meter** Electrode Spacing
Line Length ~110 m (~361 ft)
Image Depth ~22 m (~72 ft)

GTS-02 — **2.3 Meter** Electrode Spacing
Line Length ~126.5 m (~415 ft)
Image Depth ~25.3 m (~83 ft)

GTS-21 — **3.0 Meter** Electrode Spacing
Line Length ~165 m (~541 ft)
Image Depth ~33 m (~108 ft)

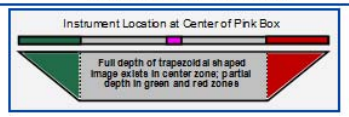
GTS-24 — **4.5 Meter** Electrode Spacing
Line Length ~247.5 m (~812 ft)
Image Depth ~49.5 m (~162 ft)

GTS-23 — **5.0 Meter** Electrode Spacing
Line Length ~275 m (~902 ft)
Image Depth ~55 m (~180 ft)

GTS-06 — **5.75 Meter** Electrode Spacing
Line Length ~316.3 m (~1037 ft)
Image Depth ~63.3 m (~207 ft)

GTS-03 — **6.0 Meter** Electrode Spacing
Line Length ~330 m (~1082 ft)
Image Depth ~66 m (~216 ft)

GTS-09 — **7.0 Meter** Electrode Spacing
Line Length ~385 m (~1263 ft)
Image Depth ~77 m (~253 ft)



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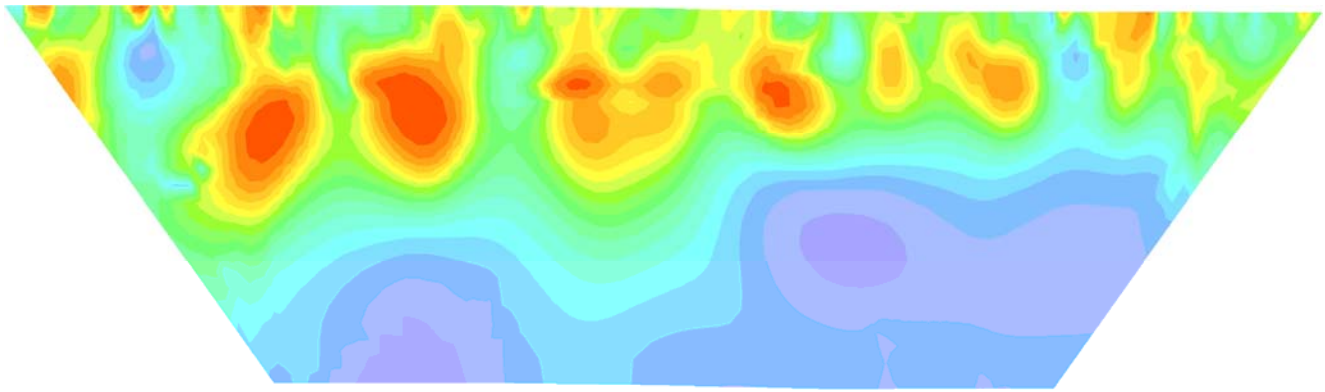
Electric Resistivity Imaging
Surface Geophysics

