NEW DIRECTIONS IN HORIZONTAL REMEDIATION WELLS

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OVERVIEW

- Drilling Capabilities
- Navigation
- Tooling and Methods
- Remediation Types & Installations

DRILLING CAPABILITIES

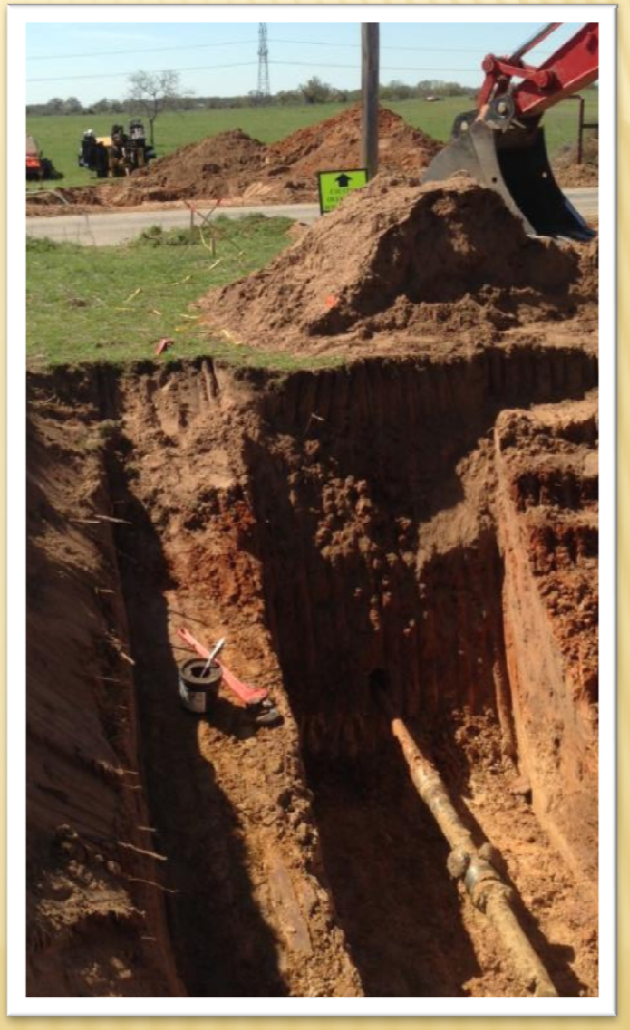
Significant increases in length, diameter capabilities

- Mid-1990's – 300-500 ft. extraction wells were the norm
- 2009 – 1,800 ft. D-E GW extraction wells [*DTD* – Pt. Loma, CA]
- 2012 – 4 in. - 1,450 ft. *Blind* SVE wells [*DTD* – Robins AFB, GA]
- 2012 – 16 in. - 9,931 ft. Gas pipeline crossing [*Michels* - Charleston, SC]

DRILLING CAPABILITIES

"All Terrain" rigs

- Dual-rod systems for directional rock drilling
- Reduces need for mud motors in hard formation
- Reduces generation of contaminated drilling fluid
- Remediation wells to >1,000 ft. in rock



LOCATING

Improvements in locating systems enable precise drilling in more challenging environments, at greater depths:

- Walkover Systems – Need physical access over bore path
- Wireline Systems – All locating occurs at the rig

WALKOVER LOCATING SYSTEMS

- No surface layout required
- Higher powered sondes; greater depths (80-100')
- Multi-frequency to avoid interference
- Data logging capabilities: pitch, position, depth, met adata

DCI SHORT STEERING TOOL

- Recent market entry
- Uses earth's magnetic field for azimuth
- Needs no surface coil or antenna
- Suitable for drilling under restricted access areas
- Viable system for smaller rigs – => 2 $^{3}/_{8}$" drill rod

GYROSCOPIC STEERING TOOL

- No walkover requirements
- No depth or length limitations
- Not affected by electro-magnetic interference
- Accuracy 0.04° Azimuth; 0.02° Inclination
- Requires rig with 4.5 – in. > drill rods

1200’ bore, diatomite, uphill, endangered flora

TOOLING AND METHODS

- Steerable air hammers
- Knock Off technology
- Measurement while drilling (mud pressure)

STEERABLE AIR HAMMERS

- Able to penetrate hard bedrock
- Couples with standard locating systems
- Penetration rates up to 150’ day
- Diameters 4.5 in. – 7 in. (ream to go larger)
- Usable with small rigs ($1\ ^{5}/_{8}$ in. drill rods)
- Bend radii from 500 ft.

KNOCK OFF TECHNOLOGY

- Blind well installation in unstable formations
- Assures precise placement of blind wells in soft material
- Well diameter limited by drill rod bore
- Current installed lengths up to 1,500 ft.

