BOS 200® LNAPL Remediation at Budget Rental Car Site in Louisville, Kentucky USA

Background Information

The Budget Rental Car Site was a former retail gasoline and diesel service station existing on approximately 3 acres located in Louisville Kentucky, USA. The investigation and corrective action work conducted at the facility was under the oversight of the Kentucky (KY) Department for Environmental Protection (KDEP), Division of Waste Management (DWM), Underground Storage Tank Branch (USTB).

Investigations and remediation of petroleum releases to the subsurface had been conducted at the terminal since the underground storage tank systems were removed from a common tank pit in 1997. Subsurface impacts have historically included accumulations of petroleum hydrocarbons in soils, accumulation of light non-aqueous phase liquids (LNAPL) in monitoring wells MW-3, MW-5 and MW-6, and aqueous phase (dissolved) benzene in groundwater as high as 11 milligrams per liter (mg/L).

The impacted area immediately surrounding the former tank pit, occupies approximately 7,000 square feet (ft) and had both soil and groundwater impacts.

Remedial Effort

In December 2010, Linebach Funkhouser, Inc., (LFI), and AST Environmental, Inc., (AST) teamed to develop a remedial approach to address the LNAPL and dissolved phase petroleum hydrocarbon impacts at the site. Specifically, an injection design was prepared and implemented to address LNAPL and dissolved phase petroleum hydrocarbons in the following monitoring wells:

- MW-1, benzene (0.94 mg/L) and naphthalene (0.8 mg/L)
- MW-2, benzene (0.35 mg/L) and naphthalene (0.6 mg/L)
- MW-3, benzene (11.2 mg/L) and naphthalene (1.4 mg/L) and LNAPL (0.15 ft thickness)
- MW-5, benzene (0.04 mg/L) and naphthalene (0.1 mg/L) and LNAPL (0.05 ft thickness)
- MW-6 LNAPL (0.01 ft thickness) – diesel range

The goal was to inject BOS 200® to remediate the site for removal all the LNAPL and reduce benzene concentration to below 0.005 mg/L in the on-site monitoring wells. The figure below provides the location of the impacted wells.