Background Electrical Signature
GTS-0630



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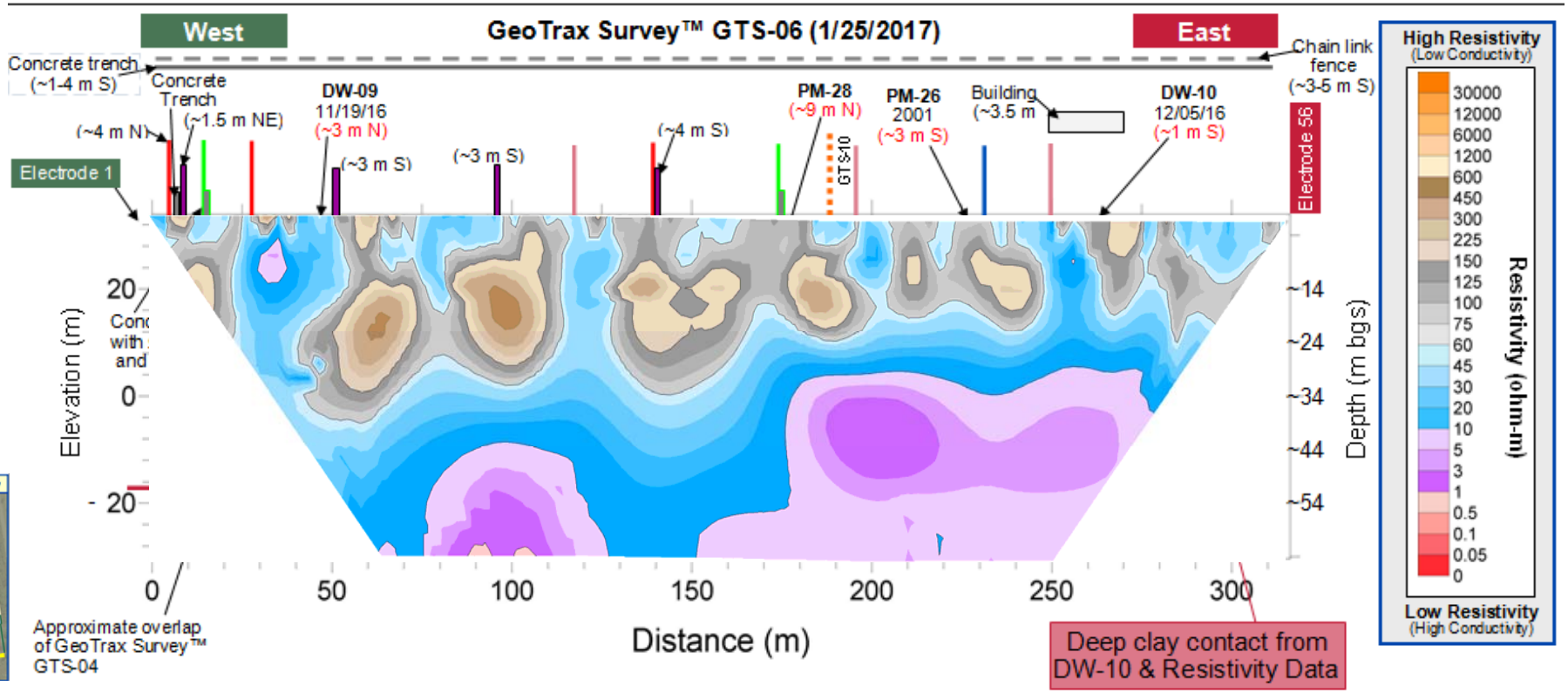
Electric Resistivity Imaging
Surface Geophysics

