



Advanced Application of Laser-induced Fluorescence for Delineation of LNAPL Treatment Zones

Tom Palaia, P.Eng., P.E.

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Coauthors

Darcy Bye

TransCanada Pipelines, Ltd.

darcy_bye@transcanada.com

Randy St. Germain

Dakota Technologies, Inc.

stgermain@dakotatechnologies.com

Agenda

- LIF Technology Description
- Gas Well Site Description
- Advanced Approach for LNAPL Subdivision
- Unique Results
- Applicability
- Conclusions



Laser-induced Fluorescence

- Ultraviolet Optical Screening Tool (UVOST™)
 - Measures fluorescence of PAHs relative to a reference emitter (%RE)
- Accepted technology for delineation of LNAPL in subsurface soil
 - Direct-push
 - Real-time
- Site- and LNAPL-specific response
 - “Calibrate” against in-well petroleum samples or analytical results of soil samples

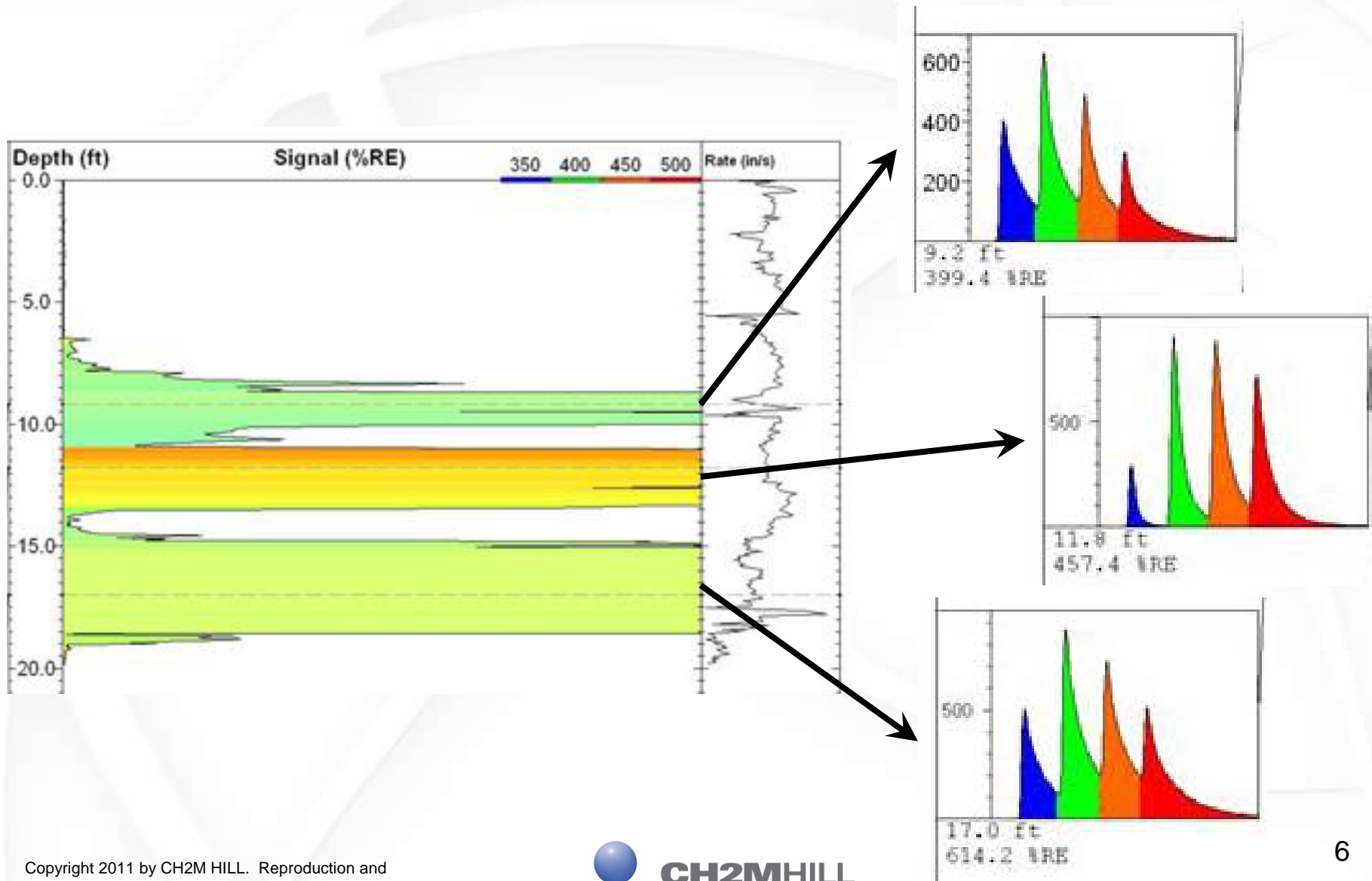


Photographs of crude oil (left) and diesel fuel (right) on water-saturated sand under room light (top) and long wavelength ultraviolet lamp excitation (bottom).

