Open Environmental Restoration Resource (OER2) Webinar

Use of High Resolution Site Characterization (HRSC) to Delineate a Mixed Contaminant Plume in Fractured Bedrock

Presented by:

NAVFAC Environmental Restoration Program

Points of Contact

- **Brian Murray (Presenter): brian.s.murray@navy.mil**
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- **Tara Meyers (moderator): tara.meyers@navy.mil**

Logistics

- **Submit all questions via chat box throughout the presentation**
- **Presentation is being recorded**
- **Complete the webinar survey (main feedback mechanism)**

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OER2 Webinar Series

- **Why Attend?**
  - **Obtain and hear about the latest DOD and DON's policies/guidance, tools, technologies and practices to improve the ERP's efficiency**
  - **Promote innovation and share lessons learned**
  - **FEEDBACK to the ERP Leadership**
- **Who Should Attend?**
  - **ERP Community Members: RPMs, RTMs, Contractors, and other remediation practitioners who support and execute the ERP**
  - **Voluntary participation**
- **Schedule and Registration:**
  - **Every other month, 4th Wed (can be rescheduled due to holidays)**
  - **Registration link for each topic (announced via ER T2 email)**
- **Topics and Presenters:**
  - **ERP community members to submit topics (non-marketing and DON ERP-relevant) to POCs (Gunarti Coghlan – gunarti.coghlan@navy.mil or Tara Meyers - tara.meyers@navy.mil)**
  - **Selected topic will be assigned Champion to work with presenter**

Speaker Introduction

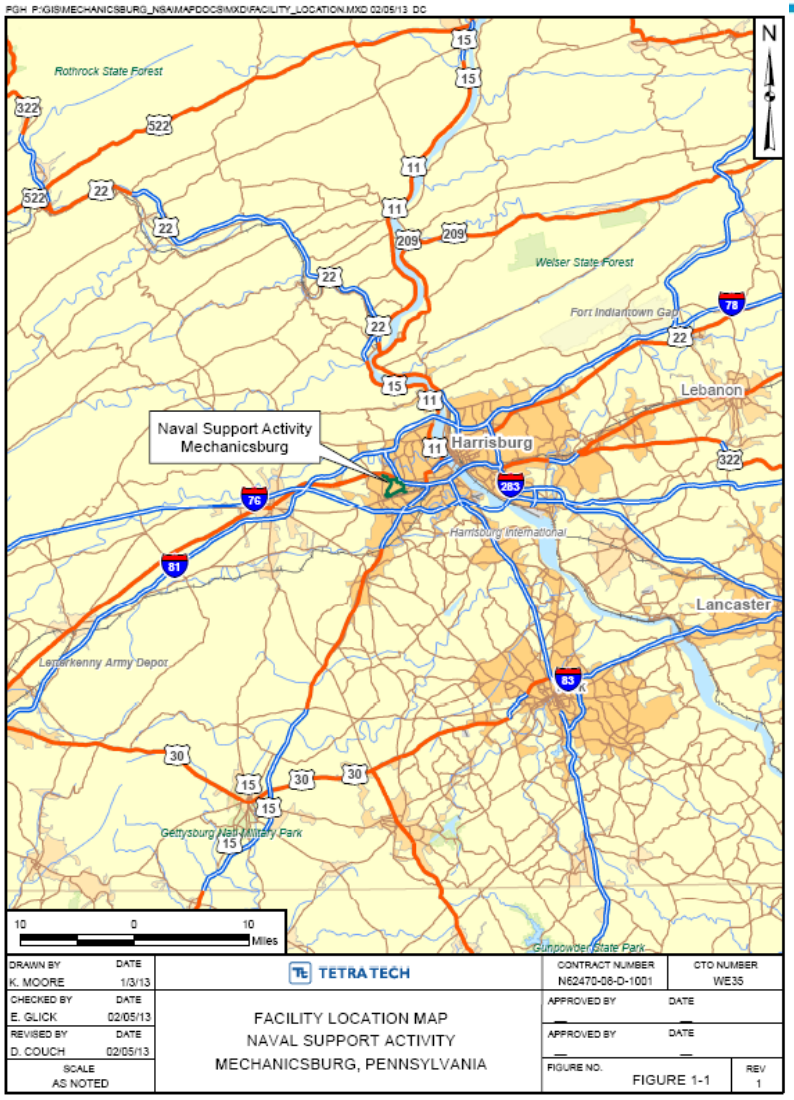
- **RPM NAVFAC Mid-Atlantic Region**
- **20+ yrs. experience in environmental restoration**
- **Manages the ER activities at Naval Support Activity Mechanicsburg (PA), Naval Weapons Station Earle, (NJ), and former Naval Reserve Ordnance Plant (MN).**

- **Senior research scientist at Battelle Memorial Institute**
- **Expertise in both biological and abiotic transformation of contaminants**
- **Lead author of NAVFAC handbook on In Situ Biogeochemical Transformation Processes for Treating Contaminated Groundwater**

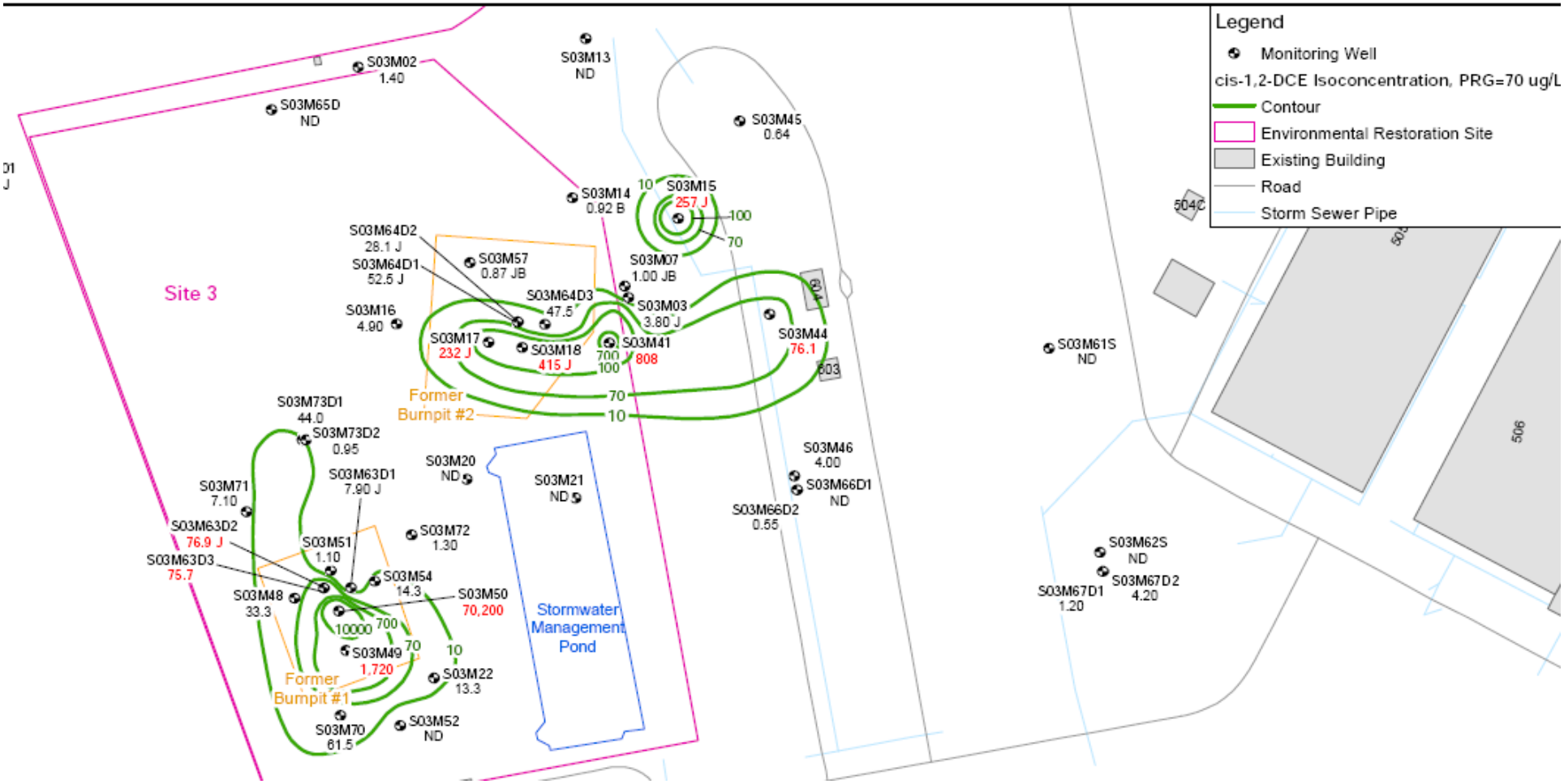
Use of High Resolution Site Characterization (HRSC) to Delineate a Mixed Contaminant Plume in Fractured Bedrock