Background Electrical Signature
GTS-0630



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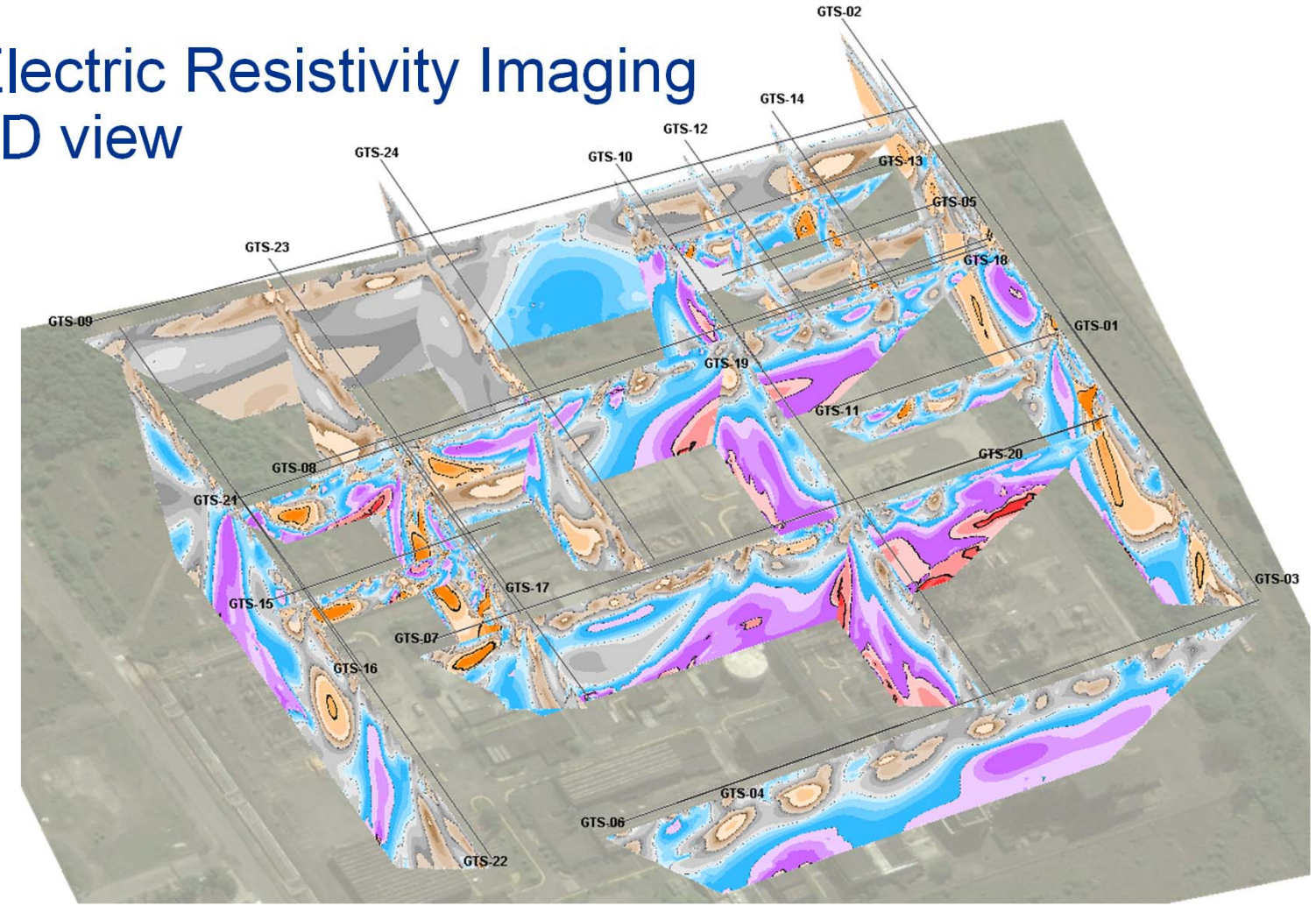
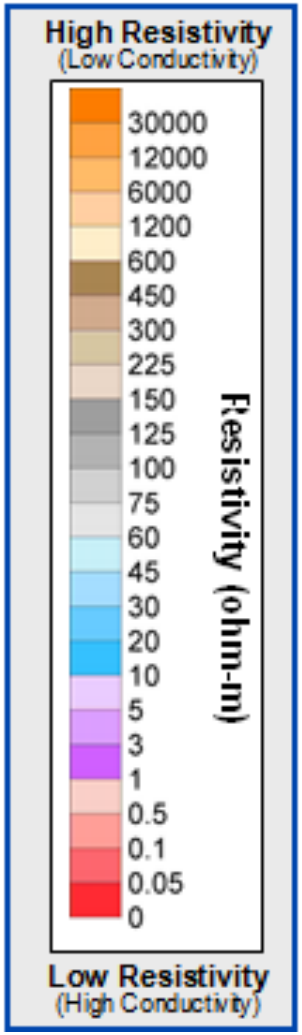
Electric Resistivity Imaging
3D view





