Advanced Design Study for the Evaluation of Dyed EVO Distribution via Recirculation in a Complex Hydrogeochemical Setting

Results you can rely on

Anthony Brown (anbrown@trcsolutions.com), Brendan J. Lazar, PE, Nidal M. Rabah, PhD, PE, LSRP (TRC, New Providence, New Jersey, USA), Randy St. Germain (Dakota Technologies, Inc.), Michael D. Lee (Terra Systems, Inc.)

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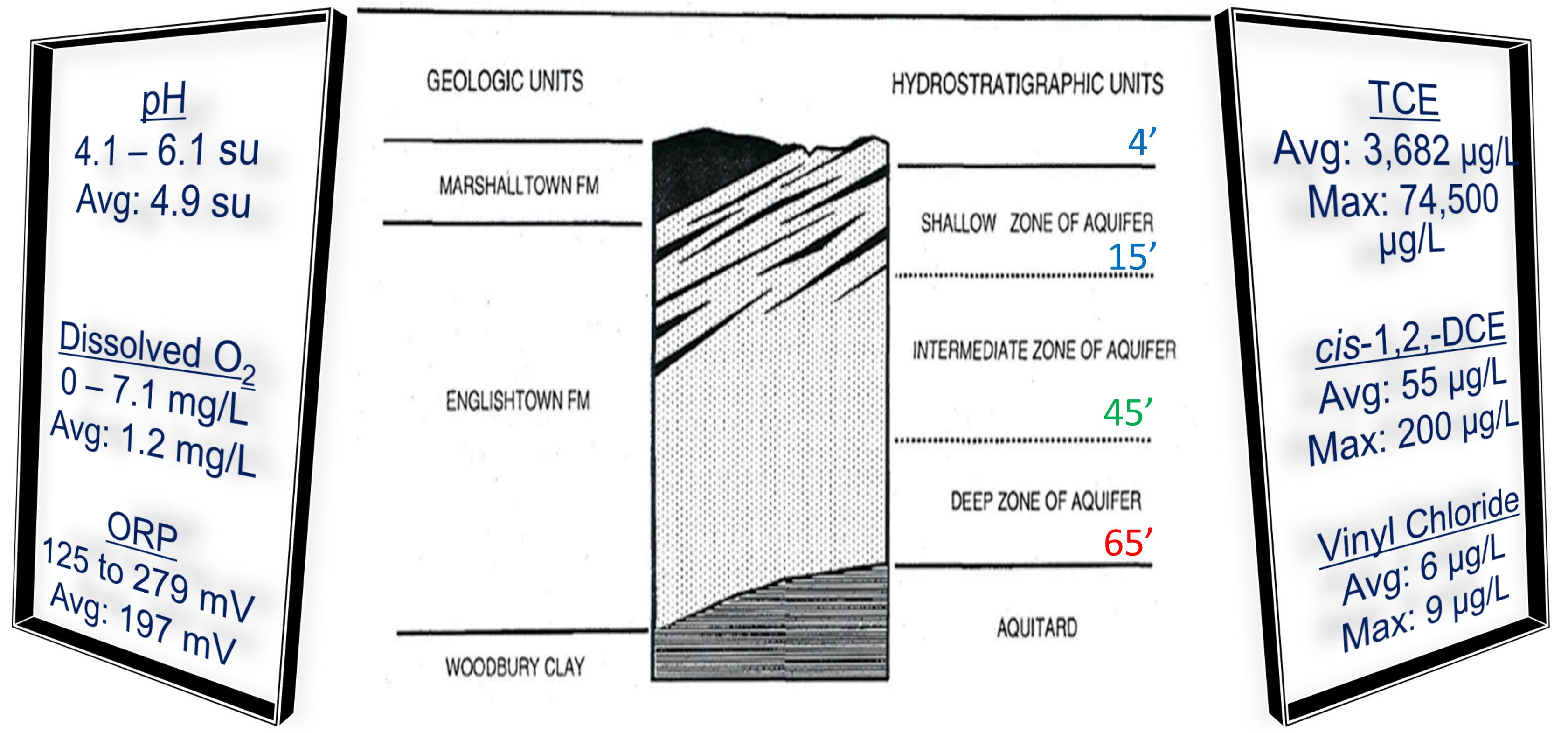
Session: B7. Lessons Learned with In Situ Technologies