Brian Murray
Ramona Darlington
June 2016

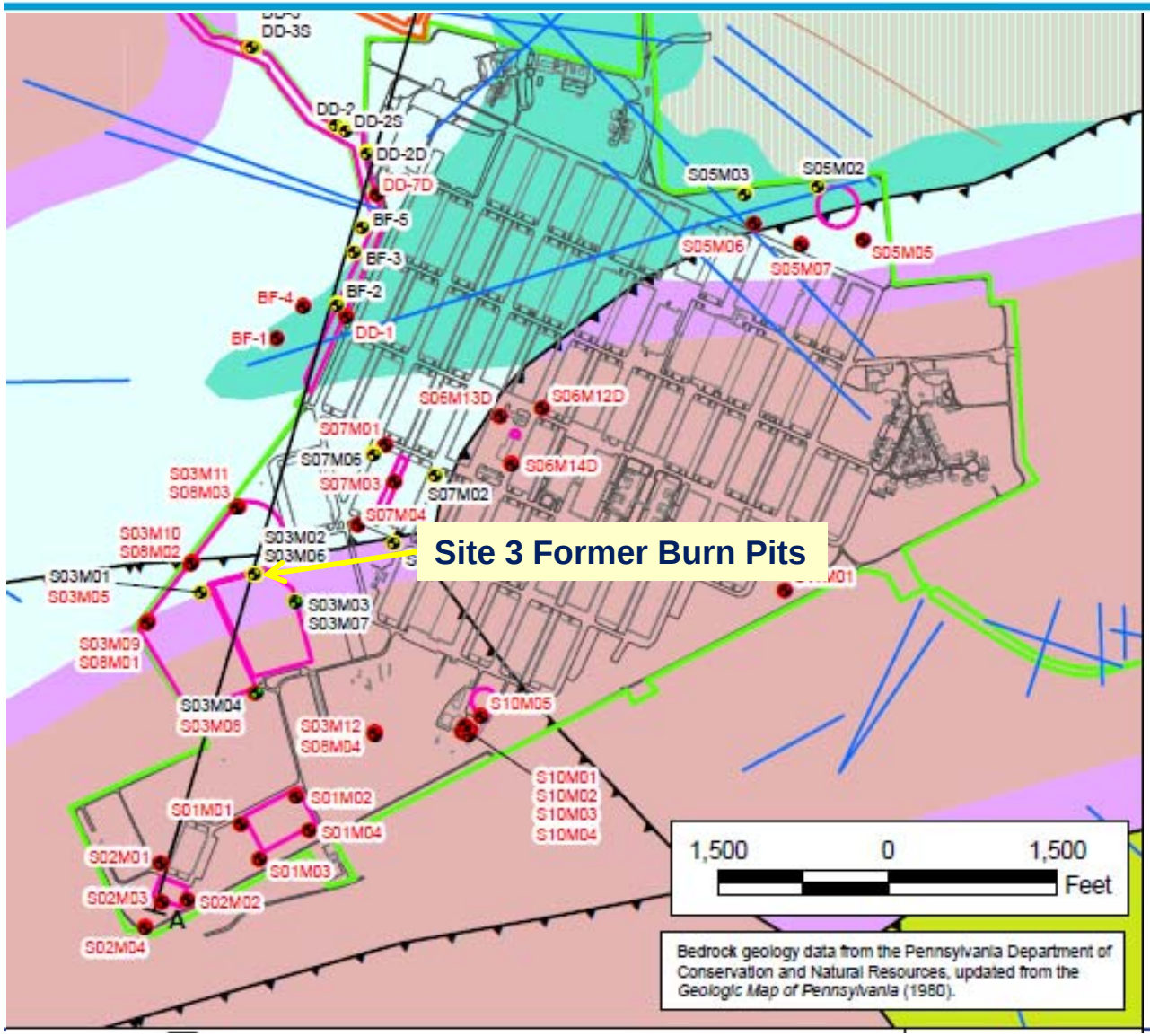
Site Background



Site History

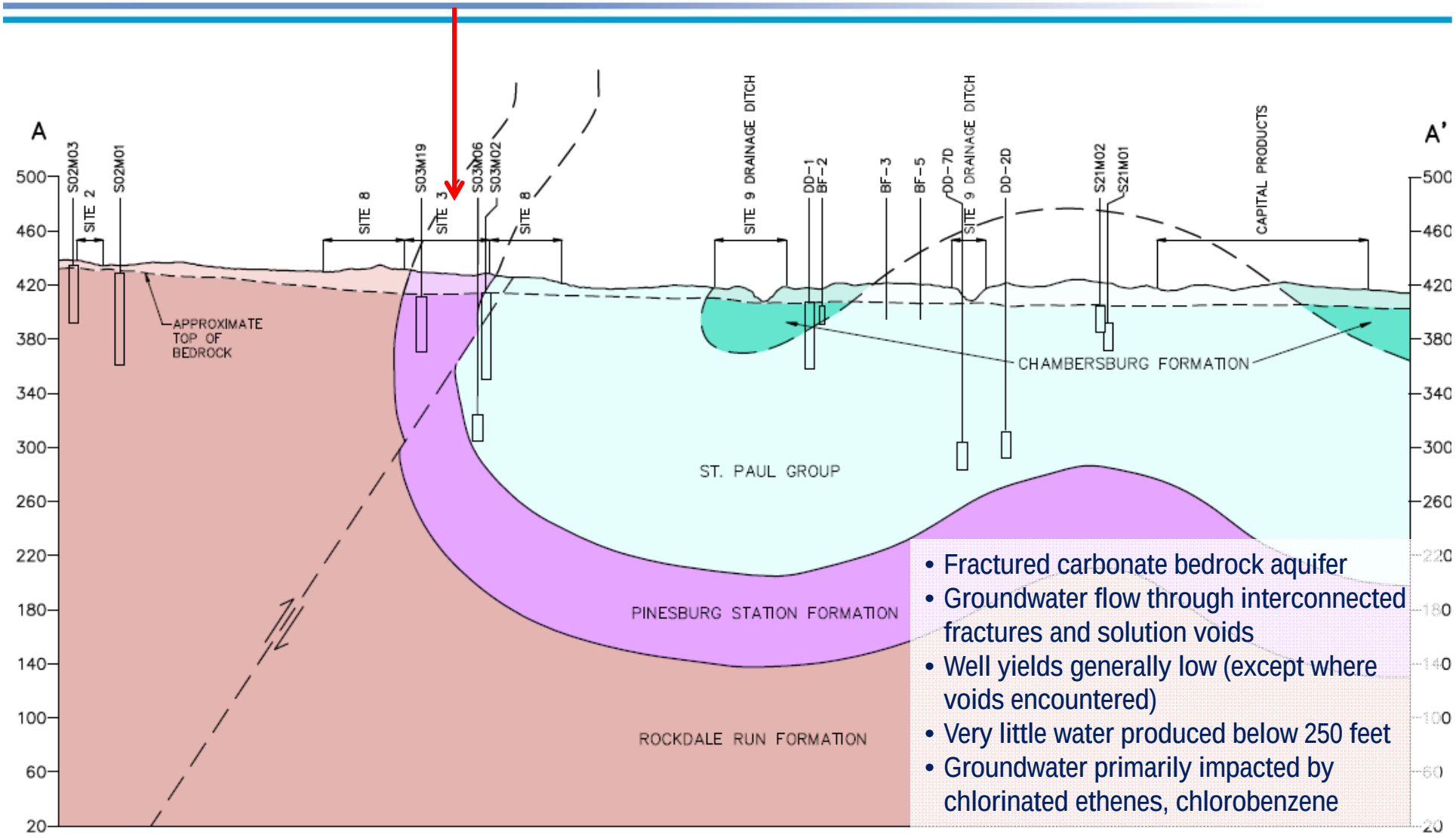


Geologic Setting of Burn Pits



- Area geology is complex (folded strata, thrust faults, varying rock properties)
- Thin veneer of clayey residual soils abv. Shallow bedrock
- Karst development results in presence of relict voids and cavities

Geologic Setting of Site 3 Burn Pit Area



- Fractured carbonate bedrock aquifer
- Groundwater flow through interconnected fractures and solution voids
- Well yields generally low (except where voids encountered)
- Very little water produced below 250 feet
- Groundwater primarily impacted by chlorinated ethenes, chlorobenzene

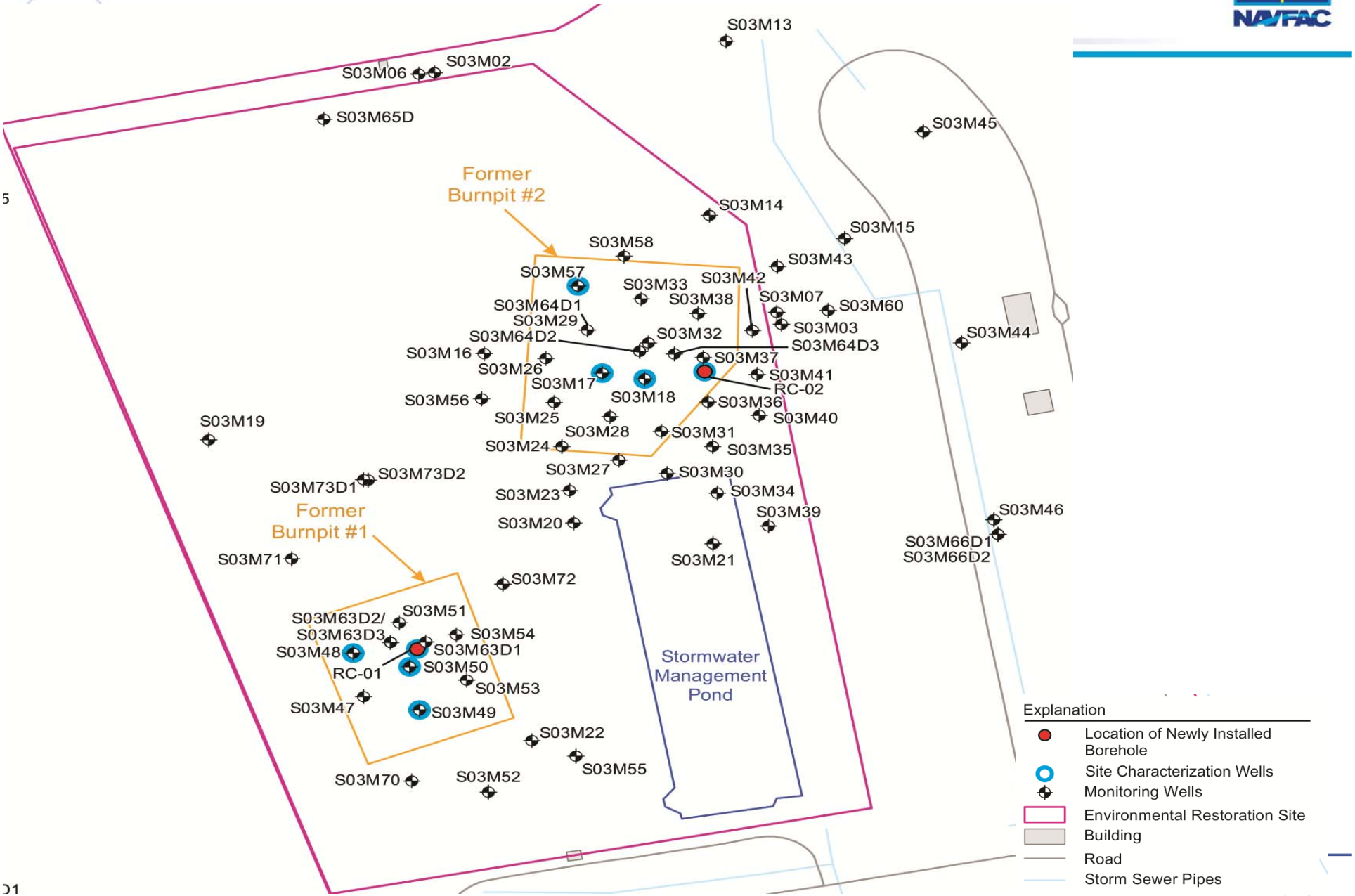
Site Contaminants of Concern (COCs)

COCs	Target Concentration
Volatile Organics (µg/L)	
TCE	5
cis-DCE	70
VC	2
1,4-dichlorobenzene	75
Chlorobenzene	100
Benzene	5
Carbon Tetrachloride	5
Inorganics (µg/L)	
As	10
Mn	314
PCBs (µg/L)	
Aroclor-1260	0.5

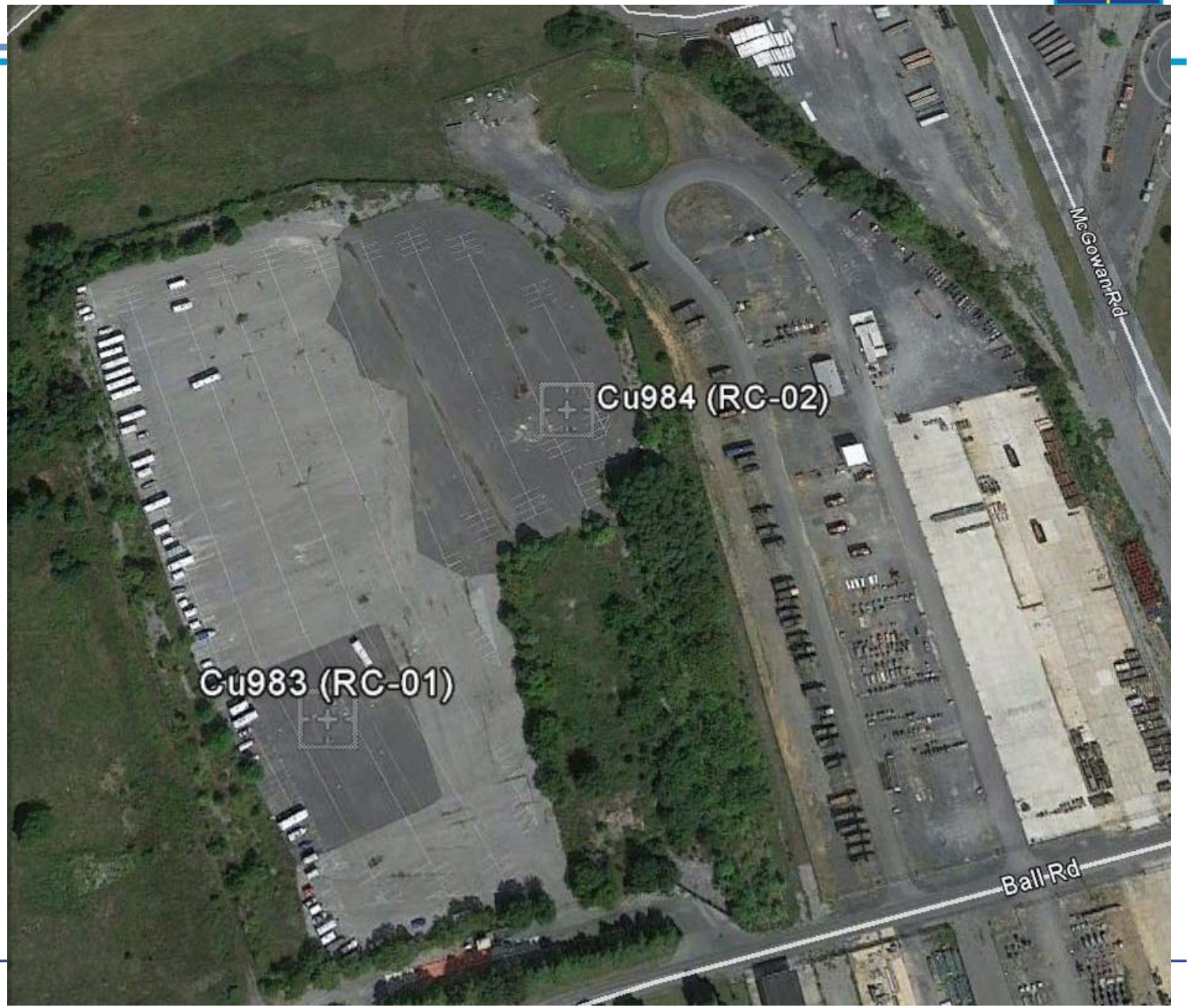
Objective of High Resolution Site Characterization