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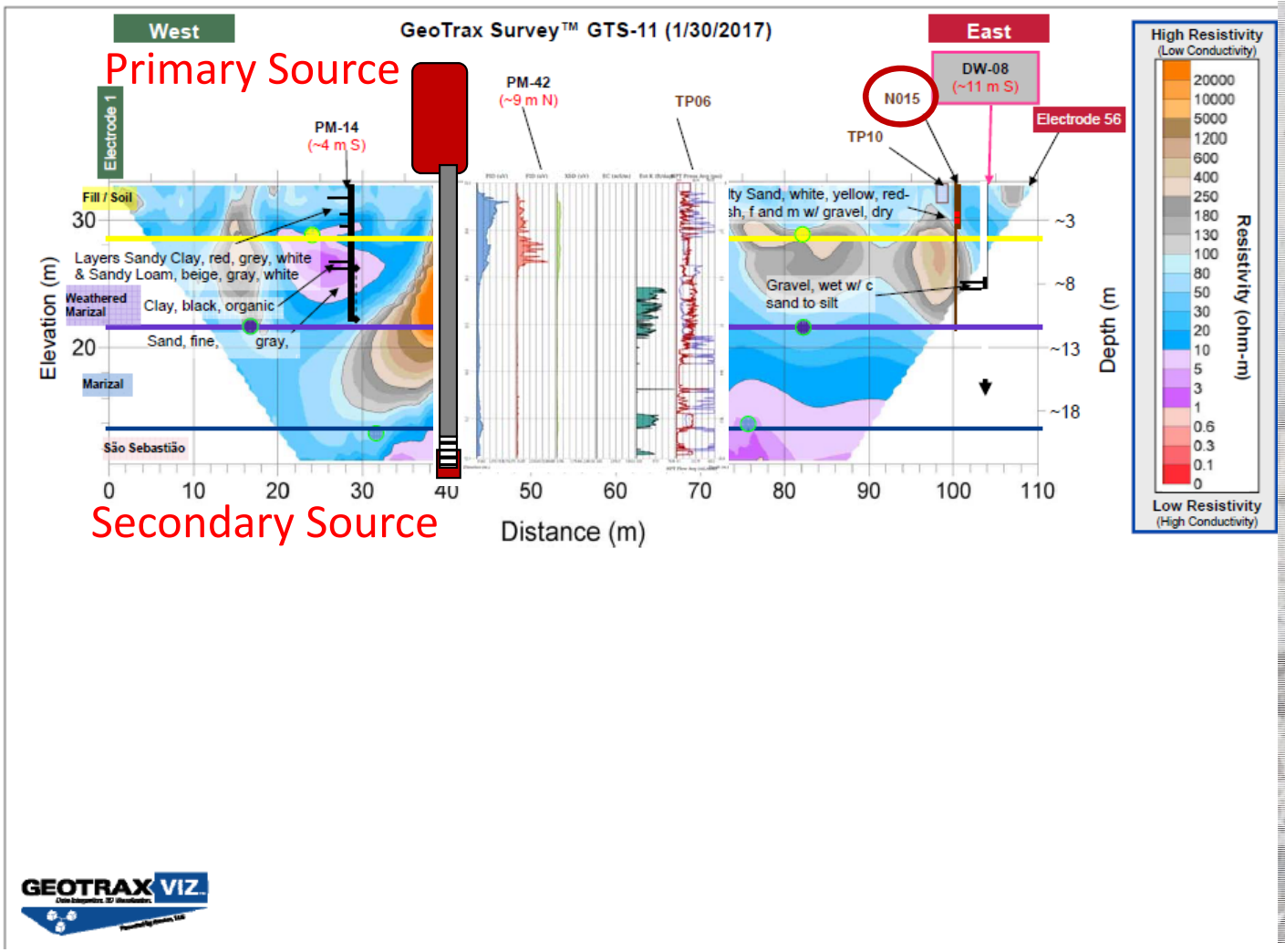