Advanced LIF Features

- Characterizes response to four different wavelengths of light
- Ratio of wavelength response can be used to semi-quantitatively characterize variation in LNAPL quality
 - Type of fuel or fuel mixture
 - Degree of weathering
- Curve fitting routine used to define “types” of LNAPL observed on LIF logs
 - Generates data files for each type of LNAPL

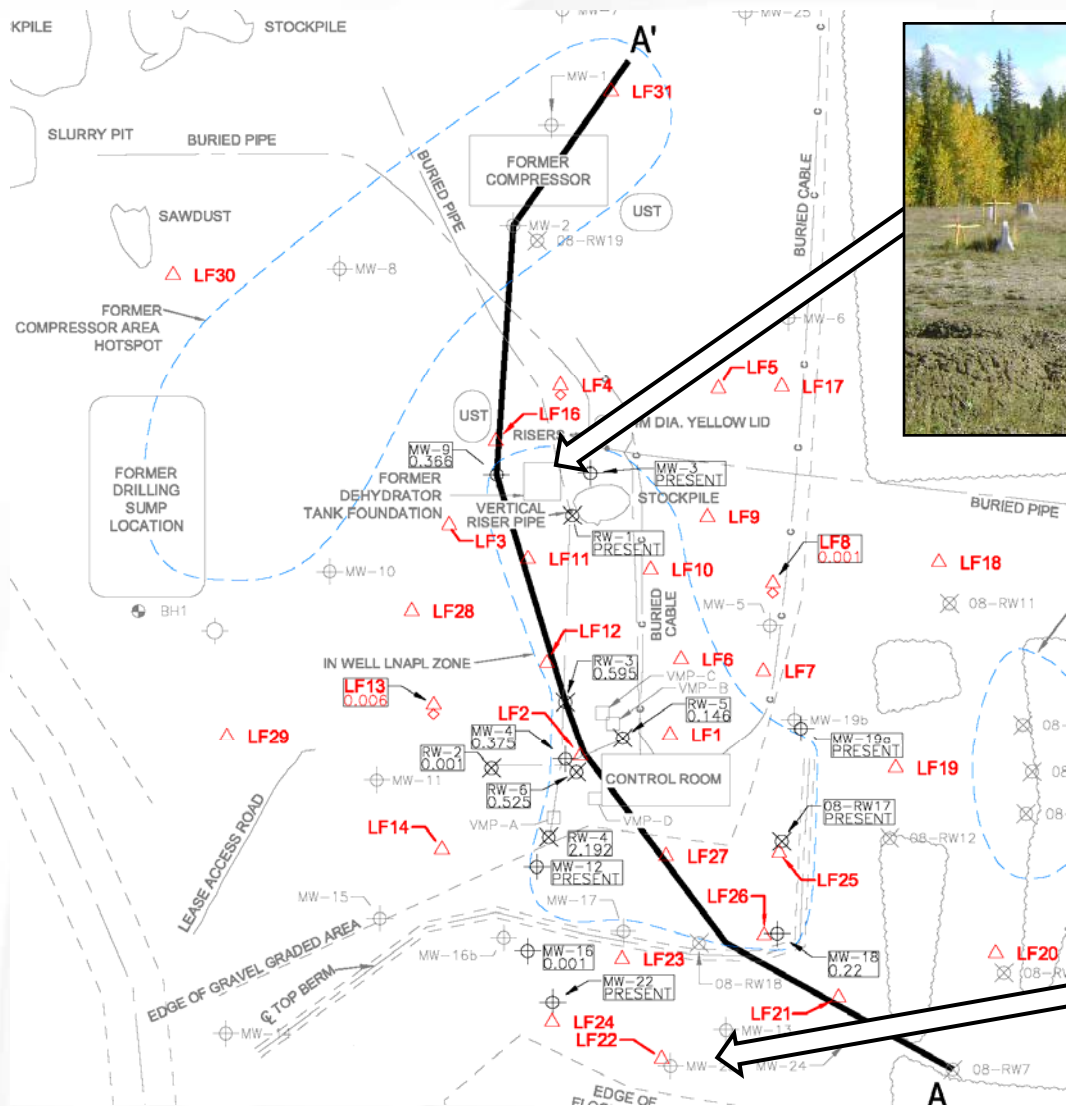
Advanced LIF Features



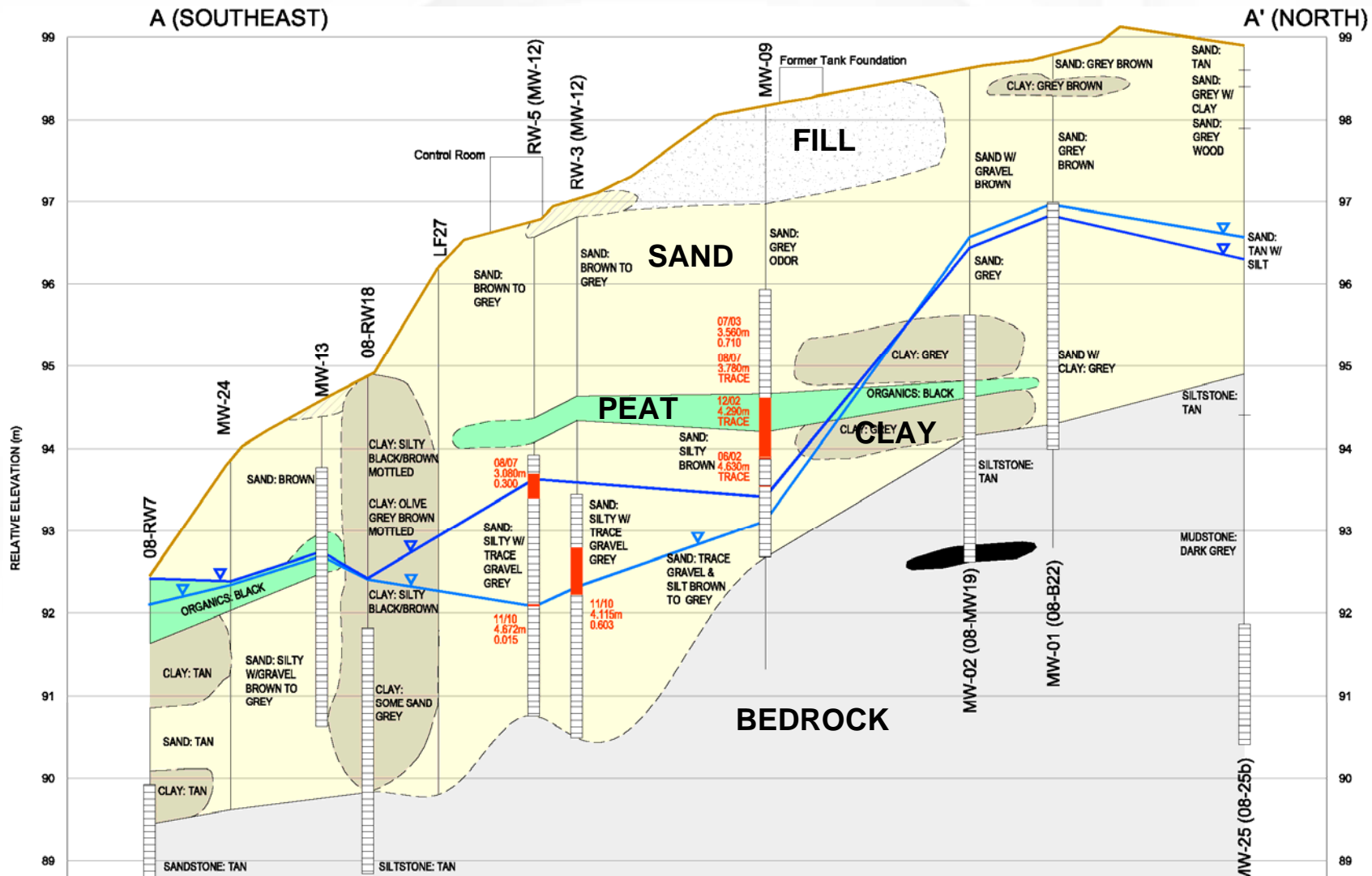
Gas Well Site Description

- Natural gas well drilled January '96, later used as an observation well
 - Former facilities
 - Compressor station, two USTs, flare stack, bermed pit, drilling sump, dehydrator and vertical culvert, and control room
- Located within the Lower Foothills Subregion of Alberta
 - Forested and marshy Natural Area
 - Within 10 m of an intermittent, unnamed tributary of the Little Sundance Creek
- Medium-grain sand with interbedded clay and organic materials
 - Bedrock depth 3 to 6.5 m bgs
 - 0.1 to 2 m/yr seepage velocity