- **Refine the understanding of site geology through the collection of rock cores and borehole logging.**
- **Determine contaminant concentrations and site geochemistry in groundwater at the location of water-bearing fractures.**
- **Understand site geochemistry prior to insitu biogeochemical transformation application**
- **Use data to target amendment injection in zones of flow and high COC concentration**

Map of New Coreholes and Existing Monitoring Wells



RC-01 and RC-02 Corehole Locations

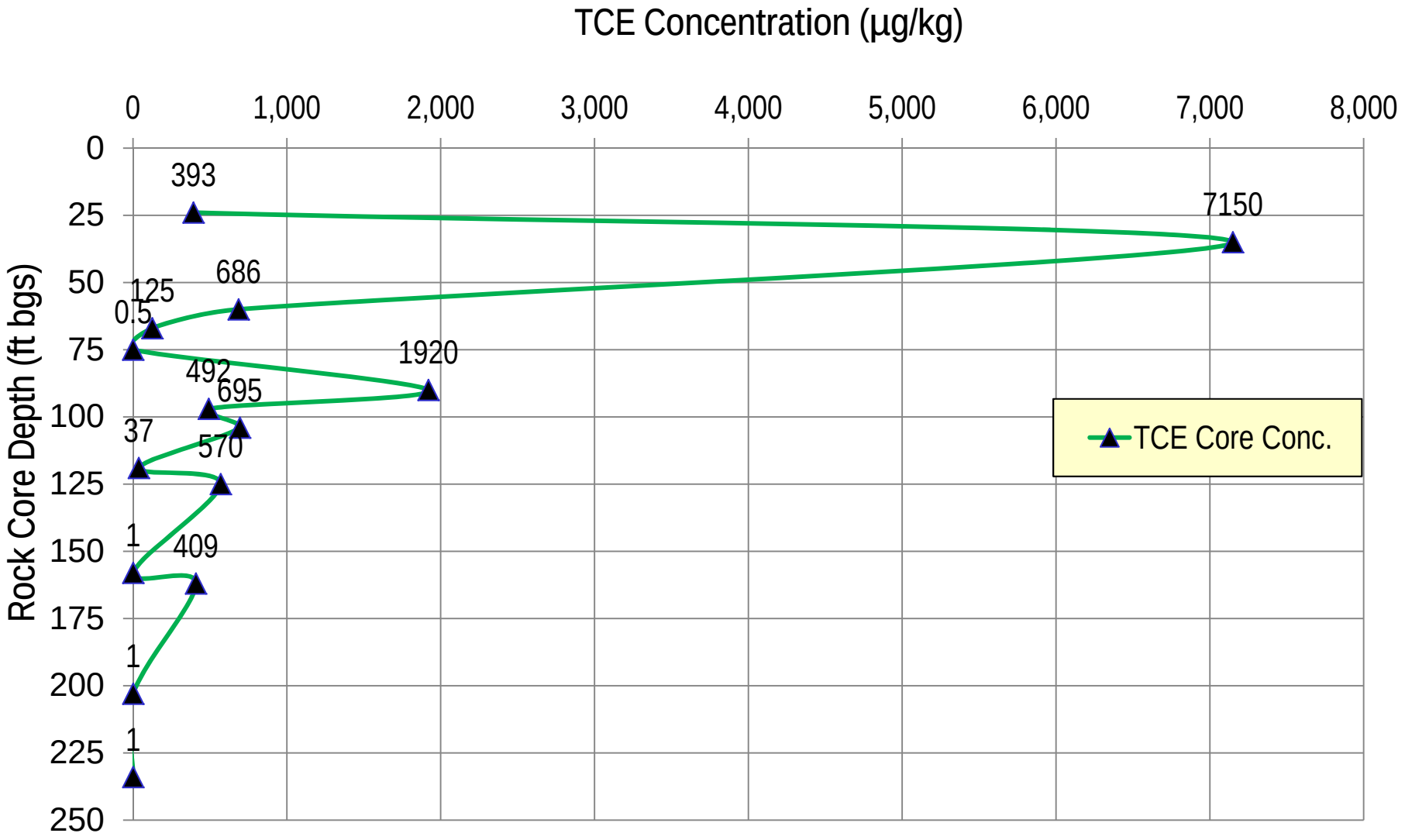


CORE ANALYSIS AND RESULTS

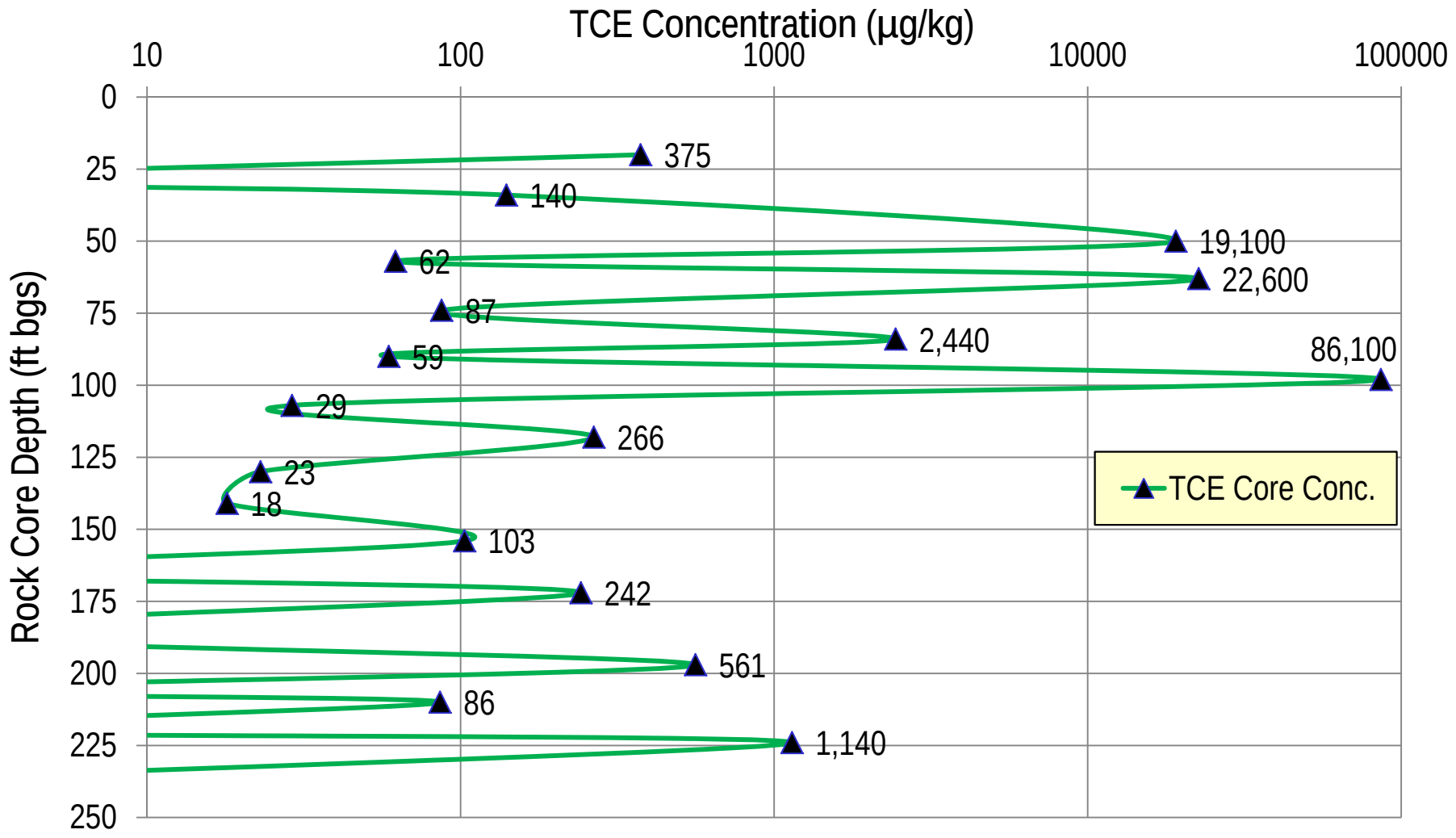
Field and Laboratory Analysis of Rock Core

- **Photoionization detector (PID) screening**
- **FLUTe™ liners**
- **Core VOC analysis**
- **Magnetic susceptibility**
- **X-ray diffraction (XRD)**
- **Scanning Electron Microscopy Energy Dispersive Spectroscopy (SEM-EDS)**

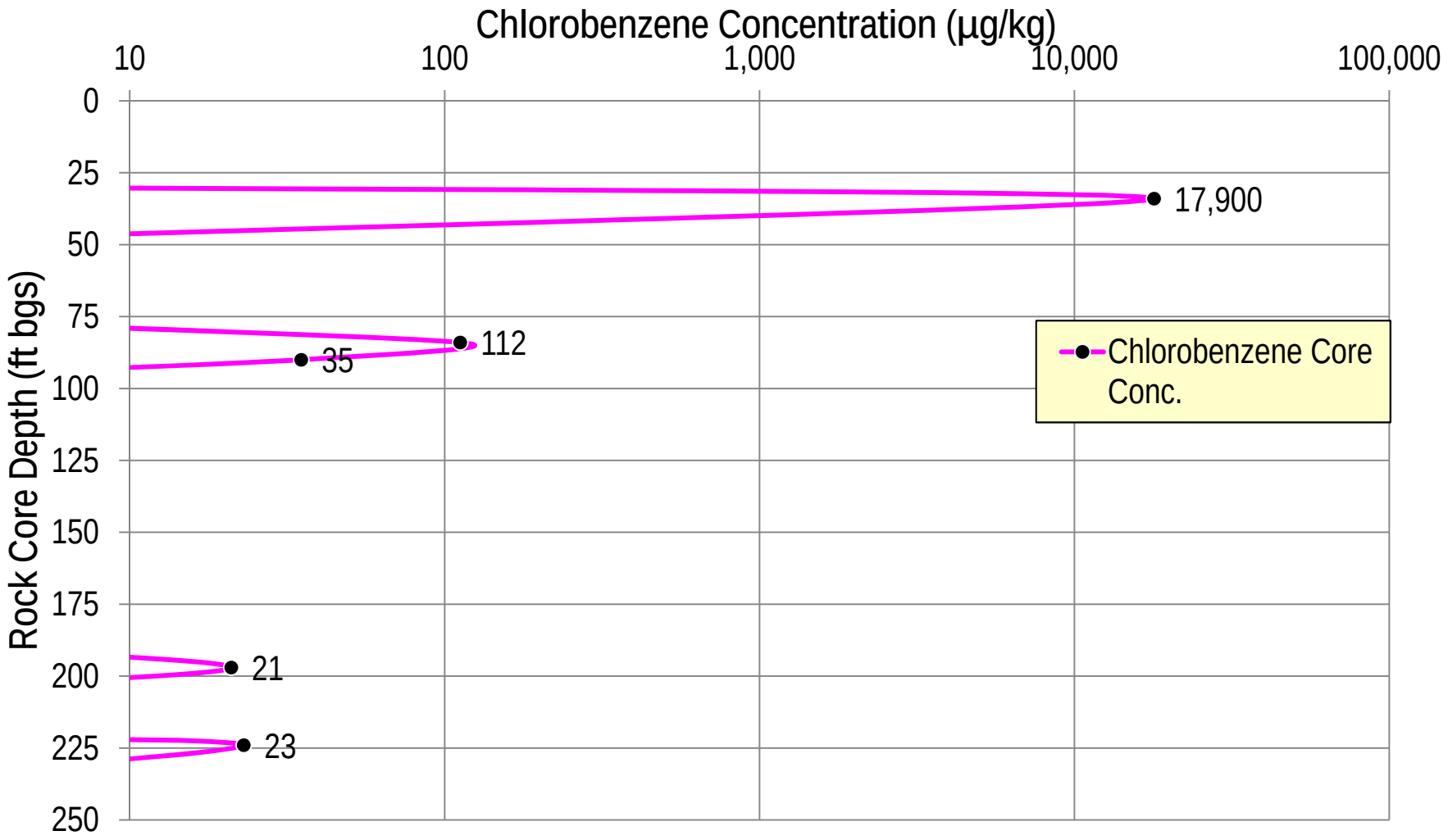
TCE Concentration in Rock Matrix - RC-01