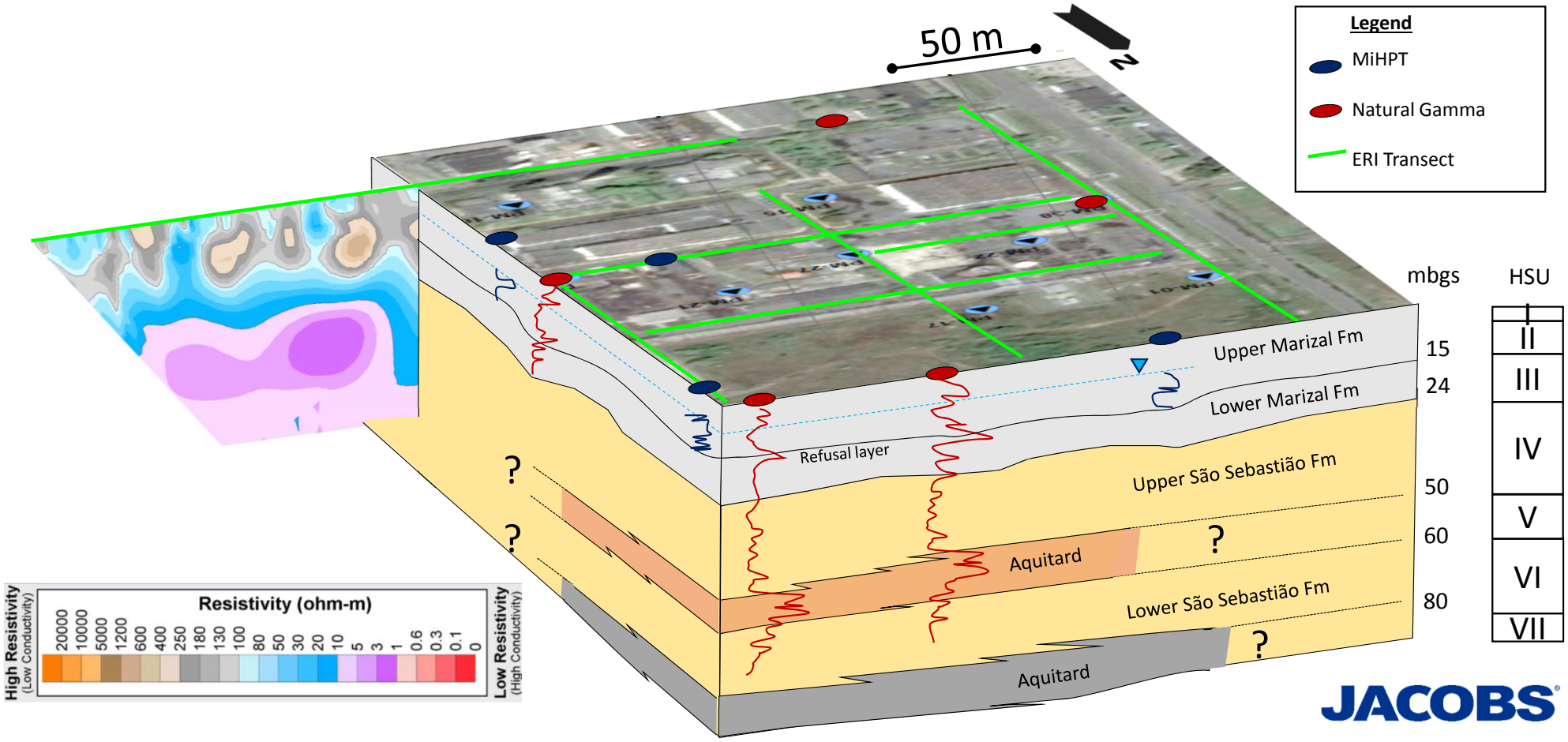
Confirmatory Drilling