Site Plan



Site Geology



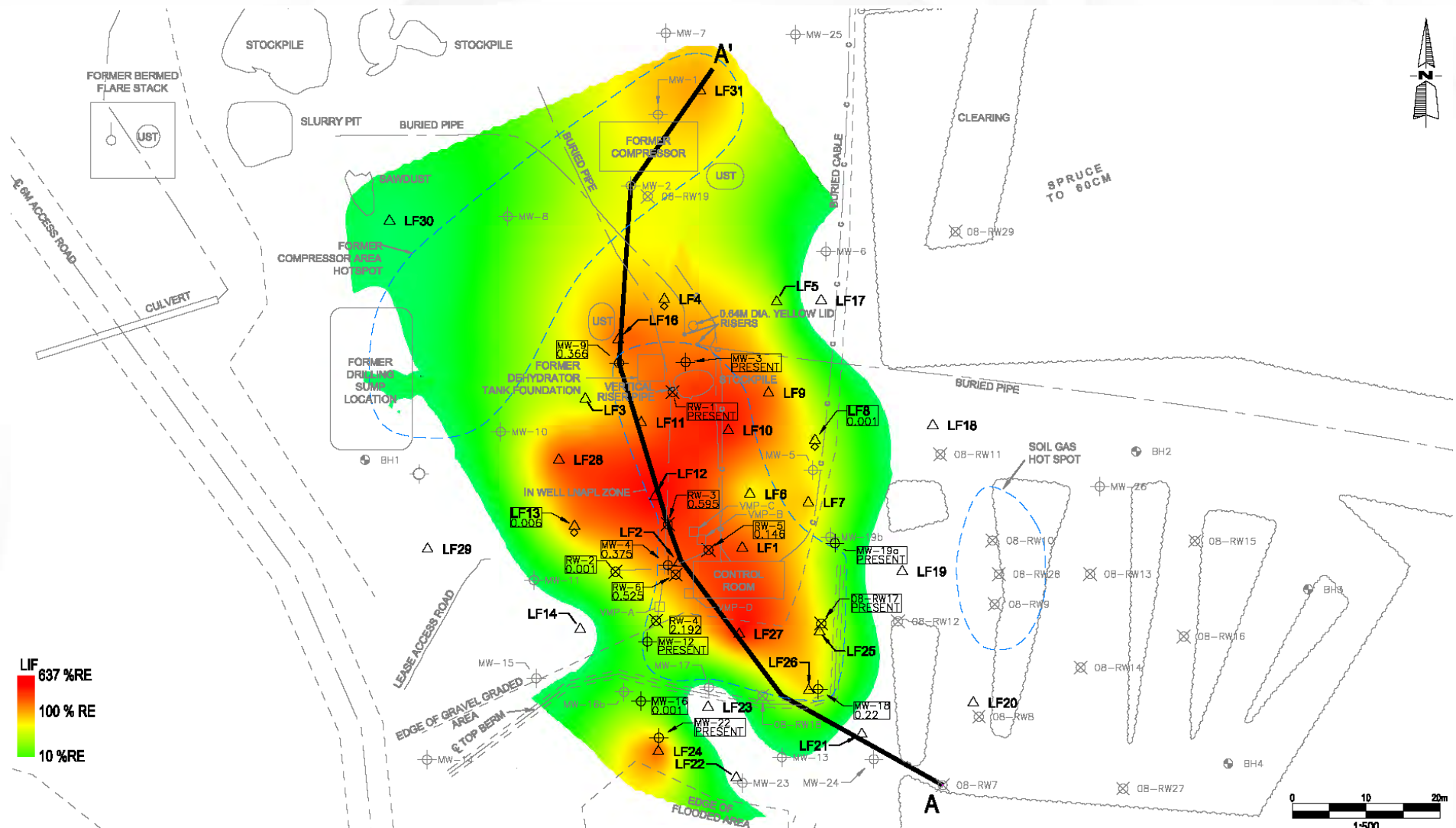
Site-specific Methodology

- Perform LIF survey
 - Dynamic work plan with clear data objectives
 - USEPA Triad derived process
- Perform soil confirmation sampling
 - Diverse targeted sample selection
- Identify unique LNAPL classes
 - From review of LIF logs and sample results
- Post-process LIF data
 - Delineate the zones of unique LNAPL

Site-specific Methodology

- Visualize the LNAPL zones in 3D
 - For best understanding of lateral and vertical extent within heterogeneous subsurface
- Identify treatment zones
 - Zones of potentially mobile LNAPL ($>100\%RE$) were identified for multiphase extraction (MPE)
 - More volatile/leachable LNAPL zones are also most amenable for MPE
 - Less volatile/leachable LNAPL zones are more amenable to bioremediation and monitored natural attenuation (MNA)

Overall LIF Survey Results



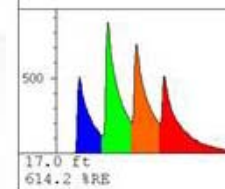
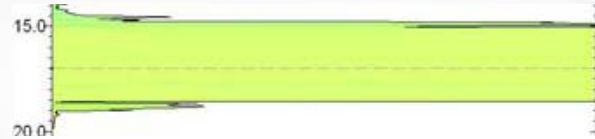
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Data Correlation

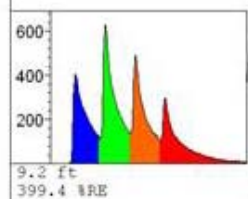
LIF Survey Location	Maximum LIF Response (%RE)	Collocated Well/ Piezometer Gauging Results*		Soil Sample Results				
		Well or Piezometer ID	Measured Product Thickness (m)	Depth (m bgs)	F1 (including BTEX) (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F4 (mg/kg)
LF01	378	RW5	0.146					
LF02	360	MW4	0.375					
		RW6	0.525					
LF04	158	LF04*	ND					
		MW5	ND					
LF08	93	LF08*	0.001					
				2.9	15,000	1,700	67	<10
LF12	657	RW3	0.595	3.65	2,300	470	370	110
				5	6,500	1,200	570	85
LF13	275	LF13*	0.003					
LF16	340	MW9	0.006					
LF18	5	08-RW11	ND					
LF20	3	08-RW8	ND					
LF21	4	MW24	ND					
LF22	7	MW23	ND					
LF23	2	MW17	ND					
LF24	341	MW22	ND	1.83	1,800	8,500	10,000	3,400
LF25	117	08-RW17	0.091	2.60	630	1,500	2,300	820
LF26	162	MW18	0.22	3.80	82	<10	<10	<10
		MW1	ND					
LF31	223	MW7	ND	4.10	650	1,600	2,700	1,000

LNAPL Type Representation

- LNAPL "A"



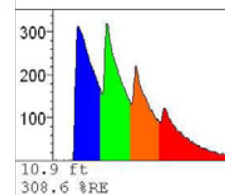
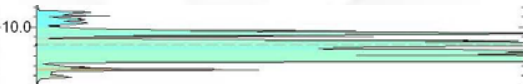
LIF12
4.6-5.5 m bgs
submerged



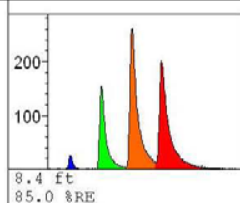
LIF12
2.7-3.0 m bgs
unsaturated

- LNAPL "B"

- LNAPL "C"