TCE Concentration in Rock Matrix - RC-02

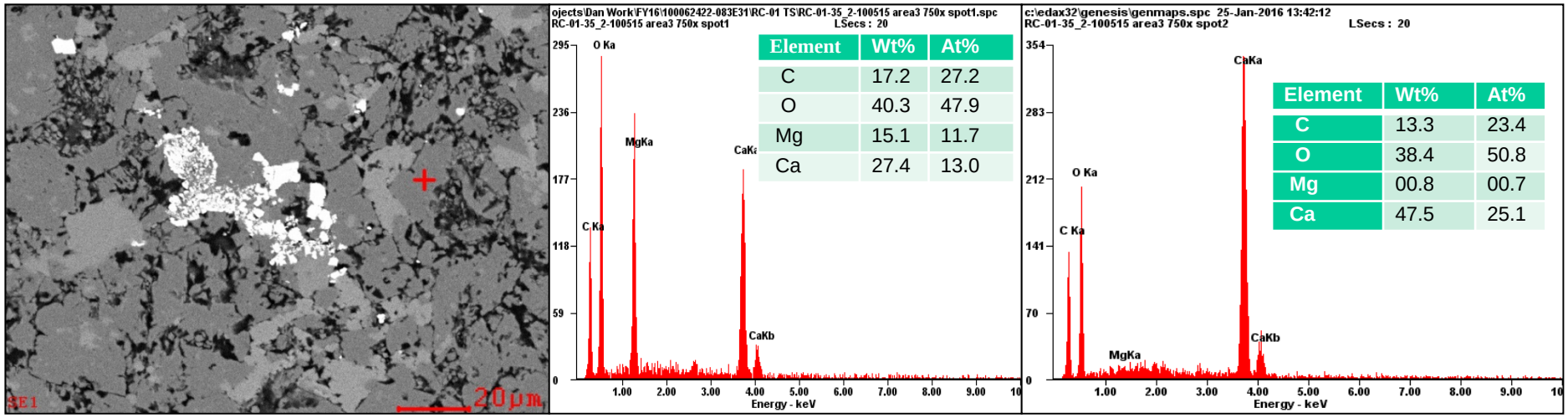


Chlorobenzene Conc. in Rock Matrix - RC-02



Magnetic Susceptibility, X-ray Diffraction, and SEM/EDS

- **Dominant minerals present dolomite, calcite, quartz, feldspar**
- **Confirmed each Former Burn Pit in a different geologic formation**
- **Magnetite levels <1%**



Summary of Core Characterization

- **Rock matrix dominated by dolomite and calcite with iron mineral (pyrite/magnetite) cement in fractures.**
- **Magnetite levels too low for abiotic MNA (need >1%)**
- **Contamination dominated by TCE, *cis*-DCE, VC and chlorobenzene**
- **Contamination mainly in the shallow zones**
- **Presence of iron sulfide minerals, e.g. FeS and FeS_2**

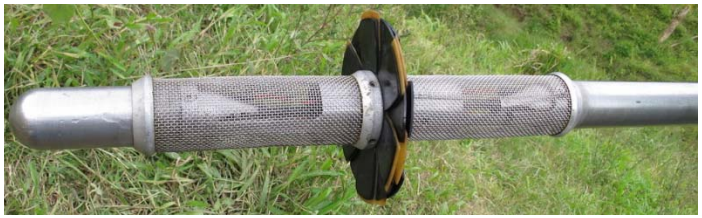
BOREHOLE GEOPHYSICAL ANALYSIS

Borehole Logging

Downhole Geophysical and Video Profiling

- Video profiling
- Caliper logging
- Natural gamma logging logs
- Fluid and temperature resistivity logging
- Heat-pulse flowmeter (HPFM) testing
- Acoustic televiewer logging

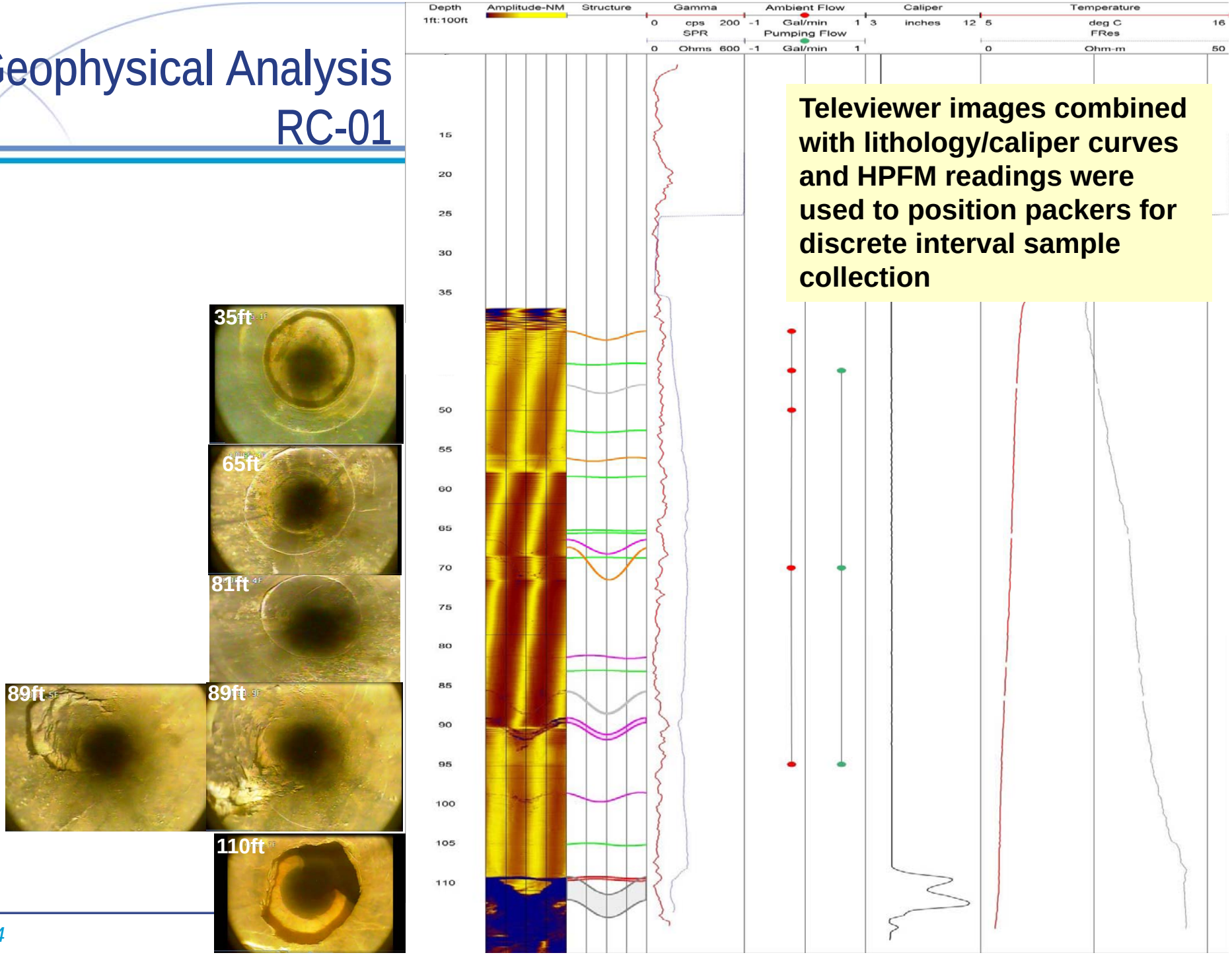
Video profiling tool



Heat pulse flowmeter – flexible baffle and flow measurement (screen) interval

Three arm caliper tool

Geophysical Analysis RC-01

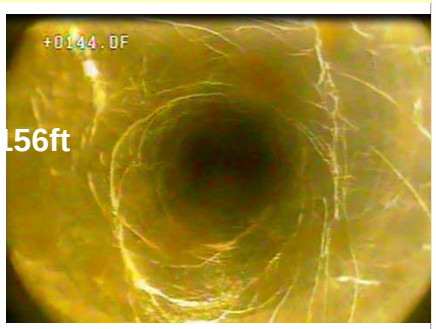


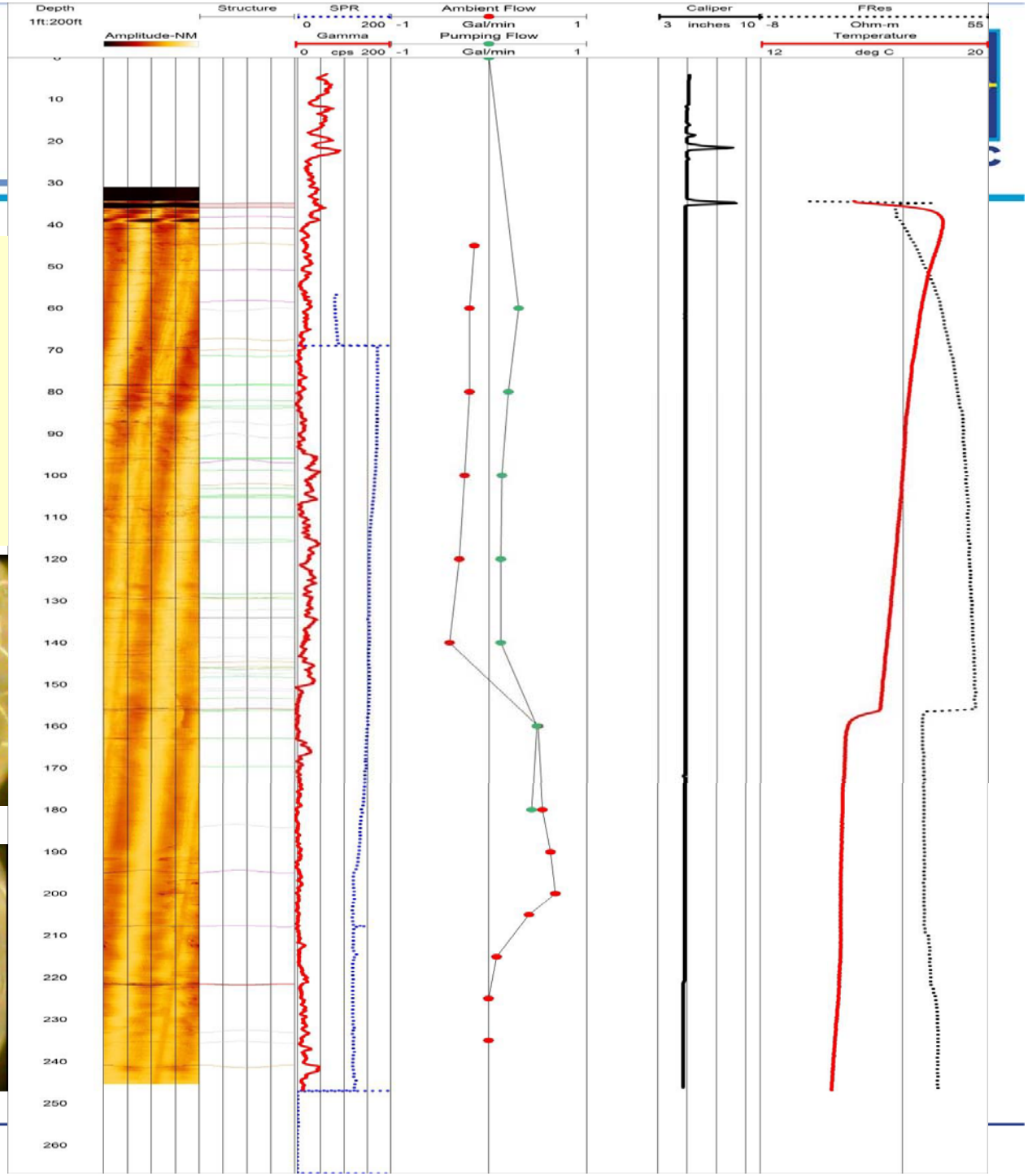
Televiewer images combined with lithology/caliper curves and HPFM readings were used to position packers for discrete interval sample collection