KNOCK OFF TECHNOLOGY

- Drill pilot bore with K-O assembly
- Install well materials inside rods
- Remove drill bit
- Pull rods back, leaving well materials in place

MEASUREMENT WHILE DRILLING

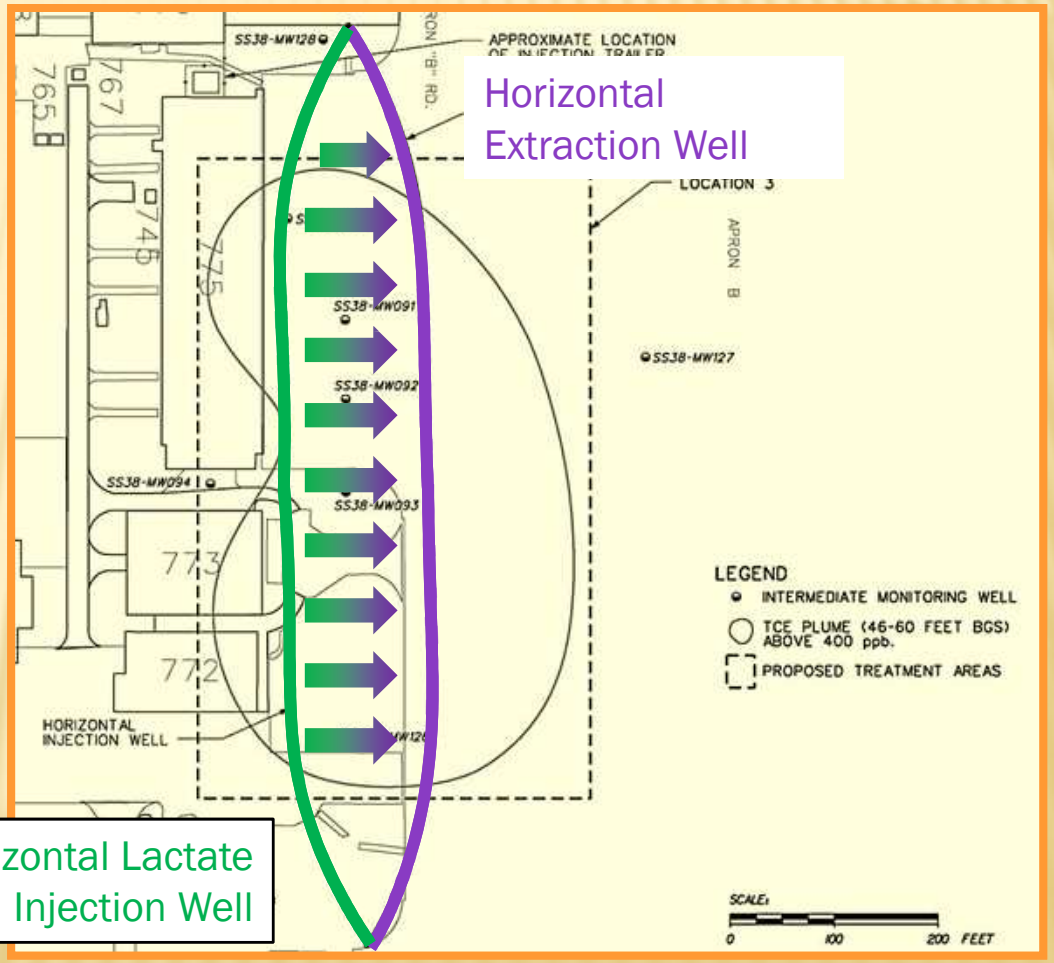
- Technology transfer from oil industry
- Monitor fluid pressure while drilling pilot bore
  - Reduce potential of frac-out in shallower bores
  - Reduce drilling fluid infiltration into formation
- Wireless MWD technology may lead to more downhole investigative options
  - Adaptations from direct push technologies
  - UVOST®/TarGOST™