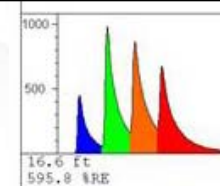
LF09
3.4-3.7 m bgs
unsaturated



LF25
2.3-2.6 m bgs
Both zones

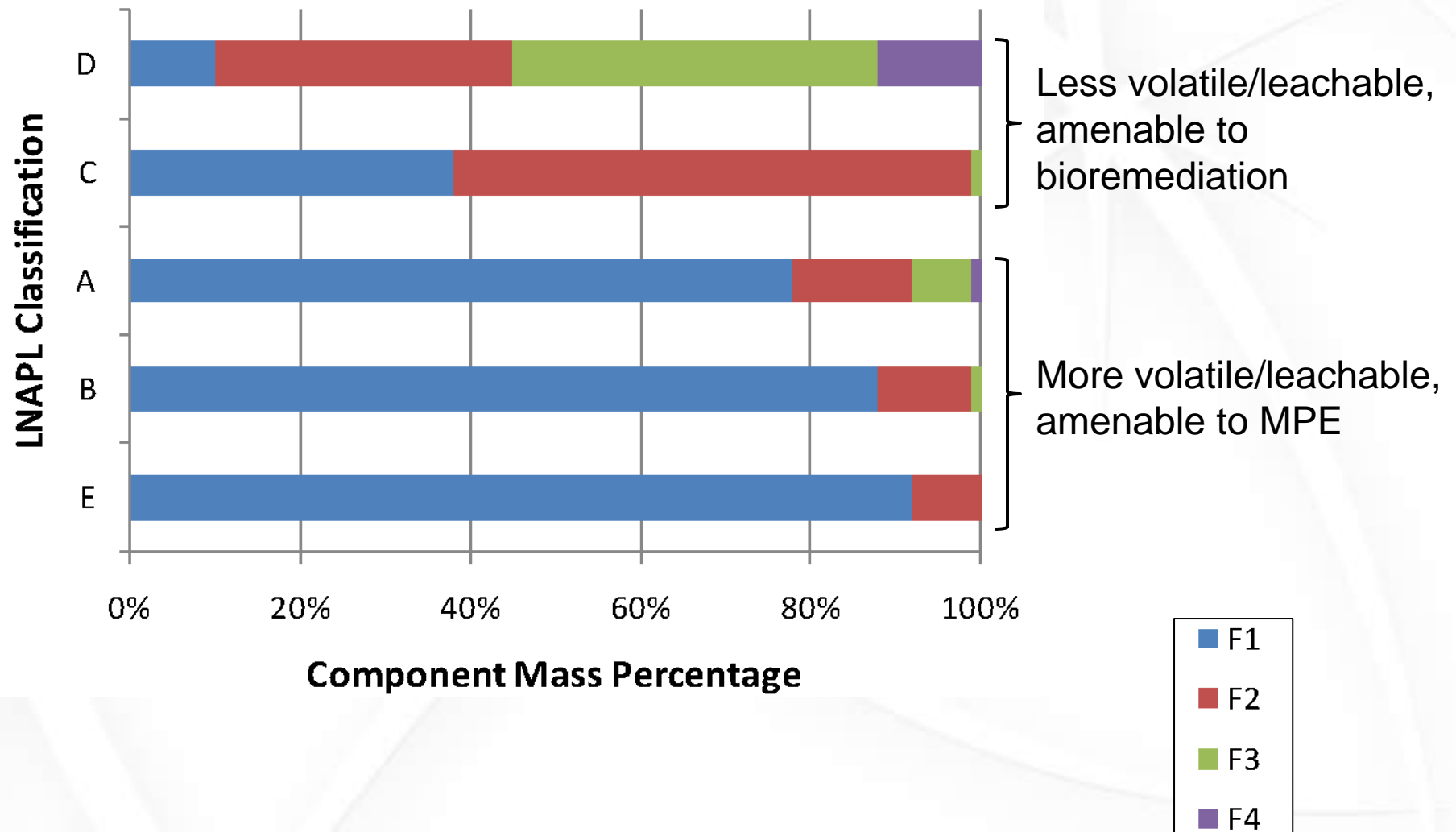
- LNAPL "D"

- LNAPL "E"