Geophysical Analysis RC-02

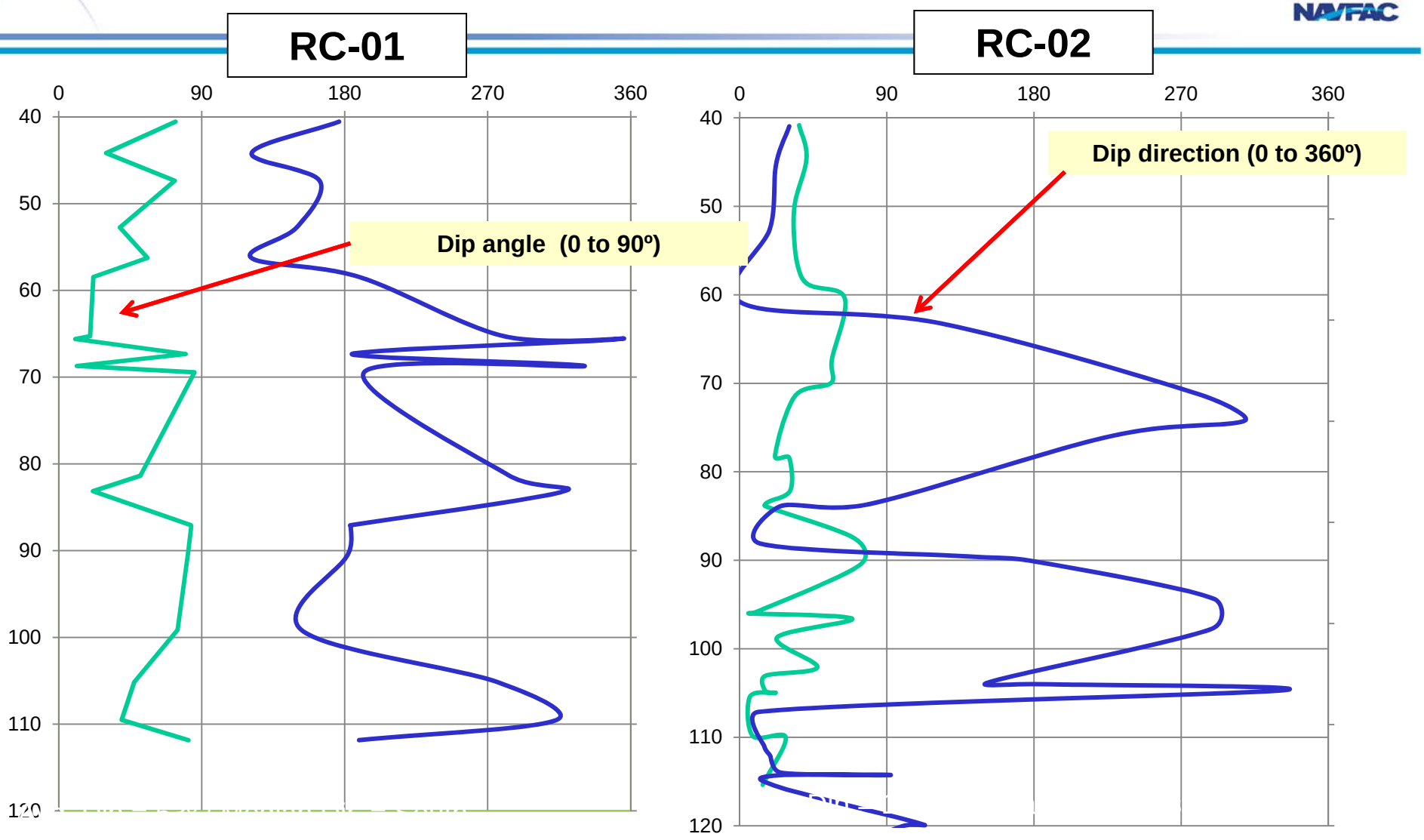
Upper image; white banding is cement-filled fractures intercepting core hole.

Lower image: open fracture/void crosscutting core hole





Dip Angle and Azimuth Comparison

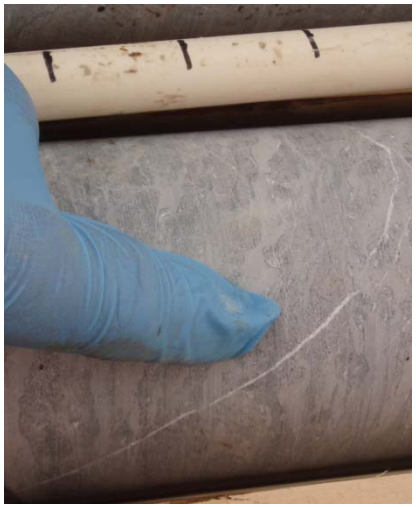


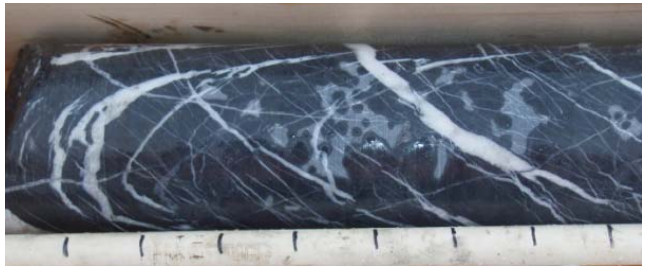
Average dip = 53º / Median Direction = South

Average dip = 110º / Median Direction = East

Preliminary Observations

- **Two Former Burn pits in two different geologic formations**
- **RC-01 – predominately limestone facies, more fractures, more folding**
- **RC-02 – predominately dolomitic with calcite-in-filling cement, low porosity matrix, fewer fractures**
- **Water bearing fractures in RC-01 at ~24 ft, 35 ft,108 to 114 ft**
- **Water bearing fractures in RC-02 at 21-22 ft, 34 to 35 ft, 156 ft, 208 to 222 ft**





DISCRETE DEPTH GROUNDWATER SAMPLING

Discrete Depth Groundwater Sampling

- **Field parameters**
- **Water quality parameters**
- **Geochemical parameters**
- **Contaminants of concern**
- **Microbial analysis**
- **Compound specific isotope analysis (CSIA)**
- **Dissolved metals**

Discrete Depth Sampling Criteria

- **Presence of fractures**
- **High rock core VOC concentrations**
- **Identified fracture flow via geophysical analysis (e.g., heat pulse flow meter)**
- **Five foot interval of isolation via packers**

Sampling Locations and Depths

	Former Burn Pit #1				Former Burn Pit #2			
	RC-01	**S03M48**	**S03M49**	**S03M50**	**RC-02**	**S03M17**	**S03M18**	**S03M57**
Borehole Depth (ft bgs)	250.2	97.05	88.22	99.1	249.3	105.68	106.95	98.42
Depths Sampled (ft bgs)	34-37	35	23	35	34-37	35	35	36
	91-96	65	40	65	59-63	50	60	61
	100-105	95	78	93	96-101	100	92	92
	109-117				154-157			
	152-167				197			

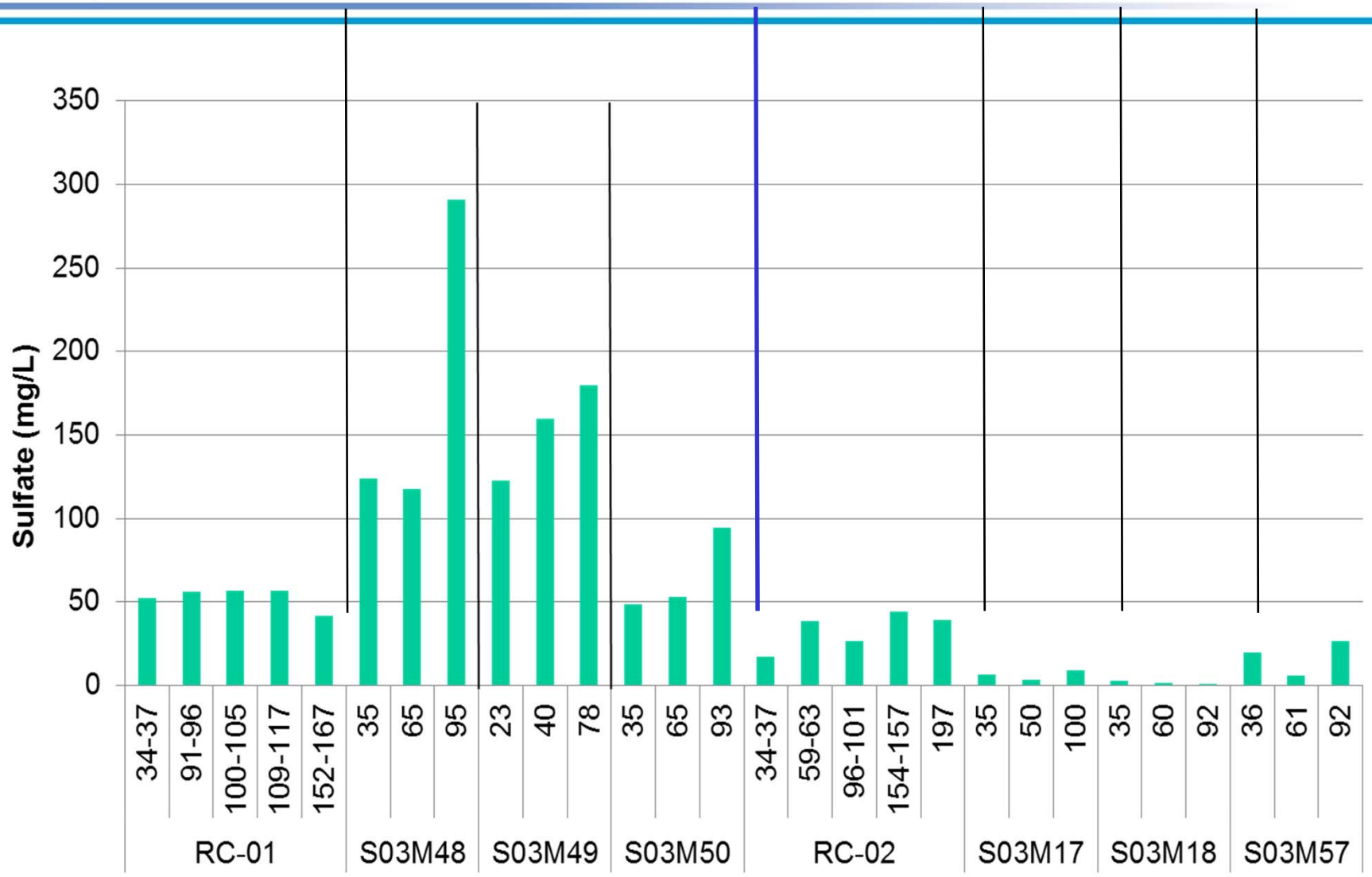
Water Quality and Geochemistry of Site Groundwater

- **Generally anaerobic (oxidation reduction potential**

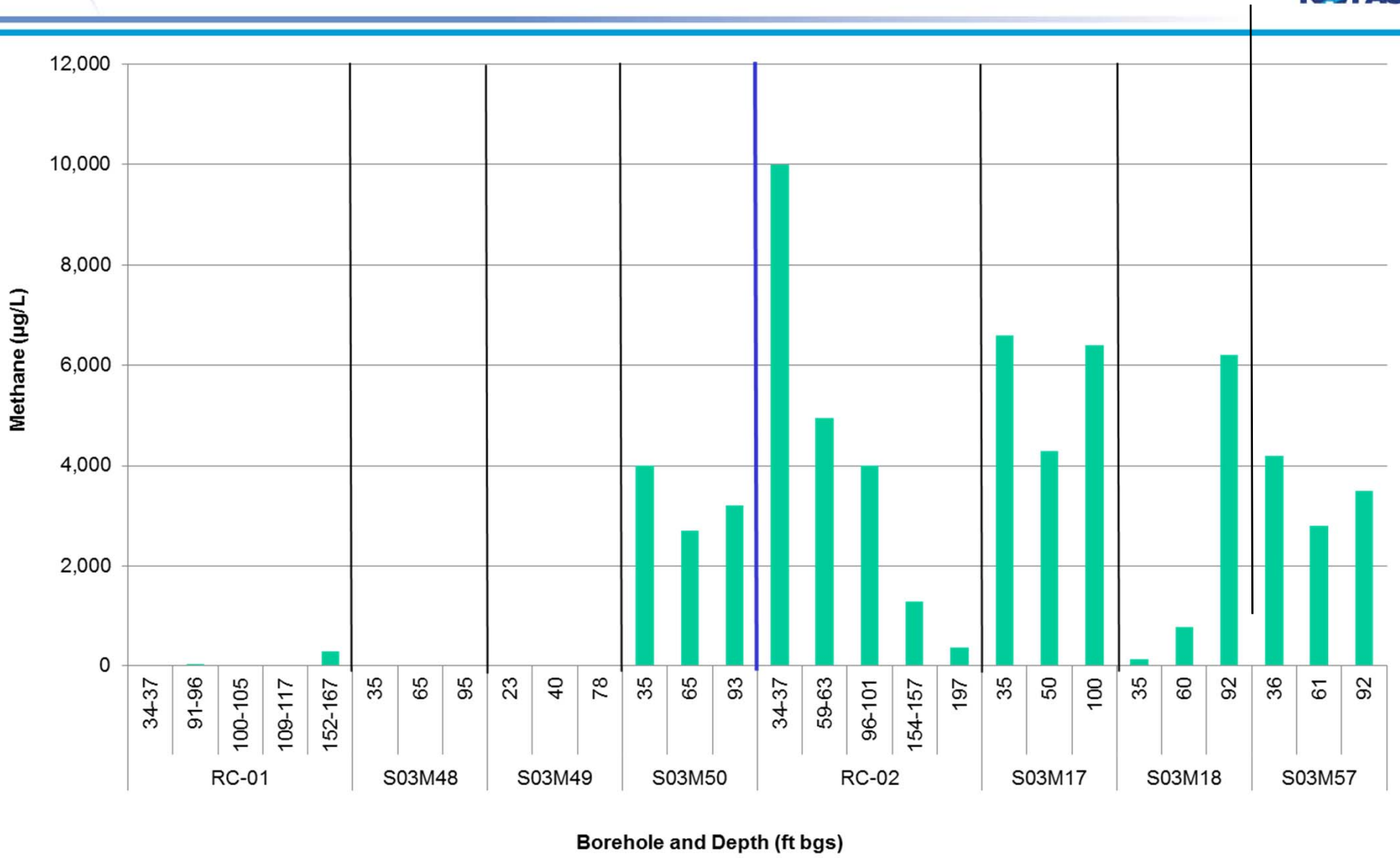
> -100 mV) except well S03M50 (< -200 mV)