REMEDIATION TYPES & INSTALLATIONS

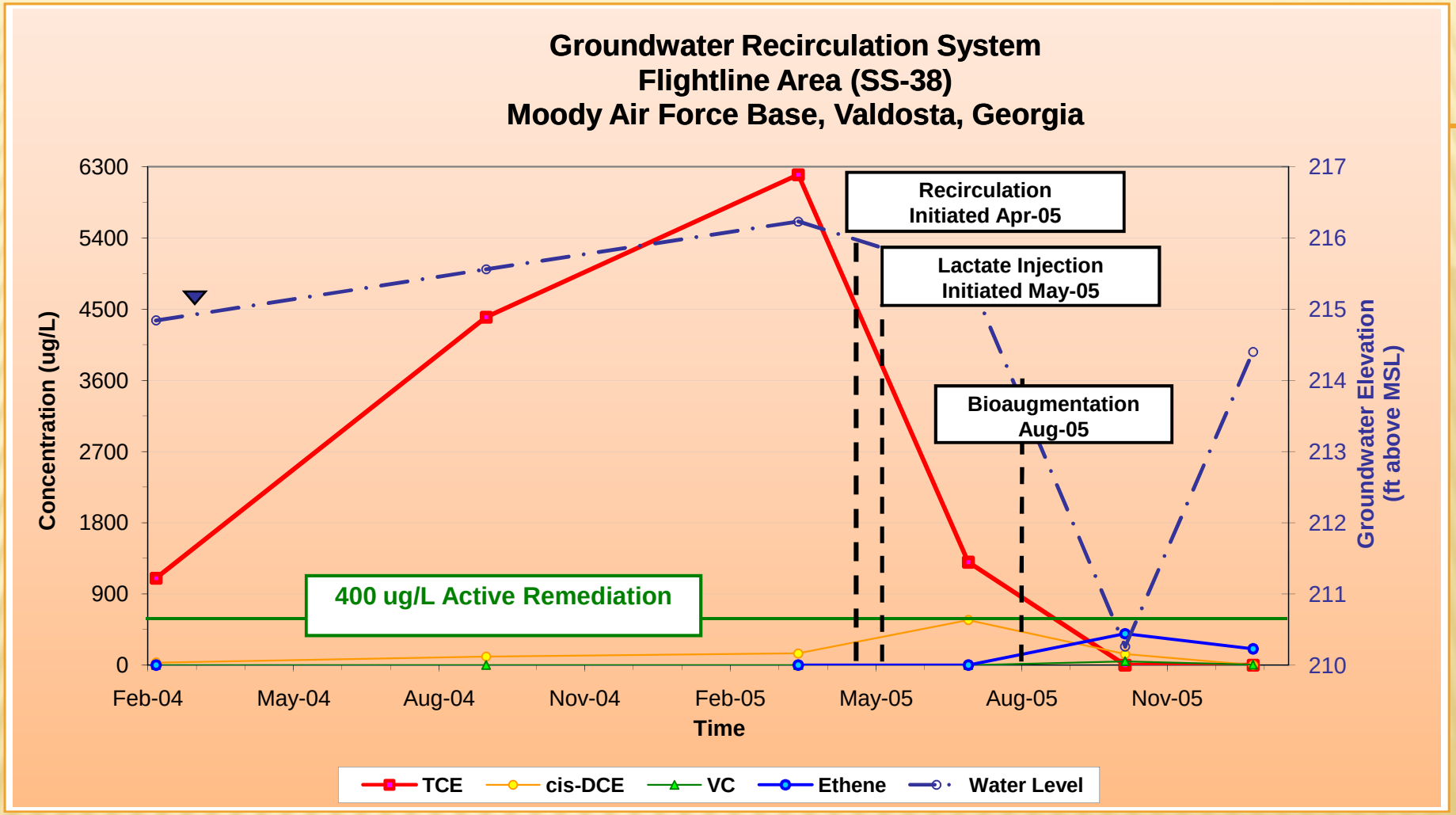
- First HDD wells primarily GWE and SVE
- Air sparging gained in popularity
- Current trend has been to *in situ* methods
  - ISCO injection
  - Biological amendments/enhancements
  - Recirculating systems
- Thermal remediation
  - Electrical resistance heating
  - Steam or hot air injection
- Future progress in passive treatment technologies

RECIRCULATING BIOAUGMENTATION SYSTEM

- Moody Air Force Base, Valdosta, GA
- Fueling apron for active flight operations
- HDD Well Pair for subsurface recirculation system
- Sodium Lactate Injection/Extraction
- 900’ long / 55’ deep



MOODY AFB – WELL LOCATIONS

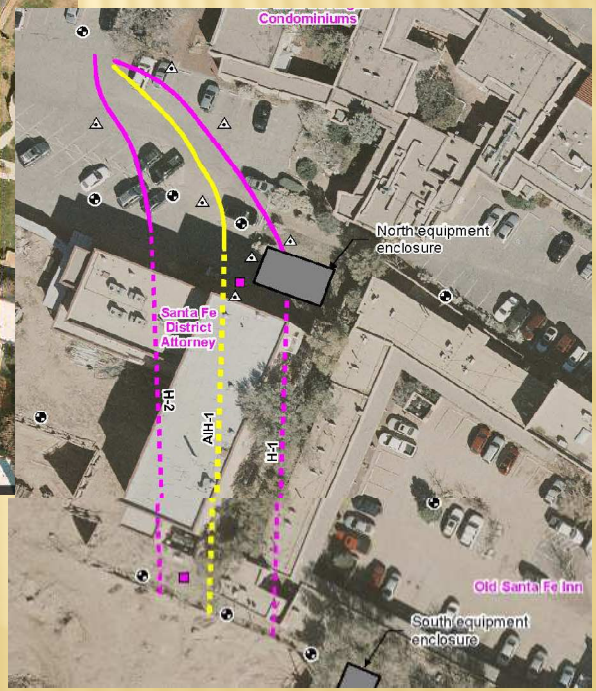


RESULTS

Listed as No Further Action after two years of operation

JUDICIAL COMPLEX, SANTA FE, NM

- Well Dimensions:
  - ~300 ft. each
  - One hot air injection
  - Two SVE
- Duration of Treatment:
  - 18 months
- Mass Removal
  - 20,500 gallons
  - >75% of contaminant mass
- No measurable free phase
  - Initially present in 12 wells
- Treatment: Completed



SUMMARY

Since its inception as a treatment tool, HDD has evolved significantly.

Wells can now be installed:

- Longer
- Deeper
- More Accurately
- Wider Range of Treatment Options
- Often less expensively

QUESTIONS AND CONTACT INFO

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