LF27
4.7-5.0 m bgs
submerged

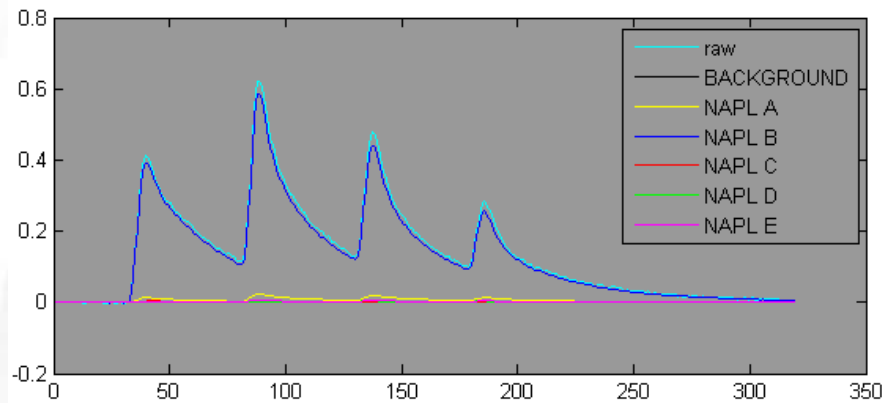
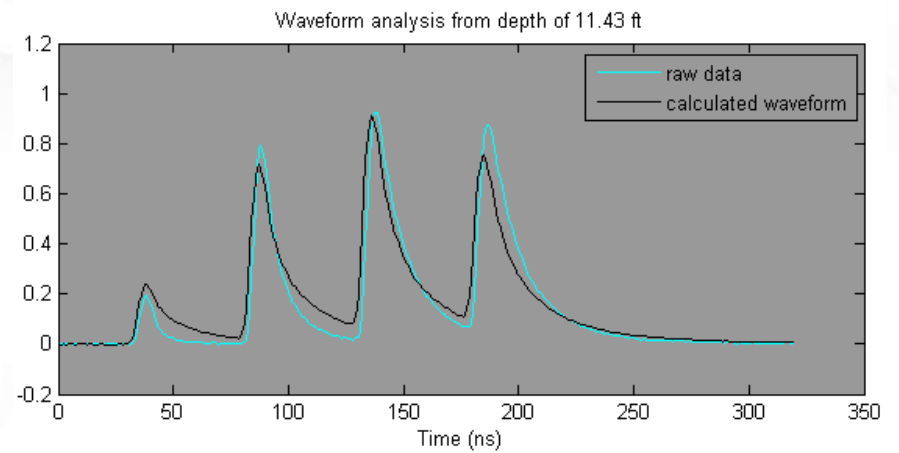
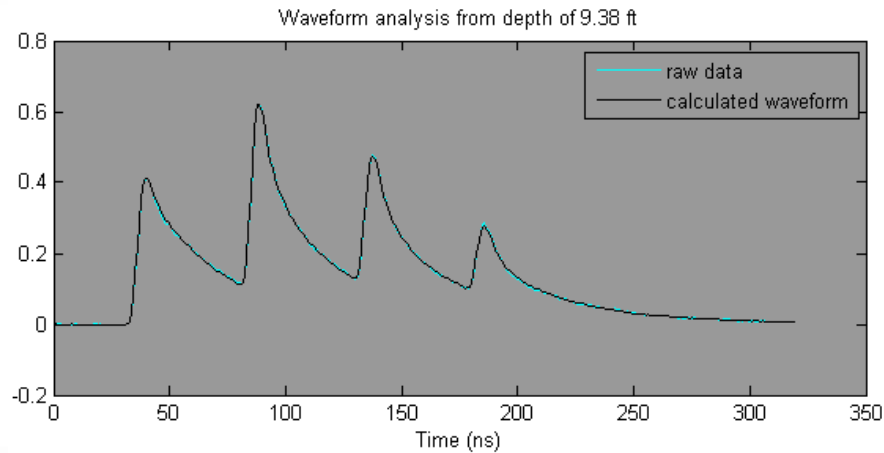
LNAPL Classification



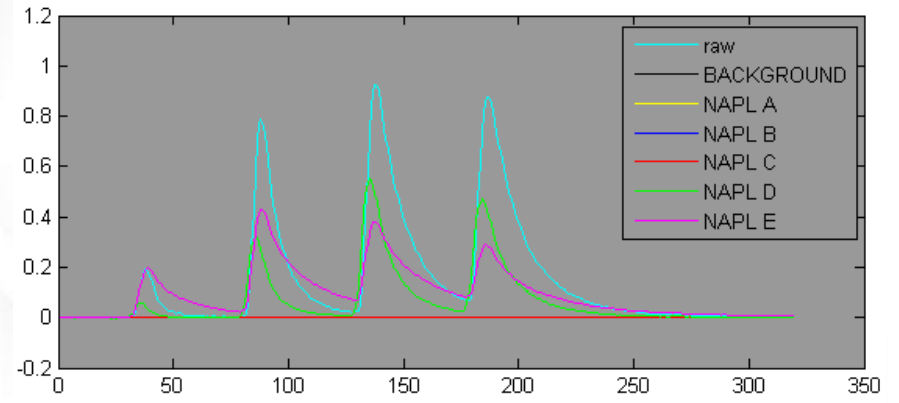
LIF Data Post-processing

- Graphical user interface in MATLAB
 - Nonnegative least-squares curve fit procedure
- Post-process LIF data to “solve” best fit to each LIF record – 100s of depth-specific waveforms per log
 - Selected a “Basis Set” of waveforms (ABCDE and background)
- End result is a revised set of LIF data files for visualization
 - The 3D distribution of each LNAPL type was plotted and used for remedial design