After 1st round of Surface and Borehole geophysics



Integrated Indirect Methods and Hydrostratigraphic Units (HSUs)



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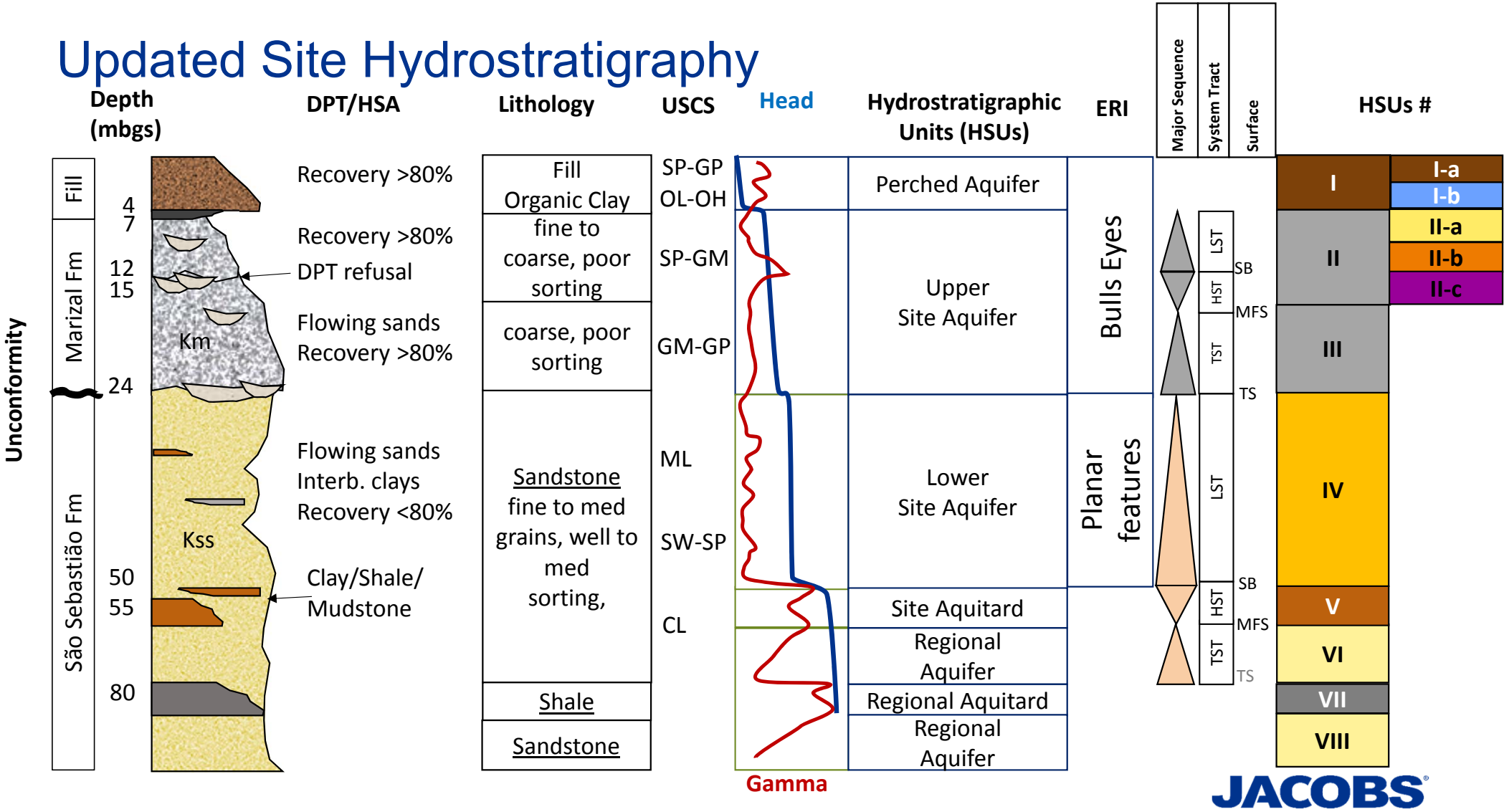
Updated Site Hydrostratigraphy