1. THE CHALLENGE

GROUNDWATER AND SOILS IMPACTED WITH TCE IN A LOW pH FORMATION HAD VARYING RESPONSES TO TREATMENT WITH CONVENTIONAL ENHANCED IN-SITU BIOREMEDIATION (EISB). USING TEMPORARY INJECTION POINTS TO TREAT THESE AREAS RECALCITRANT TO TREATMENT WOULD RESULT IN MULTIPLE COST-PROHIBITIVE ROUNDS OF INJECTIONS. A RECENT PRE-DESIGN INVESTIGATION (PDI) IN THESE AREAS REVEALED ELEVATED LOADING RATES FOR BUFFER ($NaHCO_3$) AND A HYDROGEOLOGIC SETTING THAT WOULD PROVE DIFFICULT TO ACHIEVE ADEQUATE DISTRIBUTION. PERMANENT INFRASTRUCTURE TO MEET THESE NEW DEMANDS REQUIRED PROOF OF CONCEPT FOR AN EISB APPROACH WITH EVO USING INJECTION-EXTRACTION RECIRCULATION.

GEOCHEMISTRY AND HYDROGEOLOGY



STarGOST – LIF (DAKOTA TECHNOLOGIES)

Laser Induced Fluorescence (LIF)

Direct-sensing technology.

A sensor measures fluorescence of the formation through a sapphire window.

TarGOST

Visible Wavelength Spectrum

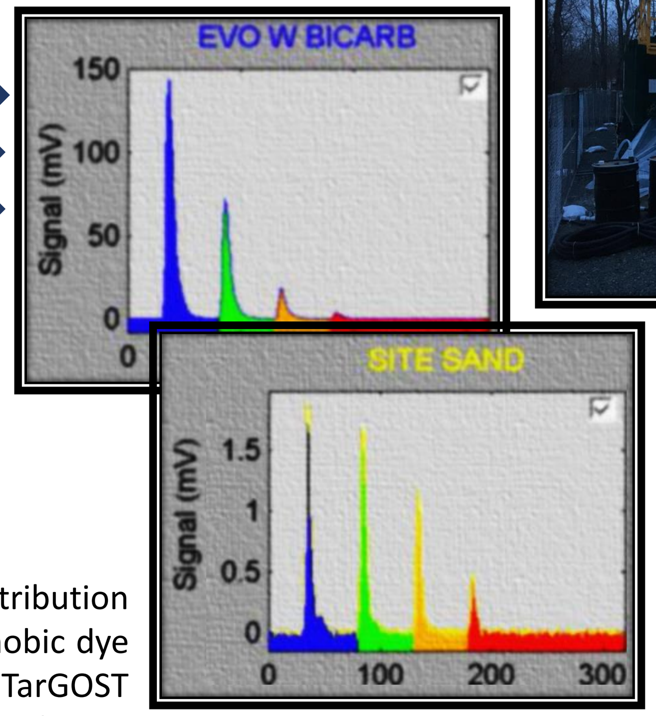
Typically used for DNAPLs (coal tars, creosote, etc.).

No response to fluorescein.

STarGOST

Typical DNAPLs not present, TarGOST scatter correction channel not useful.

Use all fluorescence input filters possible to increase the response.



TRC was seeking a high-resolution, direct-sensing technique to evaluate the distribution of EVO. Dakota Technologies, Inc. (Dakota) incorporated a proprietary hydrophobic dye into the EVO to enhance EVO's already present but weak response to their TarGOST technology. A bench-scale calibration study showed a strong response to the dyed-EVO. DyeLIF detection technology coined Sensitive-TarGOST (STarGOST) was deployed to enhance the response. The bench testing and technical insight from Dakota helped bring this study to the field. Acknowledgements: Randy St. Germain, Tom Rudolph, and Roxane Meidinger.