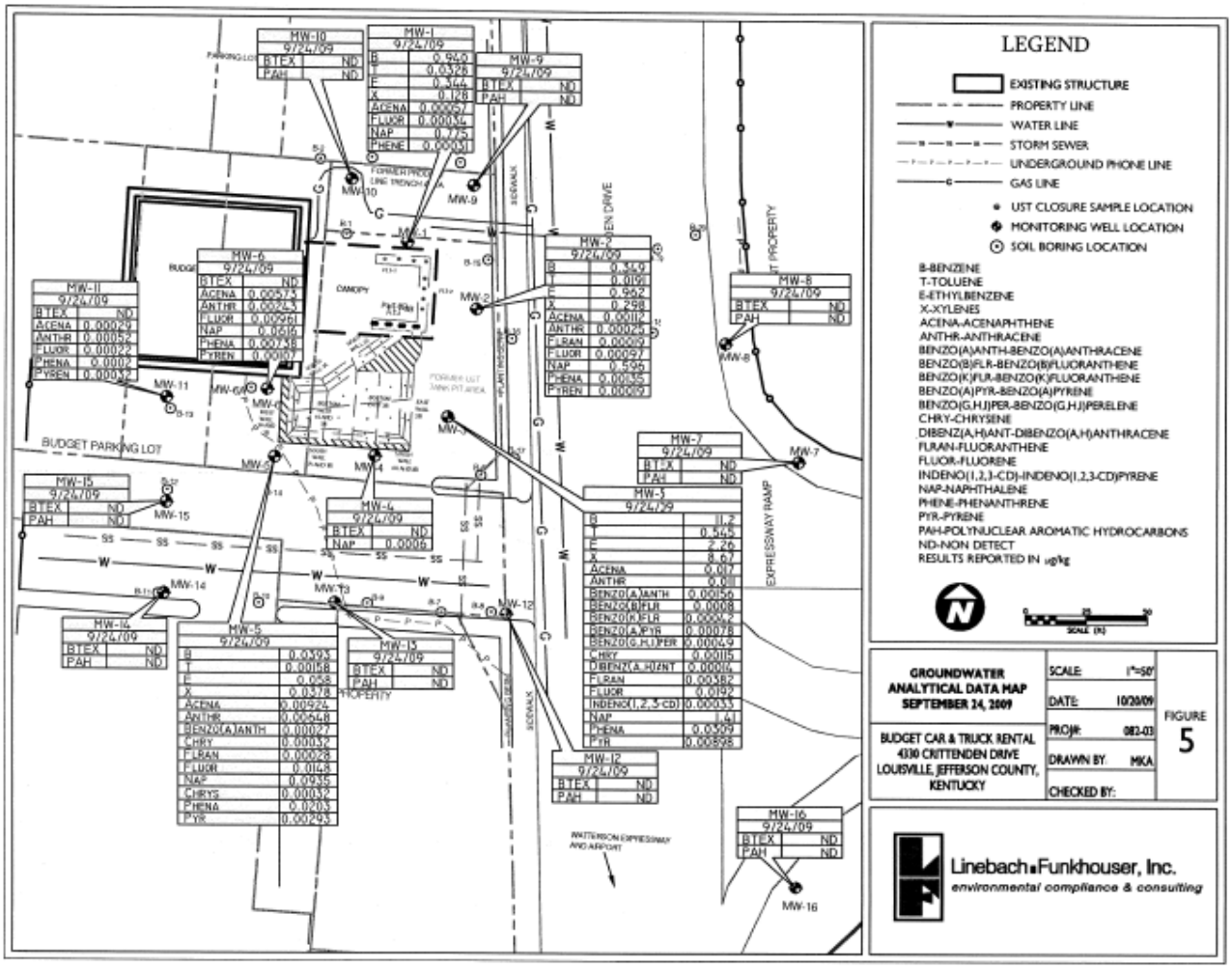

Figure 5 – Groundwater Analytical Data Map

Full Scale Design and Implementation

As shown below there are five (5) areas associated with six (6) monitoring wells that were impacted with petroleum hydrocarbons. The specific injection design for each of these areas is detailed below. The injections point spacing varied from 5 to 7.5 feet.

Area A (MW-5 and MW-6 (~1400 sf))

- 25 injection points (on 7.5' centers)
- 12 injection points injected at 6, 8, 10, 12 &14 feet below grade surface (bgs)
- 13 inject points injected at 5,7, 9, 11 &13 feet bgs
- 25 pound shots at all 125 injections ~ 3125 pounds BOS 200®
- 6.25 gallons Trap & Treat® Bacteria Concentrate
- Approximately 2,500 gallons of city water (~8 gallons per injection)

Area B (MW-4 (~450 sf))

- 8 injection points (on 7.5' centers)
- 4 injection points injected at 6, 8, 10, 12 &14 feet bgs
- 4 inject points injected at 5,7, 9, 11 &13 feet bgs
- 15 pound shots at all 40 injections ~ 600 pounds BOS 200®
- 1.25 gallons Trap & Treat® Bacteria Concentrate
- Approximately 600 gallons of city water (~8 gallons per injection)