Waveform Curve Fit Examples

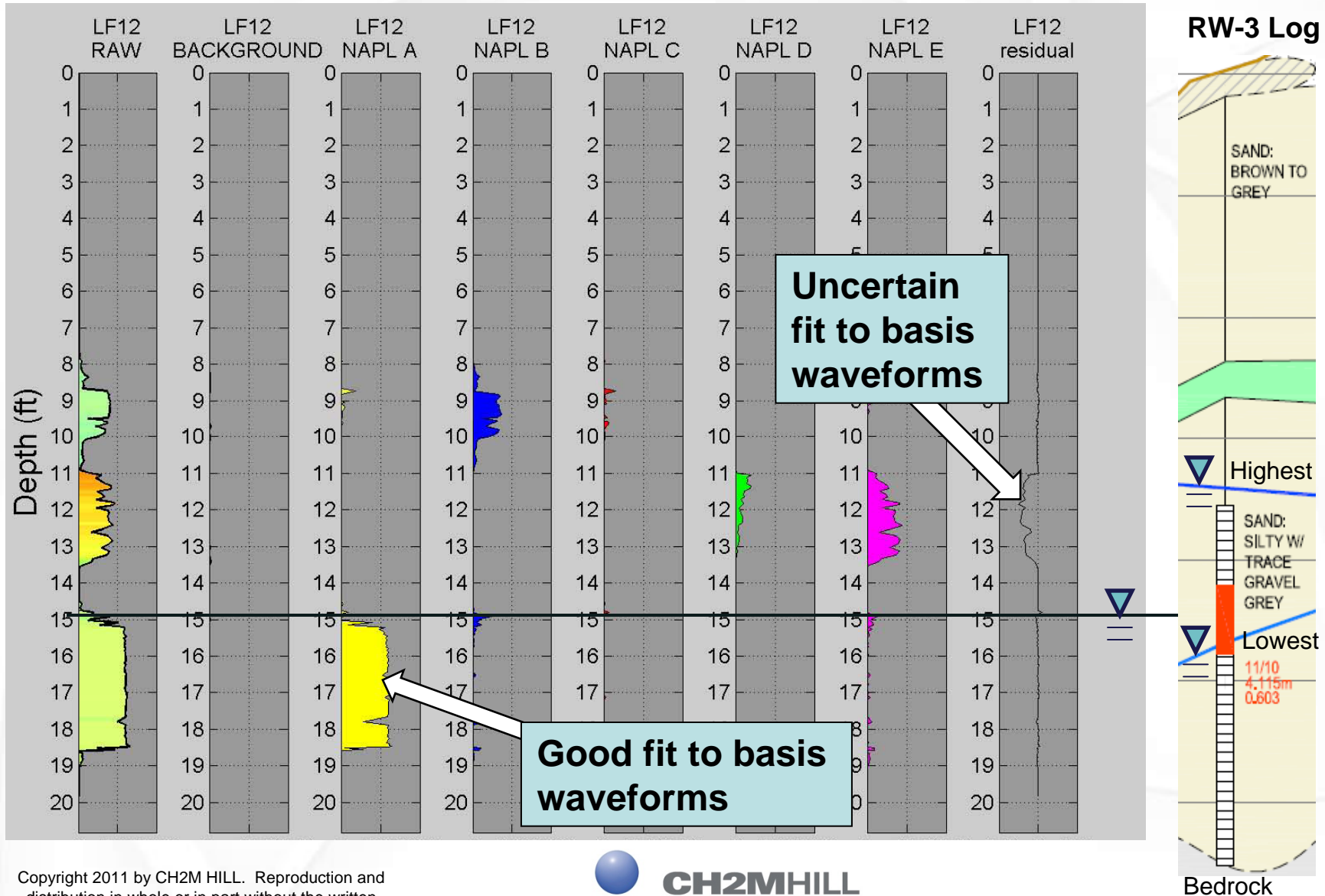


LF12 @ 2.86 m bgs



LF12 @ 3.48 m bgs

Post-processing Results



Application to Remedial Design

1.1 Remediation Strategy

The primary goal of the current remedial approach at Edson Gas Storage Facility Well Site 02-19-054-19 W5M (02-19 well site) is to reduce the contaminant plume source concentrations of light non-aqueous phase liquid (LNAPL) to expedite achievement of the Alberta Environment (AENV) Tier 1 remediation guidelines. The remedy will be a combination of soil vapour extraction (SVE), multiphase extraction (MPE), and monitored natural attenuation (MNA). The zone of potentially mobile and F1 hydrocarbon fraction-concentrated LNAPL will be a target for active removal. The zones of lower saturation and F3 and F4 hydrocarbon fraction-concentrated LNAPL will be a target for MNA. Initial efforts will install the MPE wells and field piping and will utilize the MPE wells for SVE to remove LNAPL mass from the vadose zone. After the SVE reaches its cost-effective limit, an existing TransCanada Pipelines Limited (TransCanada) -owned MPE system will be used to recover LNAPL mass from the submerged source zone. After effective source mass removal, MNA will be used to achieve the Tier 1 guidelines.

CH2M HILL Canada Limited (CH2M HILL) will use a phased approach to implement the remedy in a way that seeks to prioritize plume source treatment and mass removal and to adapt the remedial approach as new information is collected.

The cost-effectiveness of the remediation strategy lies heavily on the assumption that the TransCanada-owned MPE equipment will become available within three years and it will be in good working condition, meet the design specifications, and only require regular routine maintenance.