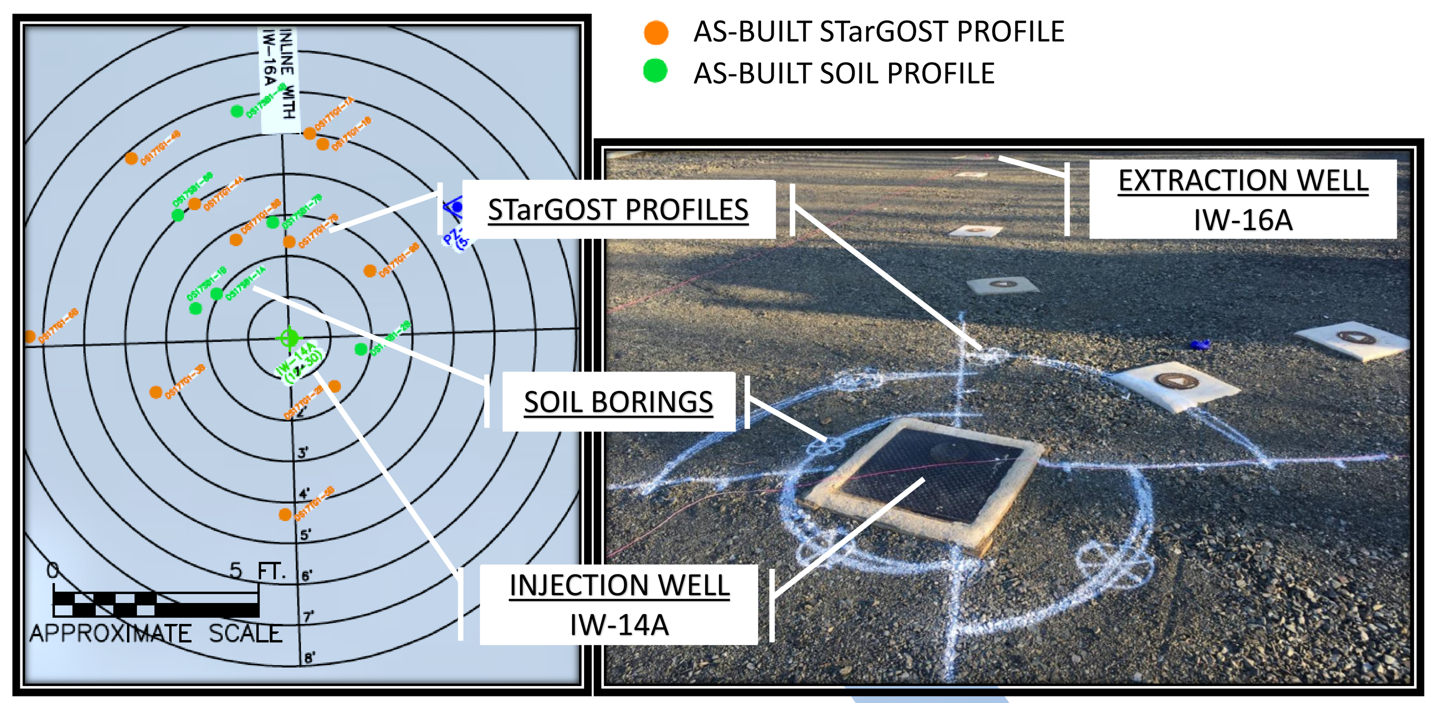
DYED EVO (TERRA SYSTEMS)

Dyed EVO was prepared in small batches by Terra Systems, Inc. (TSI) with advice from Dakota and dye supplier. At right, the vegetable oil was heated and mixed vigorously with the red hydrophobic dye prior to being emulsified. Approximately 800 gallons of TSI's Dye Labeled SRS®-SD were prepared for this study. TSI's in-house equipment and ingenuity helped bring the materials up to scale for the field study. Acknowledgements: Dr. Michael Lee and Dick Raymond.

