RAPID CLOSURE OF HEAVY CRUDE OIL SITE USING *IN SITU* BIOREMEDIATION TECHNOLOGY IN LOW-PERMEABILITY SOIL AND FRACTURED BEDROCK

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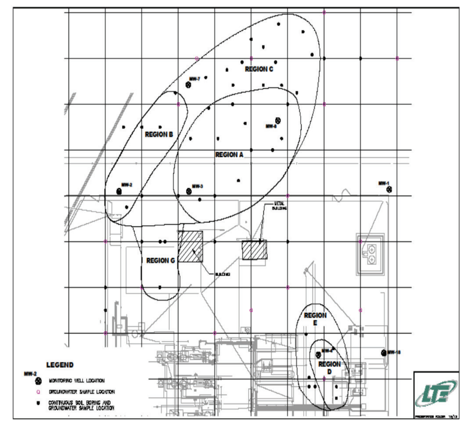
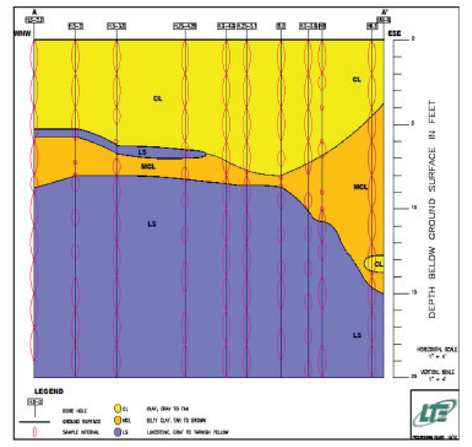
BACKGROUND / OBJECTIVES

THE SITE:

- Heavy crude oil (API gravity of 18º) released to the subsurface from a pipeline near a wellhead in the East Texas Basin generated a petroleum-hydrocarbon plume approximately 2.4 hectares (6 acres) in area.
- Solute in soil indicative of light non-aqueous phase liquid (LNAPL), i.e., concentrations over 50,000 milligrams per kilogram (mg/kg) of total petroleum hydrocarbons (TPH), was observed at depths from approximately 5.5 to 6 meters below ground surface (bgs).
- Undulating surface topography with paleo-channels (incised, erosional features) caused a dissolved-phase plume of TPH in groundwater with concentrations up to 50 milligrams per liter (mg/L) to extend approximately 385 meters downgradient from the source.
- The affected matrix was complex and included low permeability, residual clays overlying shallow, fractured limestone bedrock. The static water level was approximately 6 meters bgs.





IMPACTFUL AQUIFER CHARACTERISTICS:

- Anisotropy and heterogeneity due to variance in matrix density and grain size.
- A relatively steep gradient and the highly fractured bedrock caused solute distribution and flow direction to be unpredictable.

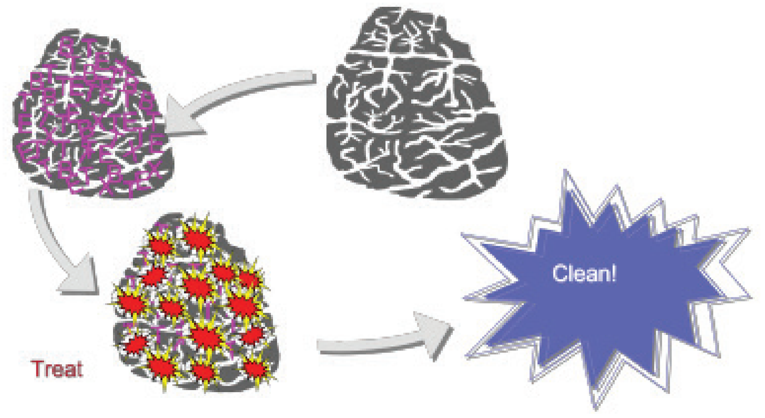
THE REMEDY:

BOS 200® is granular activated carbon inoculated with microbes (consortia of facultative microorganisms), **electron acceptors** (nitrate and sulfate), and **nutrients** (phosphorus and nitrogen).

- **Indiscriminate**: activated carbon removes virtually all organics, whether in vapor, solid, or aqueous phase.
- Efficient destruction of petroleum hydrocarbons via **biodegradation.**
- Effective in the **saturated** and **unsaturated** zones.
- Works in multiple site conditions — despite pH, dissolved O2 levels, microbial or substrate deficiencies.

BOS 200® BIODEGRADATION:

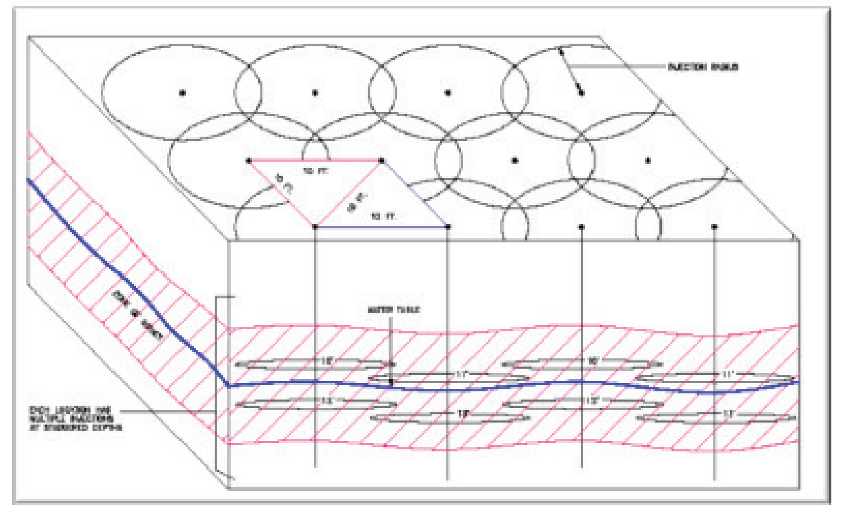
- Introduces a new biocosm, rather than enhancing indigenous bacteria.
- The new biocosm — the elemental carbon has enormous pore space surface area coated with microbes.
- The niche offered by the carbon results in a robust environment for the microbes to break down the petroleum hydrocarbons.



APPROACH / ACTIVITES

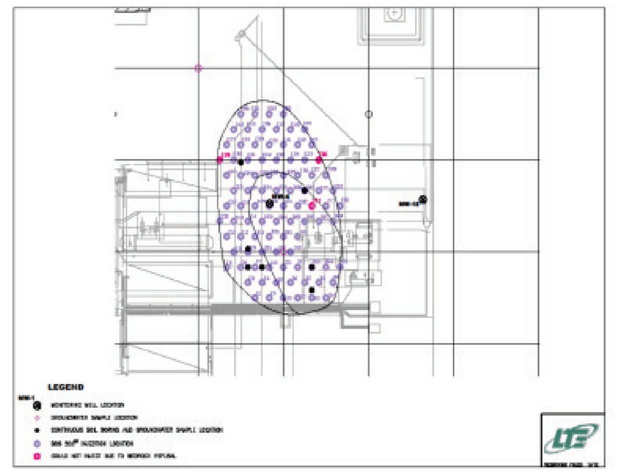
The Remedial Action Plan submitted to and approved by the Railroad Commission of Texas (RRC) was to implement an in situ BOS 200® injection program to expedite remediation for a pending property sale.

- Subtle facies changes in overlying, low-permeability soil and thin bedding planes and complex fractures in highly weathered bedrock resulted in solute concentrations that varied by orders of magnitude in distances of only several millimeters, though no LNAPL was observed.
- The first step was to conduct a high-resolution, quantitative data assessment to characterize plume strength and geometry. The outcome was an accurate conceptual site model used to:
  a. apply (continuous) soil and groundwater data to develop a discrete remedial design;
  b. inject BOS 200®;
  c. complete confirmatory/performance borings to observe remedy distribution and evaluate if "the target was hit" (or adjust subsequent injections, accordingly);
  d. analyze corresponding groundwater samples; and
  e. calculate mass reduction appropriate to achieve targeted horizontal and vertical treatment coverage.
- This sequence was repeated until cleanup goals were met in all subject areas.



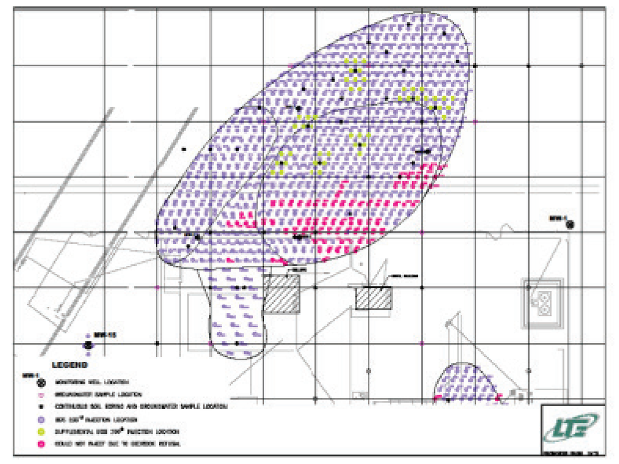
IMPLEMENTATION:

- The site was subdivided into seven regions, based on constituent concentrations treatment was implemented over a 7-month period



ONSITE:

- Treatment area divided into 3 regions based on initial concentrations and carbon loading.
- 462 injections at 89 locations and from 4 to 6 injections at each location.



OFFSITE:

- Treatment area divided into 4 regions based on initial concentrations and carbon loading.
- 1,677 injections at 630 locations and from 4 to 10 injections at each location.

R3 Presented by ***Remediation Risk Reduction, LLC***

RESULTS / LESSONS LEARNED

PERFORMANCE MONITORING:

- 120 groundwater samples were collected to monitor reductions in TPH concentrations.
- 38 additional, continuously sampled soil borings were completed to evaluate mass removal.

RESULTS:

- After 5 months, TPH concentrations were reduced by approximately 87% to 100% and plume footprint was reduced by 53%.
- After 7 months, solute concentrations in areas impacted by the plumes were below maximum contaminant levels (MCLS).
- Closure criteria had been met and the FOOTPRINT WAS EMPTY!

LESSONS LEARNED:

The project was successful because the distribution of BOS 200® was optimized by monitoring injectate placement throughout the injection program. This led to treatment-performance confirmation over the 7-month period. After a one-year (4 quarters) Closure Monitoring Program, a **No Further Action** determination was granted by the RRC.