FIELD TESTING OF THE DYELIF™ HIGH-RESOLUTION CHLORINATED DNAPL LOGGING SYSTEM

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BRIEF BACKGROUND

- Laser-induced fluorescence (LIF) is a proven tool for delineating LNAPL, creosote, and coal tar, but does not respond to most chlorinated DNAPLs.
- Injecting an indicator dye ahead of the LIF window can "force" DNAPL ganglia exposed to the LIF probe to generate an LIF response.
- DyeLIF™ uses an indicator dye – same concept as the Sudan IV or Oil Red O (ORO) dye “shake tests” used to determine absence/presence of DNAPL.
- Concept originally proposed by Dr. Stephen Lieberman et. al. at SPAWAR.
- Concept "reinvigorated" by Murray Einarson and Adrian Fure at AMEC Geomatrix (now with Haley & Aldrich).
- System development recently completed - with a capstone demonstration.
VALIDATION PLAN

- located a site that had a confirmed DNAPL release (59% trichloroethylene, 34% 1,1,1-trichloroethane) - fine sand and silt with intermittent silt and clay layers and groundwater at ~20 ft bgs
- teamed with University of Guelph for validation process (expertise in high resolution sampling)
- planned DyeLIF deployment the first week, co-located sampling and analysis the second week
- validation sampling to be taken next to and across depths where DyeLIF logging had identified DNAPL the prior week
- planned to sub-sample cores at high density horizontals then analyze the samples with ORO, PID, lab analysis and bench-top DyeLIF
ESTCP DEMONSTRATION PROJECT
DYELIF LOGGING – WEEK ONE
• conducted 25 DyeLIF locations to an average depth of 70 ft (21.3m)

• averaged 395 ft/day (<10 hour days)

• rate of penetration averaged 0.4 inch/second (1 cm/sec)

• 0.01 g/second dye solution delivery rate (equates to ~2-3 g per log)

• pushed majority of locations with a Geoprobe® 5400 – remainder with 7720

• no “downtime” - i.e. no damaged tooling with exception of one parabolic mirror adjustment during the week of DyeLIF probing

• successfully ‘bounded’ the DNAPL - with the exception of under a small building
EXAMPLE DYELIF LOGS

DYELIF RESPONSE RANGED FROM NON-DETECTS TO MAJOR HORIZONS OF PERCHED DNAPL
EXAMPLE DYELIF LOG
EXAMPLE WITH SMALL TO MEDIUM RESPONSES

these are “hits”
NON-NEGATIVE LEAST SQUARES POST-PROCESSING
ON-SITE, 5 MINUTE PROCESS
CRITICAL FOR ISOLATING SMALL “HITS” AT HIGH RESOLUTION (0.5 cm)
ESTCP DEMONSTRATION PROJECT
VALIDATION - WEEK TWO

• extremely challenging sampling conditions – even with an experienced team of high-resolution sampling experts with site-specific experience

• after trying numerous techniques arrived at Geoprobe MC7™ sampler with sealed piston adaptation to improve recovery

• after three days of technique refinement (and anguish), average recovery climbed to 65% (actually impressive in light of the difficult geology)

• lateral heterogeneity made stepping off the DyeLIF location <2 ft and encountering Dye-LIF-identified DNAPL a “hit/miss” affair

• persistence eventually yielded a sufficient number of cores –those were sampled to produce 260 depth-discrete sub-sample horizons

• PID, ORO visual, and DyeLIF were run on high-resolution sub-samples

• 50% of the sub-sampled horizons (133) were sent to lab for VOC analyses (based on what was observed with screening tools
EXAMPLE - DYELIF & VALIDATION AT LOCATION #24

positive ID with DYE shake test

positive ID with DYE-LIF (adjacent log, sub-core data not fully processed yet)

DYE-LIF is able to see thin lamina of DNAPL with NNLS processing; consistent with ORO dye test
DYELIF BENCH TOP FLUORESCENCE VS. ESTIMATED DNAPL PORE SATURATION
CORRELATION BETWEEN DYELIF & SAMPLING

- Generally very good agreement with DyelIF logs (heterogeneity occasionally causes discrepancies)
- DyeLIF being more suited for regional assessment - not the field scale - not the visual - not the up-hole "what is it?"
- Excellent samples for DNAPL and LNAPL
  - 100% match for samples of > 2.5% pore saturation DNAPL
  - 98% match for 1.0% pore saturation DNAPL
- While results not yet complete, detection limits vary between 1.0% and 2.5% pore saturation. These values MIGHT vary site-to-site with Lowell test site being higher.
3D VISUALIZATION

all DyeLIF DNAPL “detects” shown on pipes

size of ring and heat of color correspond with increasing strength of response
all DyeLIF DNAPL ‘detects’ with core screening results plotted alongside positive ORO and PID in red
CPT DELIVERY  3 DAYS IN MARCH, 2014

- Pushed 11 logs to >68 ft, total of 805 ft in 3 days which included integration and takedown of DyeLIF system
- Maximum penetration was 78 ft (bedrock)
- Unfortunately we were not allowed to push in “the heart” (wanted to compare to 2013 DyeLIF percussion logs)
- Pushed at 1.5 cm/sec (ASTM bottom limit) – we feel 1.0 cm/sec would be optimal (desire higher resolution to detect smaller ganglia)
CONCLUSIONS

- DyeLIF produced the equivalent of an ORO shake test at 0.5 cm spacing with an average daily production of 395 ft

- DyeLIF responded preferentially to DNAPL with no dissolved or vadose phase response (as expected)

- field LoD of ~1.0%-0.1% DNAPL pore saturation

- in other words, under these site conditions the DyeLIF generated the equivalent of >10,000 ORO shake tests per day - with 100% “recovery”

- DYELIF has a monotonic response - more fluorescence equates to higher pore saturation of DNAPL

- tracking the indicator dye solution injection pressure reveals details of hydraulic conductivity with depth

- DyeLIF data is going to ‘challenge’ the 3D visual community
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