- **Low Dissolved Oxygen**
- **Low Nitrate – (2.6 mg/L)**
- **Low Ferrous Iron - (1.6 mg/L)**
- **Low Sulfide (2.9 mg/L)**
- **Alkalinity – average 356 mg/L**
- **pH (between 6.5 and 8.5)**
- **Total Organic Content - < 7 mg/L**

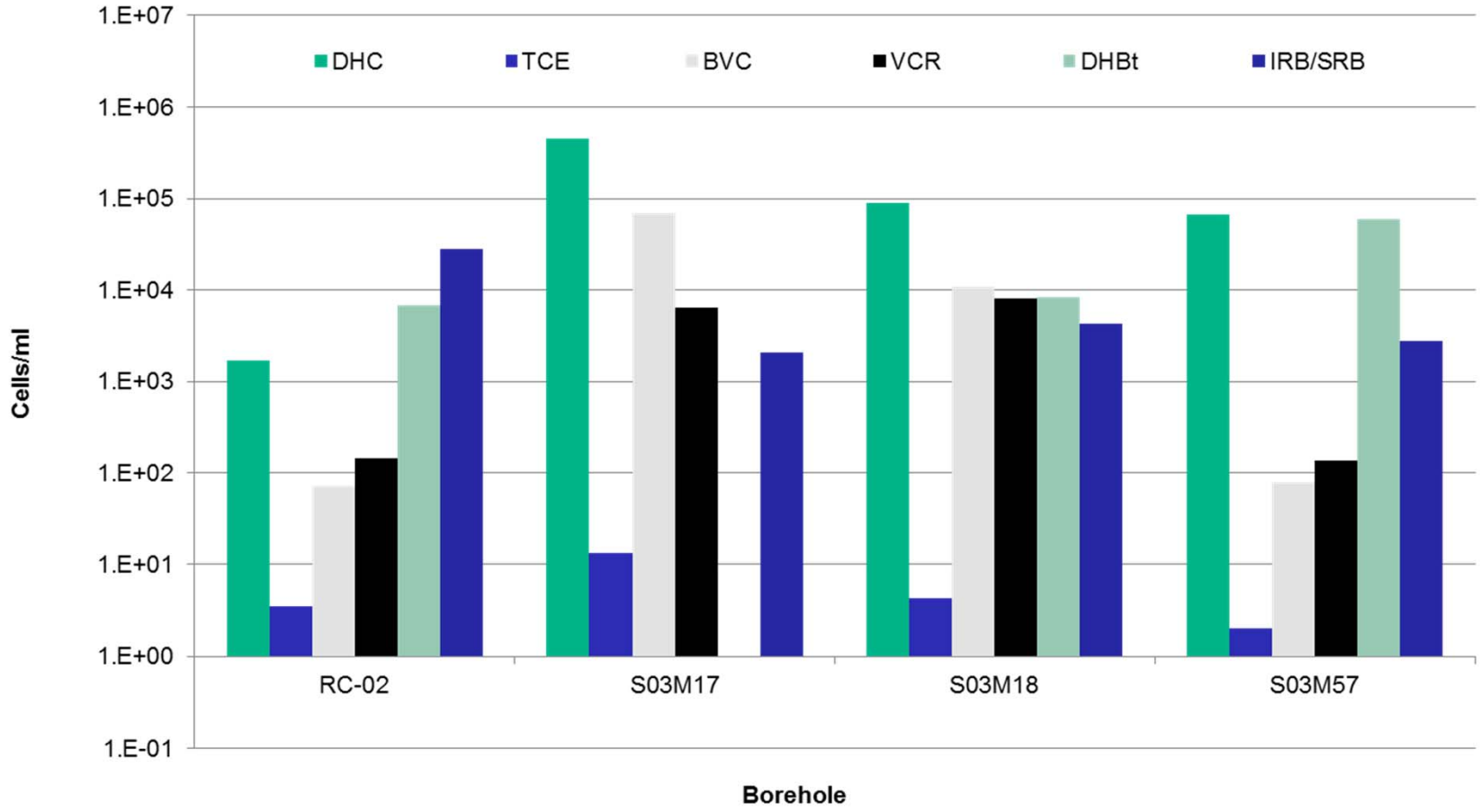
Sulfate Concentration - Former Burn Pits #1 and #2