THE TEAM

Dave Marx
Yitian Sun
Adriana Herrera
Raymond Boyd
Heath Potter
Jeff Hansen
Tony Mancini
Phil Bosco
Gail Bradbury
Chad Berner
Stefanie Crosby
Alayna Callanan
Sam Spangler
Peter Wanfried
Will Sullivan

THE INJECTION AREA

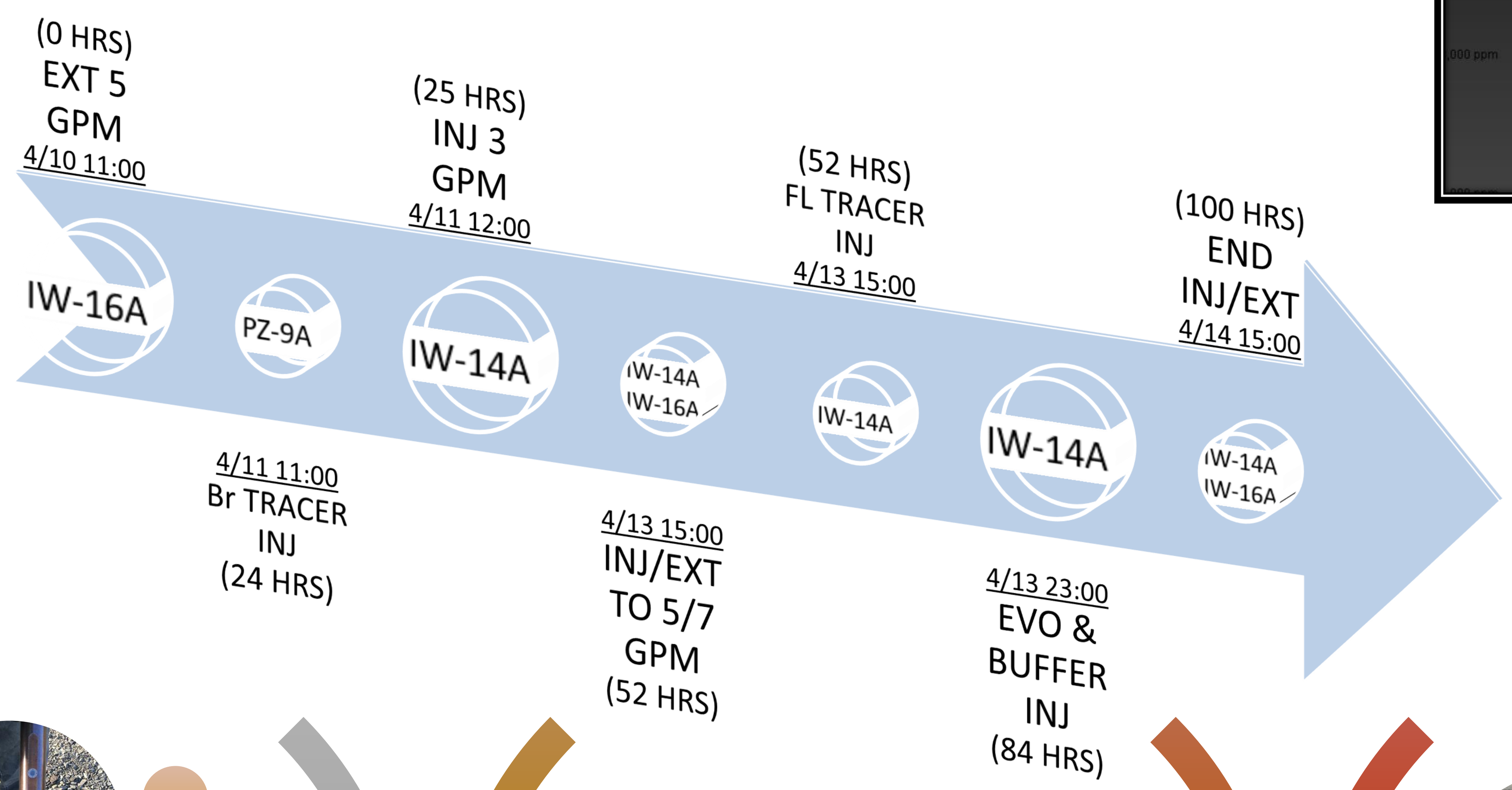


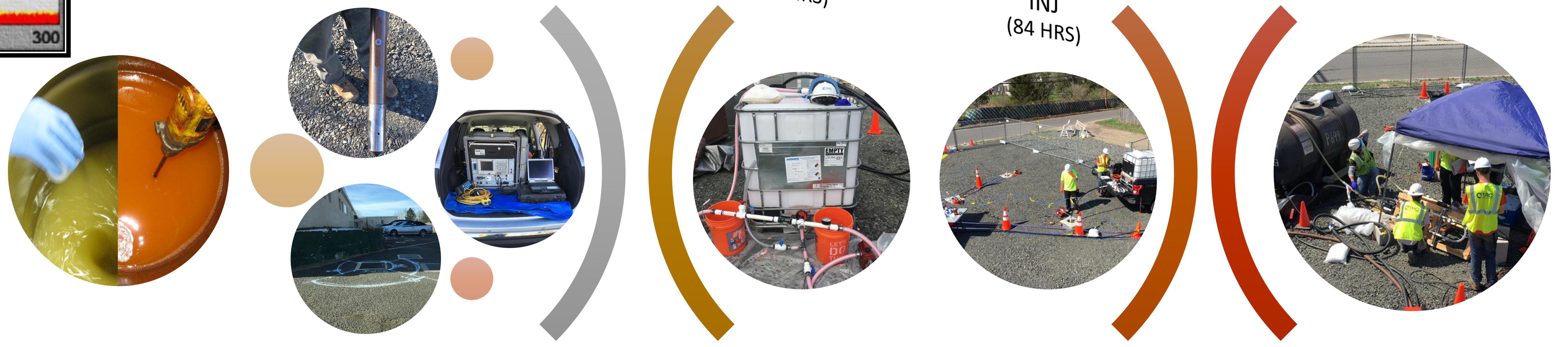
2. THE APPROACH

OVER THE COURSE OF 5 DAYS, EXECUTE A PUMPING TEST, CONVENTIONAL POTASSIUM BROMIDE (Br) EXTRACTION (EXT) TRACER STUDY, CONVENTIONAL FLUORESCEIN (FL) INJECTION-EXTRACTION (INJ-EXT) TRACER STUDY, AND A NOVEL INJ-EXT HYDROPHOBIC DYE LABELED EVO TRACER STUDY. COLLECT PRE AND POST-INJECTION SOIL PROFILES SAMPLED FOR FATTY OILS AND GREASE (FOG) AND LASER INDUCED FLUORESCENCE (LIF) PROFILES—LIF MEASURES THE INTENSITY OF RESPONSE TO THE HYDROPHIBIC DYE. ATTEMPT TO QUANTIFY THE DISTRIBUTION OF EVO AS TOTAL ORGANIC CARBON (TOC) BY CALIBRATING BOTH FOG AND LIF RESULTS TO TOC. USE FOG AND LIF, AS TOC, TO MAP THE 3D DISTRIBUTION OF EVO AROUND THE INJECTION WELL.

THE TIMELINE

24/7 INJ + EXT





THE CALIBRATION

The retardation factor for EVO was estimated using the Bioscreen[1] model. At right, inputs in bold were calibrated using results from the extraction tracer study or from direct measurements during the design study.

The conceptual site model (CSM) is supported by a 3D model created with C-Tech's Mining Visualization System (MVS) software. The model is comprised of data for groundwater elevations, the chlorinated solvents plume, impacted soils, and lithology. The model was calibrated to known conditions and found to confirm and expand upon many aspects of the CSM.