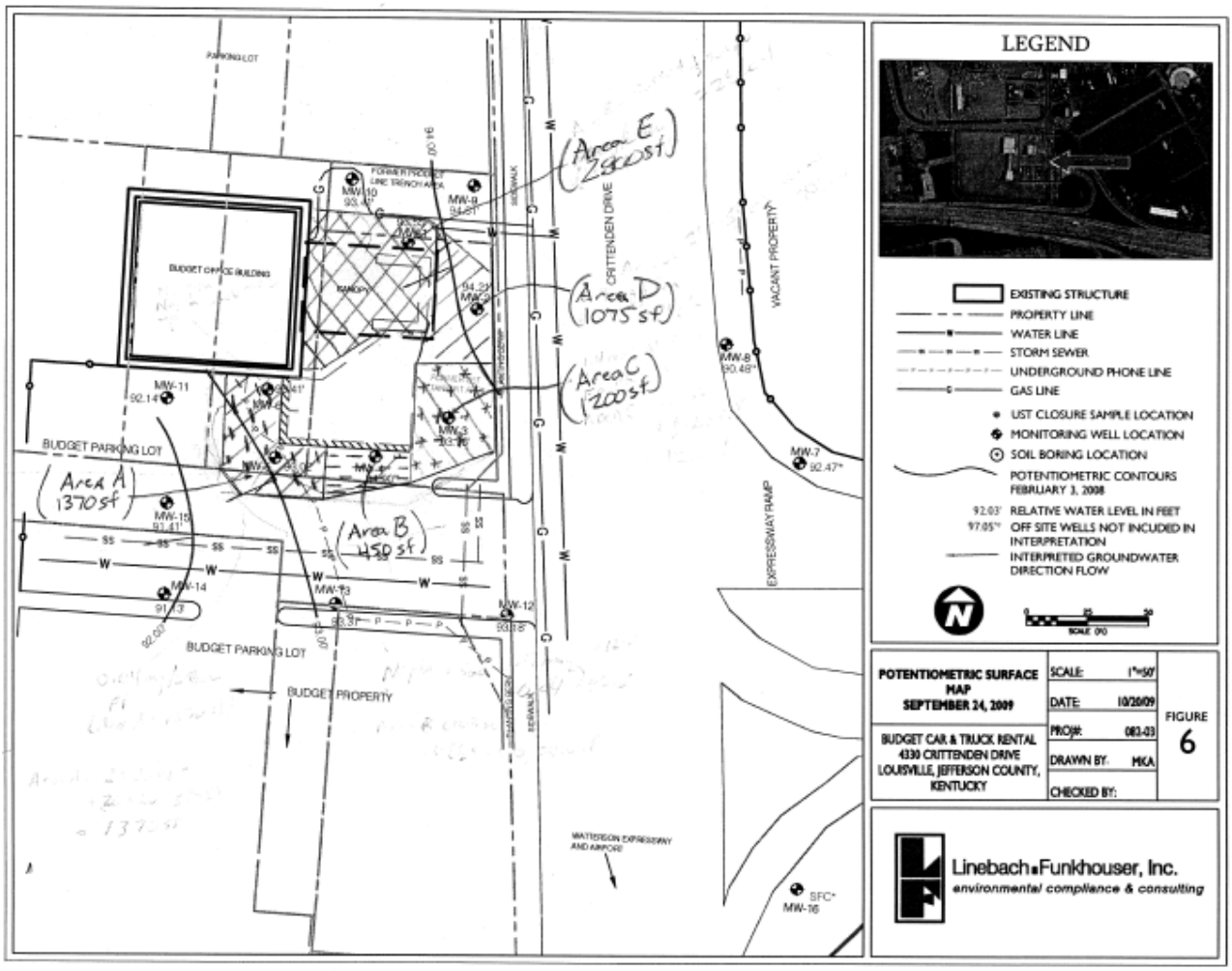

Figure 6 – Injection Areas Identified

Area C (MW-3 – 11 mg/L (~1200 sf))

- 48 injection points (on 5' centers)
- 24 injection points injected at 6, 8, 10, 12 &14 feet bgs
- 24 inject points injected at 5,7, 9, 11 &13 feet bgs
- 1st Injection Event
  - 20 pound shots at all 240 injections ~ 4,800 pounds BOS 200®
  - 10 gallons Trap & Treat® Bacteria Concentrate
  - Approximately 1950 gallons of city water (~8 gallons per injection)

2nd Injection Event –

- 48 injection points (on 5' centers)
- 24 injection points injected at 6, 8, 10, 12 &14 feet bgs
- 24 inject points injected at 5,7, 9, 11 &13 feet bgs
  - 20 pound shots at all 240 injections ~ 4,800 pounds BOS 200® (the design to be finalized after 6 month sampling event after the 1st injection)
  - 10 gallons Trap & Treat® Bacteria Concentrate
  - Approximately 1950 gallons of city water (~8 gallons per injection)