Methane Concentration - Former Burn Pits #1 and #2

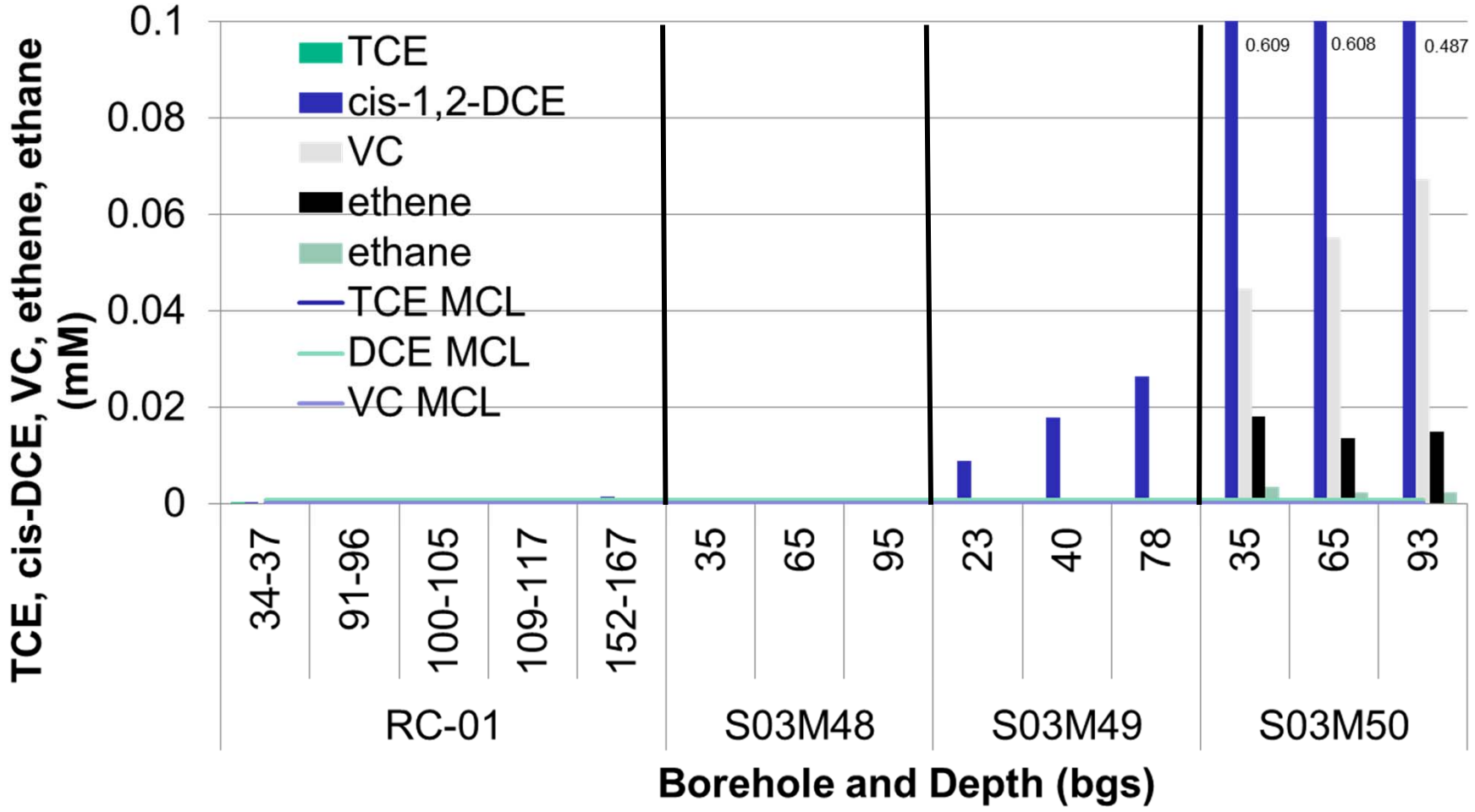


Microbial Analysis - Former Burn Pit #2

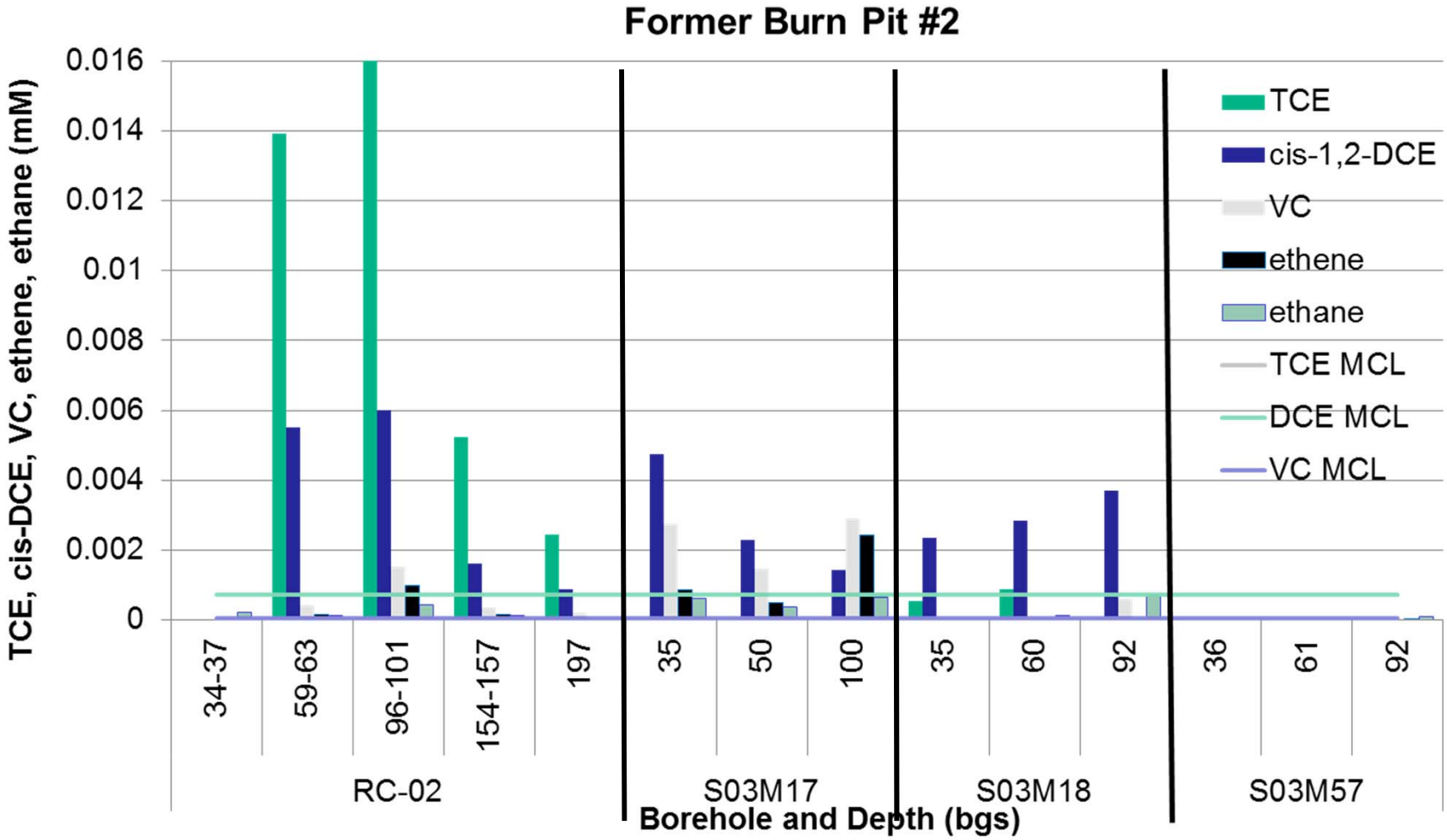


CONTAMINANT CONCENTRATIONS

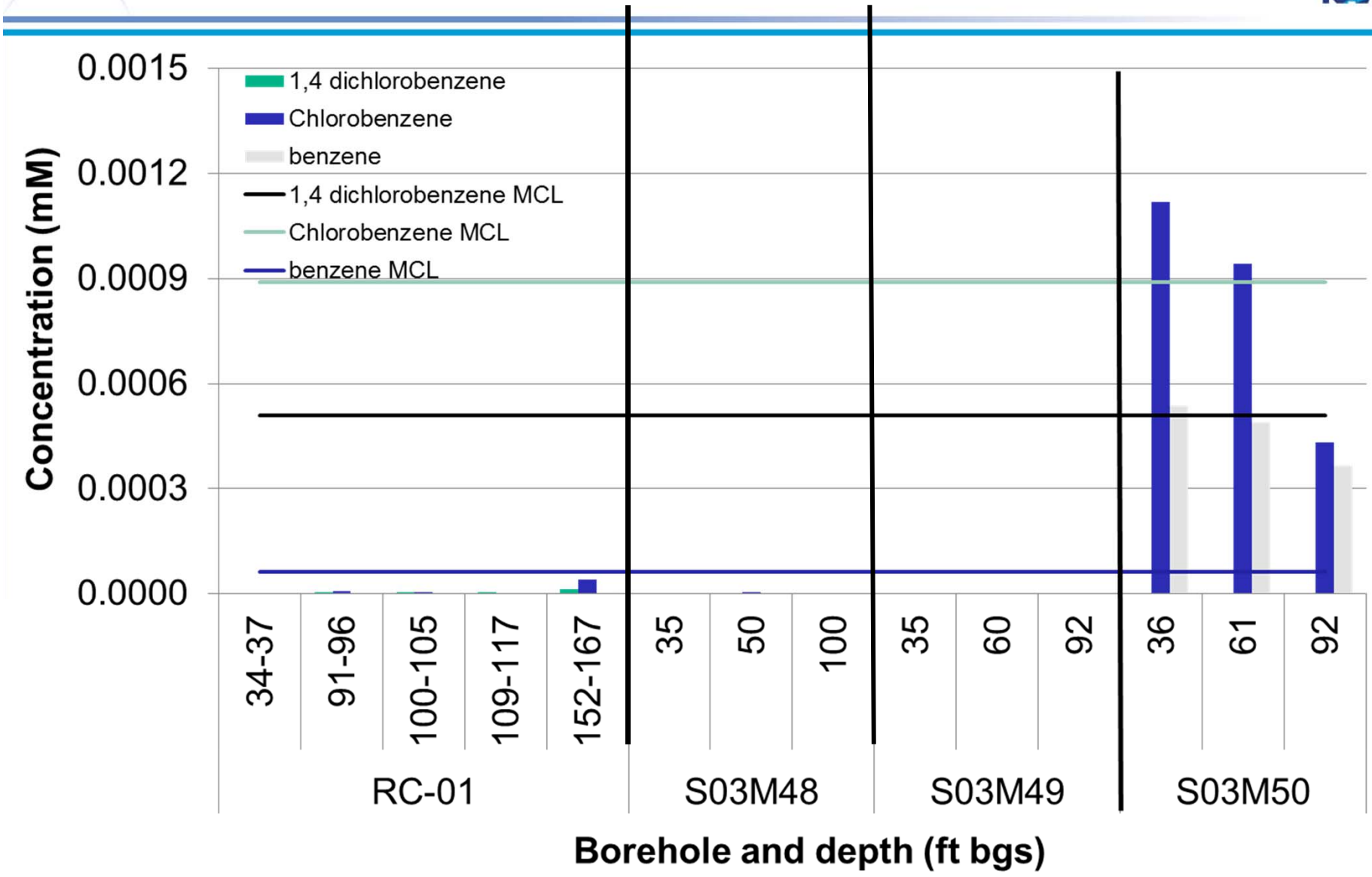
Chlorinated Ethenes - Former Burn Pit #1



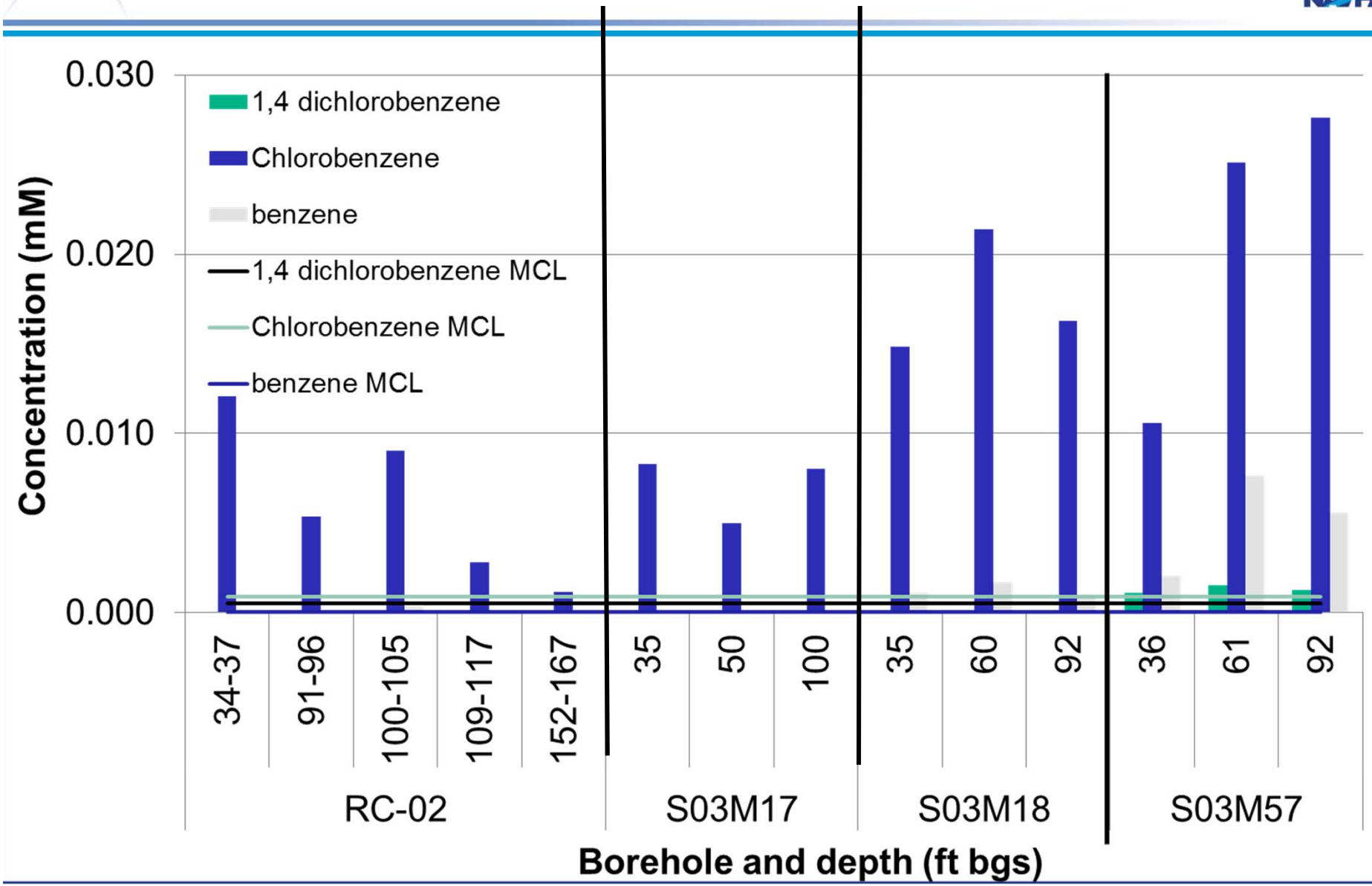
Chlorinated Ethenes - Former Burn Pit #2