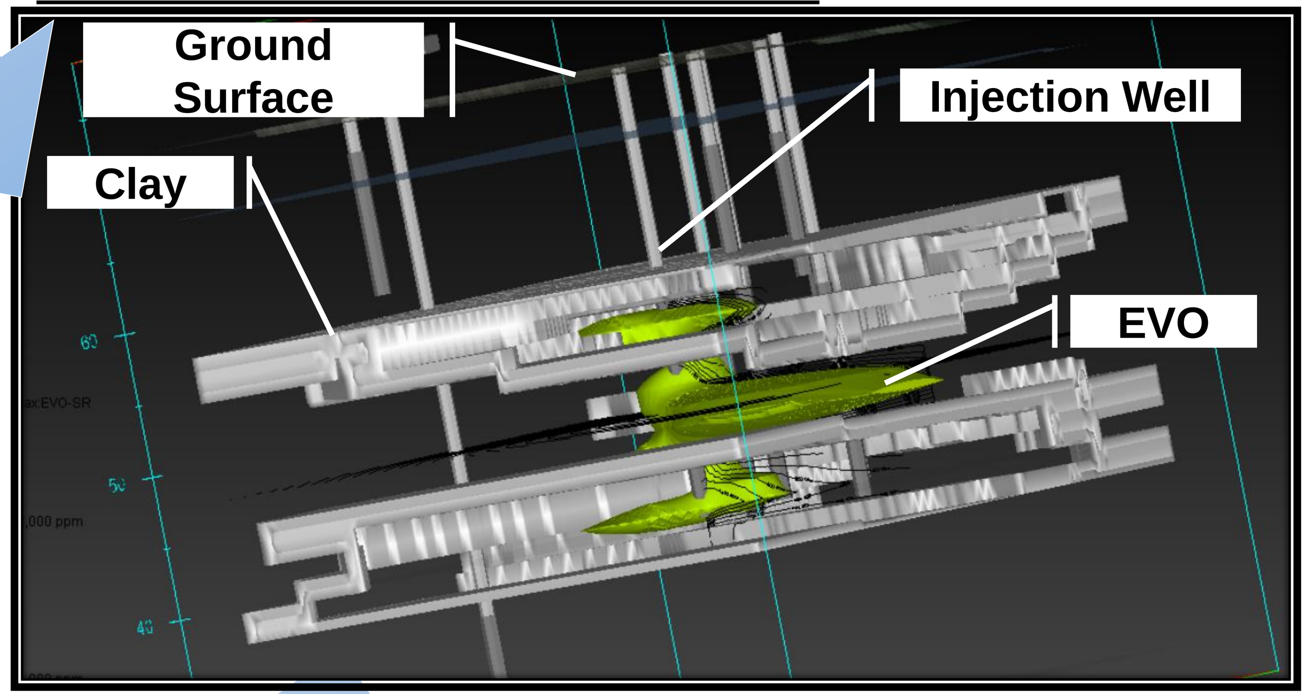
LIF results were converted to total organic carbon (TOC) concentrations using a decade dilution series field calibration. The results were input to the 3D model. TOC concentrations downgradient of the injection well were extracted from the 3D model. These concentrations were used to calibrate the retardation factor of EVO in Bioscreen (right).

[1] US EPA (1996). BIOSCREEN Version 1.4. July 1997.

Modeled Parameters		
Hydraulic Conductivity	**K (cm/s)**	**1.4E-02**
Hydraulic Gradient	**i (ft/ft)**	**0.11**
Porosity	**n**	**0.38**
Longitudinal Dispersivity	alpha x	3
Transverse Dispersivity	alpha y	6
Vertical Dispersivity	alpha z	6
Retardation Factor	**R**	**3**
Simulation Time	**(hrs)**	**15**
Source Concentration (TOC)	**(mg/L)**	**74000**
Source Mass (TOC)	**(Kg)**	**700**

Distance from Source (ft)	Modeled TOC Conc. (mg/L)	STarGOST TOC Conc. (mg/L)
0	15089	0
1	17997	20000
2	25847	26000
3	24065	23000
4	16454	15000
5	10808	11000
6	6797	8000
7	4080	6000
8	2330	3000
9	1263	0
10	648	0
Coefficient of Determination		0.99