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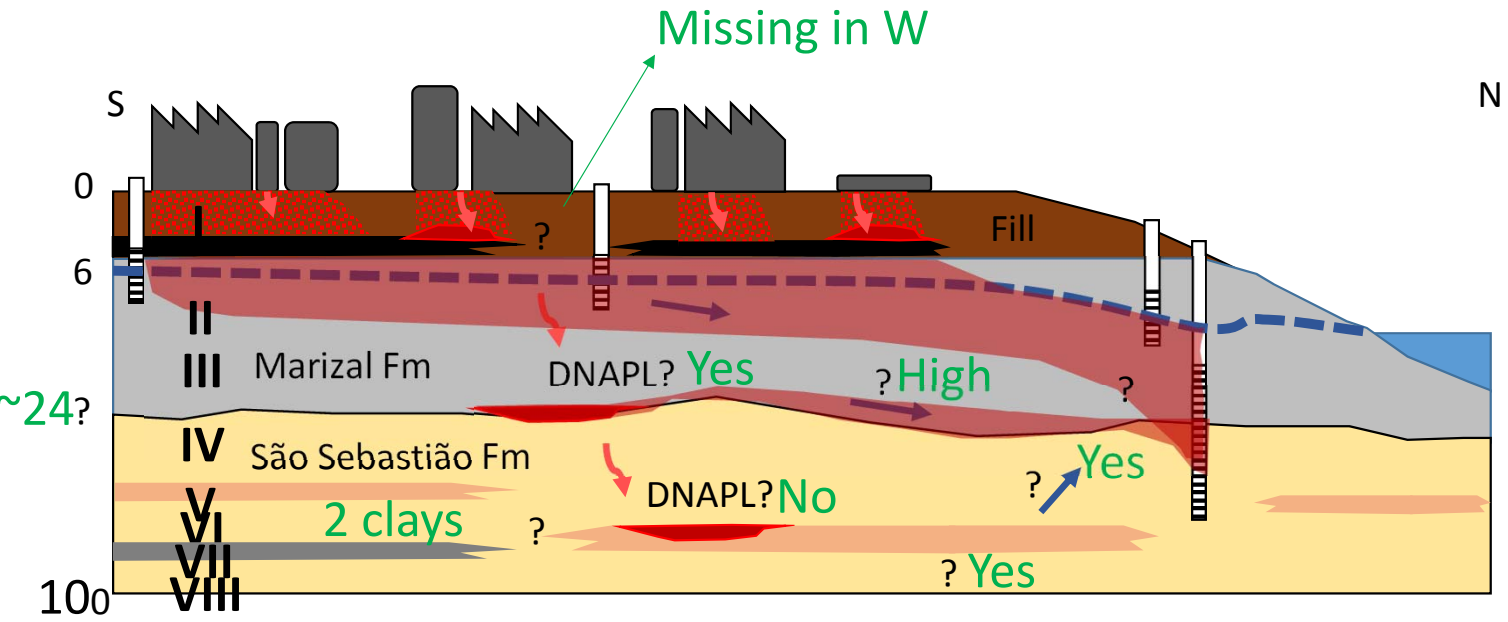
Revisiting CSM

- Unconformity as an important limit for mass distribution of COIs
- Zones of preferential flow in Marizal Fm
- Hydraulic Gradient between Regional and Site aquifer
- No indication of NAPL on site aquitard
- Semi-confinement conditions of the Regional Aquifer



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Conclusions and Take Away

Drill Smart!

Collaborative scenario:

Which tools to use in each HSU?

- MiHPT ➔ remedial design
- Gamma ➔ sequence stratigraphy
- ERI ➔ sitewide view

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Thank you!

Innovation that provides sustainable solutions to complex challenges worldwide

Site Hydrostratigraphy Refinement:
Integrated Field Methods for Characterizing a NAPL-Impacted Sedimentary Aquifer in Brazil

April 11th 2018

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