Benzenes - Former Burn Pit #1

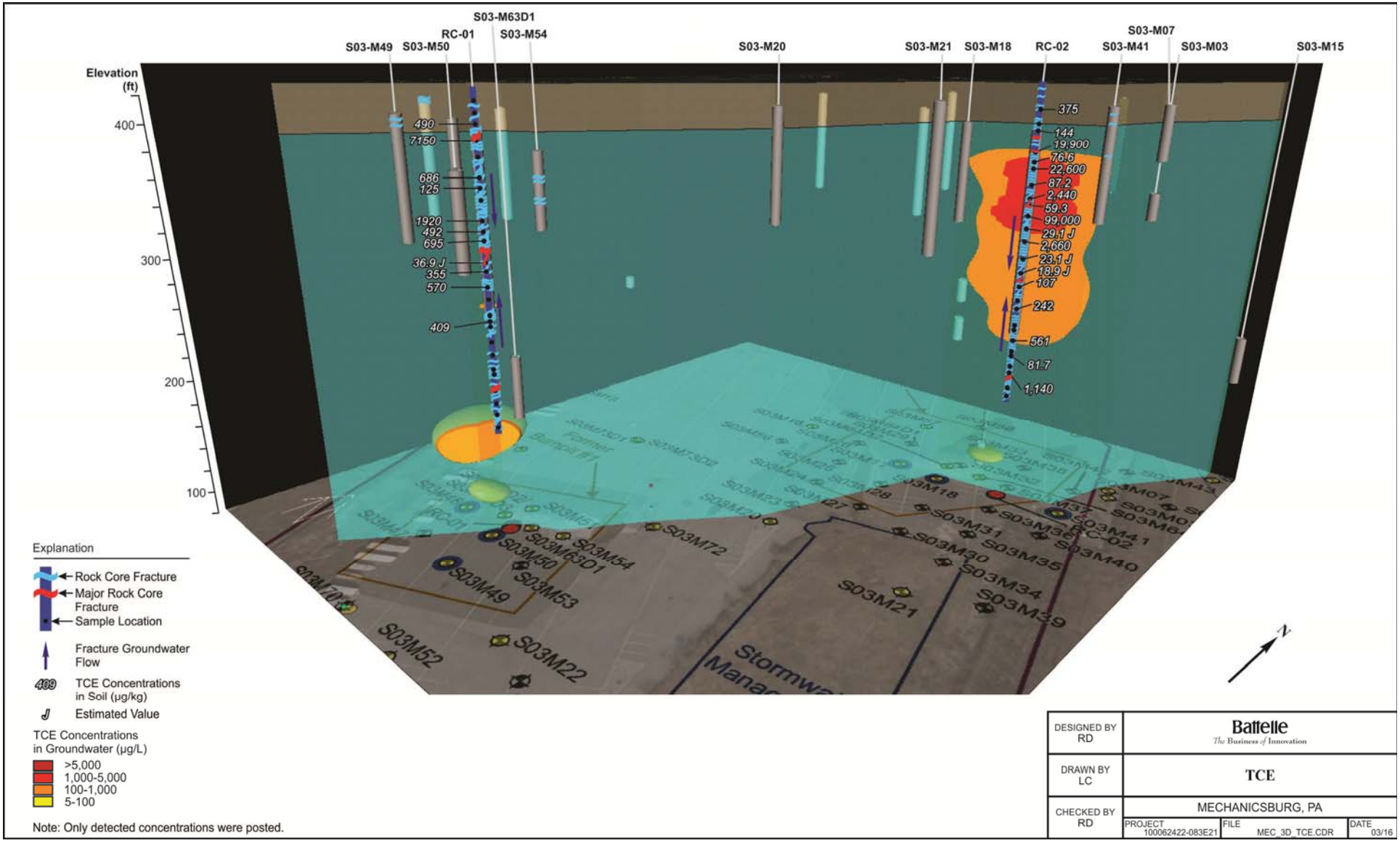


Benzenes - Former Burn Pit #2



PLUME MODEL DEPICTION

TCE Plume Model Depiction



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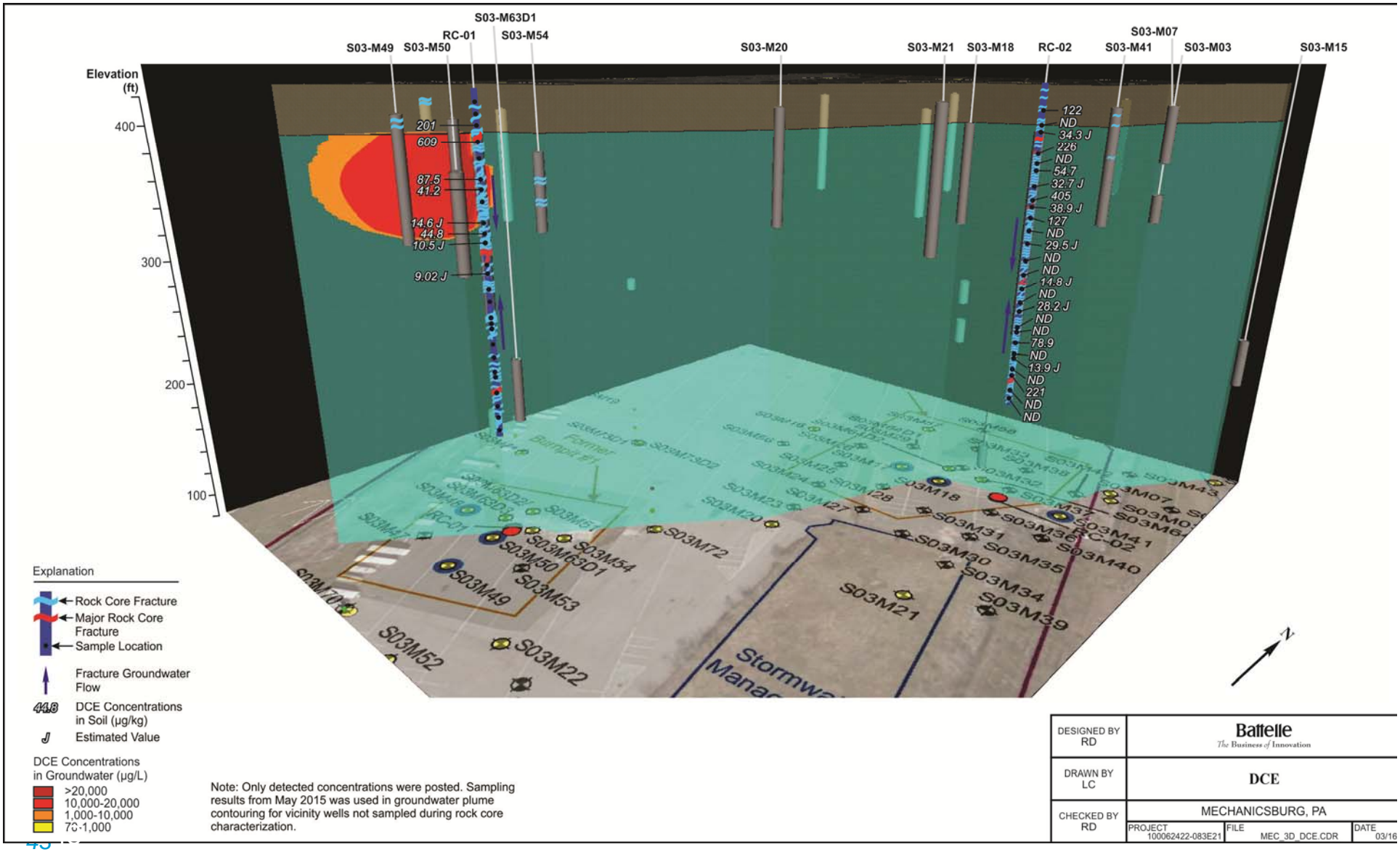
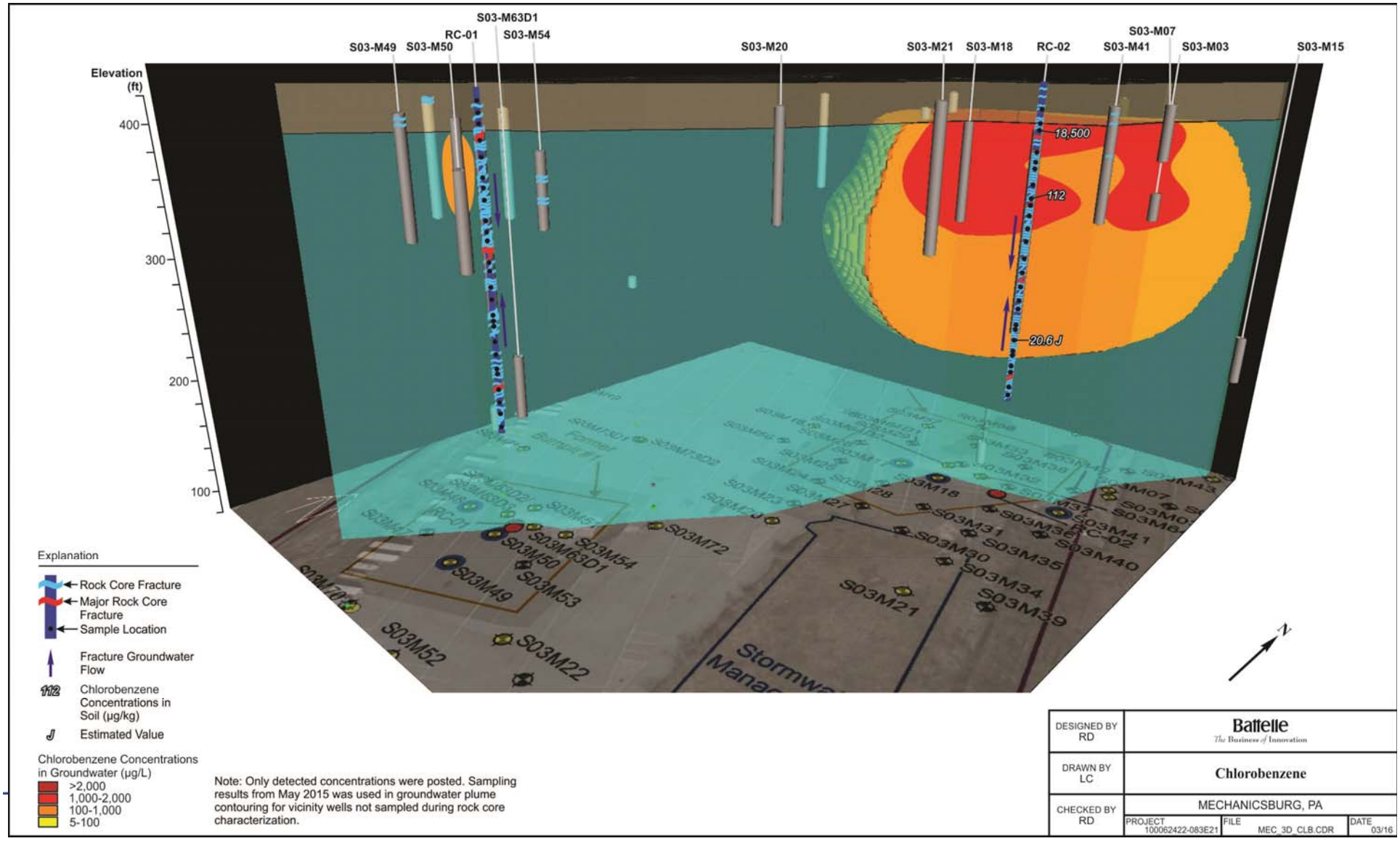
DRAWN BY LC	TCE		
CHECKED BY RD	MECHANICSBURG, PA		
PROJECT 100062422-083E21	FILE MEC_3D_TCE.CDR	DATE 03/16	

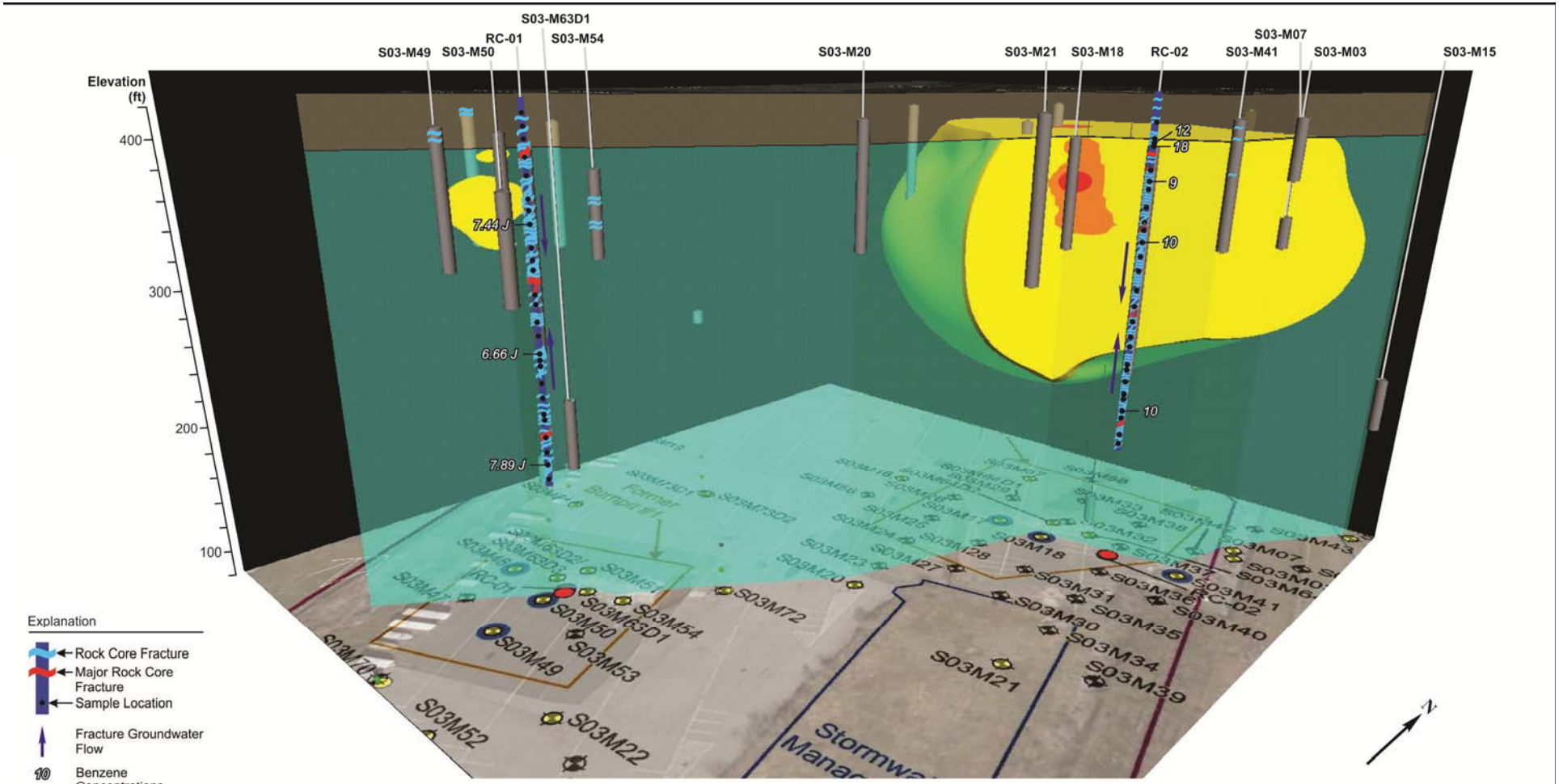
cis – DCE Plume Model Depiction



Chlorobenzene Plume Model Depiction



Benzene Plume Model Depiction



Note: Only detected concentrations were posted. Sampling results from May 2015 was used in groundwater plume contouring for vicinity wells not sampled during rock core characterization.

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Summary of Findings

- **Extent of contamination greater in Former Burn Pit #2**
- **High contamination around borehole S04M50 in Former Burn Pit #1**
- **Presence of *cis*-DCE and vinyl chloride indicate microbial degradation occurring naturally**
- **Microbial counts confirm microbial degradation occurring**
- **Low TOC numbers may be limiting factor**
- **Groundwater flow is complex due to fracture network and relict cavity flow intervals**

Use of High Resolution Site Characterization Methods

- **Allows improved delineation and understanding of vertical geology, especially since stratigraphy and structure are complex**
- **Coring and rock analysis provides VOCs concentration in matrix vs. diffused phase concentrations as measured in groundwater samples**
- **Better understanding of insitu controls on groundwater flow and contaminant distribution that allows successful targeting of zones for amendment injection**
- **Matching of borehole geophysical data with rock core properties will strengthen conceptual site model (both at borehole and site scale)**
- **Data of this resolution will allow full evaluation of technical practicability of remediation of this highly complex site**

Wrap Up

- **Please complete the feedback questionnaire at the end of this webinar. We are counting on your feedback to make this webinar series relevant!**

- **Check the T2 email for upcoming OER2 Webinar Announcements!**

- **Thank you for participating!**