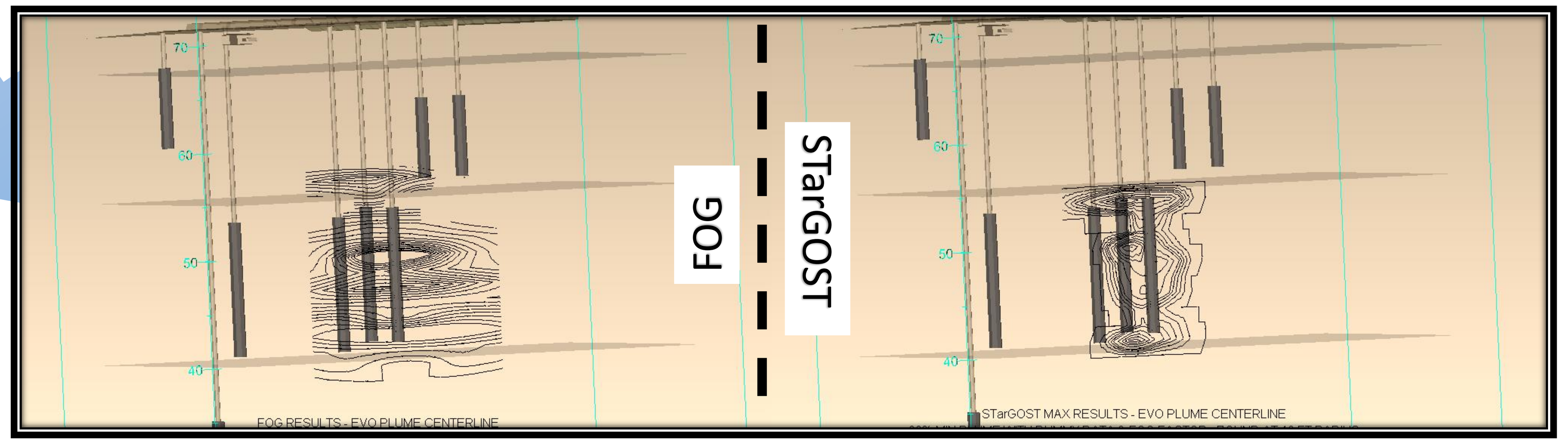
3D AMENDMENT DISTRIBUTION



THE 3D MODEL

At left, lithology from over 100 soil borings were characterized into sand or clay. The model's interpretation of the LIF response to dyed-EVO shows a more expansive distribution in the sand (void space) and less influence in the clay (grey space).

DISCRETE SAMPLING (FOG) vs HIGH RESOLUTION TECHNOLOGY (LIF)



3. CONCLUSIONS

A COMPARISON OF DISCRETE SOIL SAMPLE RESULTS AND HIGH RESOLUTION LIF, SHOW THAT STarGOST'S IN-SITU RESPONSE TO THE DYED EVO PRESENTED AN ACCURATE INTERPRETATION OF EVO DISTRIBUTION IN A HIGHLY HETEROGENEOUS FORMATION WITH THE ADDED BENEFIT OF HIGH RESOLUTION TECHNOLOGY. FACTORS THAT POTENTIALLY AFFECTED INTERPRETATION OF RESULTS INCLUDE AN OBSERVATION THAT THE CONCURRENTLY INJECTED SODIUM BICARBONATE REDUCED SIGNAL INTENSITY AND AN INFERENCE THAT LIF RESPONSE TO THE EX-SITU DILUTION SERIES USED FOR CALIBRATION MAY DIFFER FROM THE IN-SITU RESPONSE DUE TO DIFFERENCES IN BULK DENSITY BETWEEN EX-SITU AND IN-SITU MEASUREMENTS. FURTHER TESTING, LIKELY A COLUMN STUDY, IS NEEDED TO INCREASE CONFIDENCE IN THE ESTIMATED RETARDATION FACTOR.