1.2 Remedial Action Objectives and Guidelines

The remedial action objectives (RAOs) are as follows:

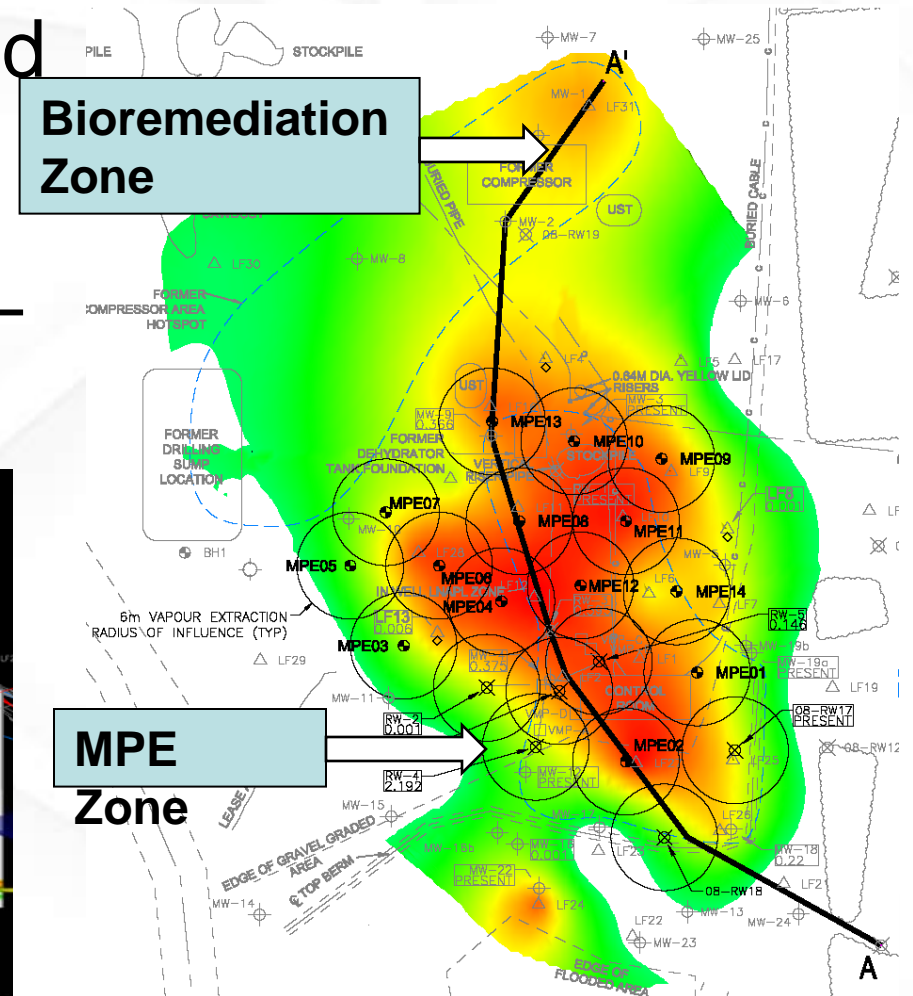
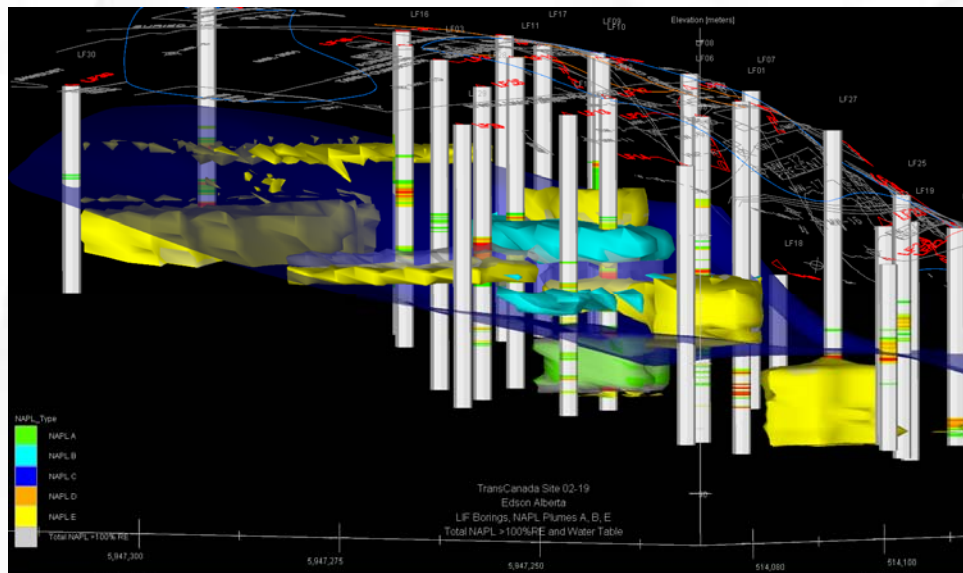
- Reduce plume source concentrations
- Reduce mass flux of contaminants to offsite areas
- Achieve AENV Tier 1 guidelines for groundwater
- Maintain zero contaminant exposure pathways
- Minimize the impact on property owners

LNAPL is present in soil and wells; soil and groundwater are impacted with petroleum hydrocarbons at levels above the AENV Tier 1 guidelines. Remediation will be implemented to treat and monitor the soil and groundwater to AENV-acceptable levels prior to closure.

- Define zones mobile LNAPL
- Define zones of more volatile and leachable soil contamination
- Tailor remedial design
 - MPE for mobile and volatile zones
 - Bioremediation for residual and less volatile zones

MPE Treatment Zone

- Results plotted in 3D and MPE treatment zones defined
 - Containing in-well LNAPL and F1-dominant soil contamination



Conclusions

- Application of advanced LIF is an effective method for optimization of LNAPL treatment zones
 - Relatively inexpensive data mining process
 - Derive a cost-effective remediation strategy that analyzes character of LNAPL and locates remedial technology accordingly
 - Can reduce footprint of active remediation
- Applicable to all LNAPL sites

Questions

- THANK YOU for your time and interest!