Area D (MW-2 - 0.4 mg/L (~1075 sf))

- 19 injection points (on 7.5' centers)
- 9 injection points injected at 6, 8, 10, 12 &14 feet bgs
- 10 inject points injected at 5,7, 9, 11 &13 feet bgs
- 20 pound shots at all 95 injections ~ 1900 pounds BOS 200®
- 4 gallons Trap & Treat® Bacteria Concentrate
- Approximately 800 gallons of city water (~8 gallons per injection)

Area E (MW-1 - 0.94 mg/L (~2800 sf))

- 50 injection points (on 7.5' centers)
- 25 injection points injected at 6, 8, 10, 12 &14 feet bgs
- 25 inject points injected at 5,7, 9, 11 &13 feet bgs
- 40 pound shots at all 250 injections ~ 10,000 pounds BOS 200®
- 20 gallons Trap & Treat® Bacteria Concentrate
- Approximately 2,250 gallons of city water (~8 gallons per injection)

On Friday, August 19, 2011, 20,400 lbs of BOS 200® was delivered to the Budget Site. On the morning of August 22, 2011, AST mobilized personnel and equipment to the site and setup for the injection effort to begin that day. The injections were completed in 8 workdays with AST injecting the 20,400 pounds (lbs) in 150 injection points to approximately 14' below grade surface. AST prepared BOS 200® slurries and injected it into the subsurface through probe rods. The slurry is pumped through the probe rods using a positive displacement diaphragm pump capable of delivering 1,200 pounds per square inch (psi) at 35 gallon per minute (gpm). The injection pressure varied from 200 to 600 psi. The pressure injection scheme created extensive "fracturing or soil lifting" of the soil to create preferential pathways within the fine grain clay which are filled with BOS 200®.

The injection effort was completed on 8/31/2011.

The table below provides the results for the LNAPL monitoring and the post-injection analytical. As seen in the table LNAPL monitoring was performed in January and June 2012. Both events demonstrated no presence of LNAPL. Also, groundwater sampling was performed on June 01, 2012 and the results from this provided benzene concentrations below the clean-up standard of 0.005 mg/L. Although, not shown here ethylbenzene, toluene, xylenes and naphthalene concentrations were all below 0.5 ug/L. There were some trace (1.8 ug/L) hydrocarbons noted in MW-6 during analyses, but these are suspected from old diesel impacts.

Table 1 – Pre- and Post-Injection Results Summary

Well ID	Pre-Injection Benzene (mg/L) (9/24/09)	Post-Injection Benzene (mg/L) (6/01/12)	LNAPL (ft) Pre-Injection (8/22/11)	LNAPL (ft) Post-Injection (1/3/12)	LNAPL (ft) Post-Injection (6/01/12)	Notes
MW-1	0.94	ND	Not Present	Not-Present	Not-Present	The KY USTB requires 4-quarters of sampling to be performed with results at or below the clean-up standard prior to issuance of a No Further Action.
MW-2	0.35	ND	Not Present	Not-Present	Not-Present	The KY USTB requires 4-quarters of sampling to be performed with results at or below the clean-up standard prior to issuance of a No Further Action.
MW-3	11.2	ND	0.15	Not-Present	Not-Present	The KY USTB requires 4-quarters of sampling to be performed with results at or below the clean-up standard prior to issuance of a No Further Action.
MW-5	0.04	ND	0.05	Not-Present	Not-Present	The KY USTB requires 4-quarters of sampling to be performed with results at or below the clean-up standard prior to issuance of a No Further Action.
MW-6	<1	ND	0.01 (diesel related)	Not-Present	Not-Present	The KY USTB requires 4-quarters of sampling to be performed with results at or below the clean-up standard prior to issuance of a No Further Action.

ND- Non-detect (<0.0005 mg/L (or <0.5 ug/L) benzene)