The Use of A Horizontal Extraction Well In Conjunction with Air Stripping to Intercept A MTBE Plume and Protect a Municipal Water Supply Well

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Abstract

In 1994, a catastrophic line release occurred at a retail petroleum facility in Central Indiana. Initial remedial efforts were successful in recovering separate-phase hydrocarbons in the groundwater but failed to contain the dissolved methyl tert butyl ether (MTBE) plume. Over the course of ten years the MTBE plume migrated 400 feet beneath a residential neighborhood toward a municipal water supply well. In the summer of 2003 detectable concentrations of MTBE were noted 15 feet upgradient of the municipal supply wells.

As a temporary measure, the threatened municipal supply well was taken out of service as much as possible. Due to the length of the plume, the immediate threat to the municipal drinking water well and the location of the plume beneath an established residential neighborhood, it was decided that a horizontal well would be the best means of containing and recovering the MTBE plume. Given that the aquifer is prolific sand, air stripping with activated carbon polish and discharge to surface water via a NPDES permit was the only practical means of removing MTBE from the groundwater.

In December of 2003 a horizontal well was installed through the center of the longitudinal axis of the MTBE plume. A total of 100 feet of screen were used giving the well an estimated maximum yield of approximately 85 gallons per minute. An additional vertical recovery well was placed between the municipal water supply well and the edge of the MTBE plume to provide additional capture near the water supply well.

Working in cooperation with the local Town government, a portion of a maintenance building near the water supply well was allocated to house the water treatment equipment. An NPDES permit was obtained to discharge the treated water to a nearby stream. The groundwater treatment system became operational in August of 2004 and has proven to be very effective in reducing the size/concentration of the dissolved plume and removing MTBE from the captured groundwater. This project was completed in such a way that there is almost no visible sign of the groundwater collection, treatment or discharge visible to the public.

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Site Description

The focus of this remediation project is a retail petroleum facility ("Site") in the center of Converse, Indiana. Converse is a small town of approximately 1,100 residents in a predominantly agricultural area of north-central Indiana, located approximately 60 miles north-northwest of Indianapolis (see Figure 1). The surficial geology of this region is dominated by basal till from Wisconsinian Age glaciation. This till consists primarily of sandy and Sitly clays interbedded with isolated or interconnected more permeable layers of sand or silty sand. The surficial geology of areas adjacent to streams is typically alluvium with thick deposits of permeable sands and gravels with some silt.

Figure 1 Site Location

The Site is located across the street, to the east of the Converse Public Library ("Library"). West of the Site is a residential area which is bordered to the west, across Maple Street by Municipal buildings, including the Converse water treatment plant. Little Pipe Creek, which flows to the north, is adjacent to the west of the municipal buildings. The general area west of the Site is shown in Figure 2.

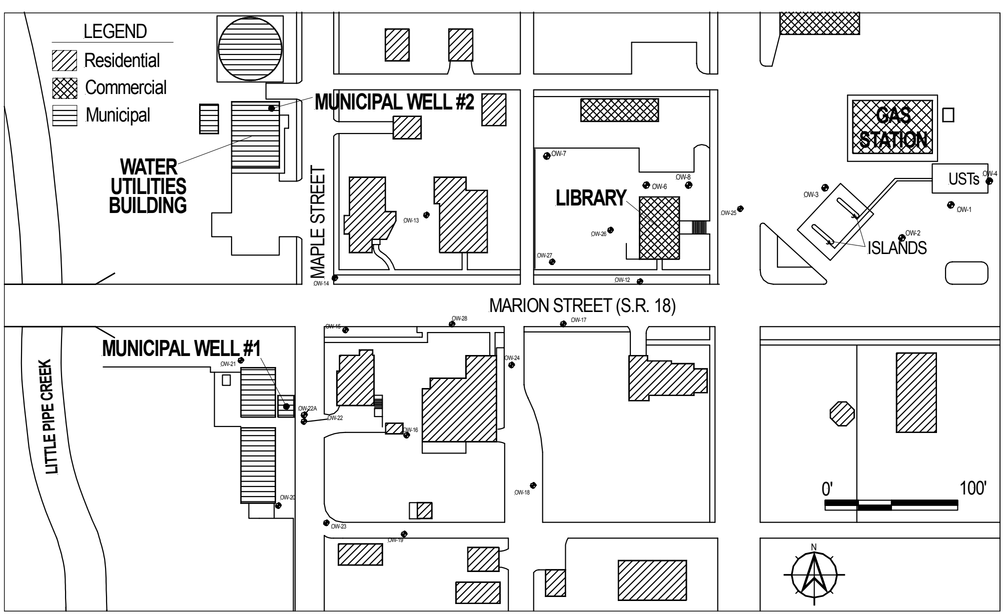

Figure 2 Site (upper right corner) and surrounding vicinity.

Movement of material in the subsurface is dominated by local topography and groundwater flow direction, both of which trend to the west-southwest, toward Little Pipe Creek (see Figure 3). Contamination at this Site was caused by a catastrophic release of gasoline from a product delivery line in 1990. An estimated 3,600 gallons of MTBE-containing gasoline was released into the subsurface before the broken pipe was identified and repaired.

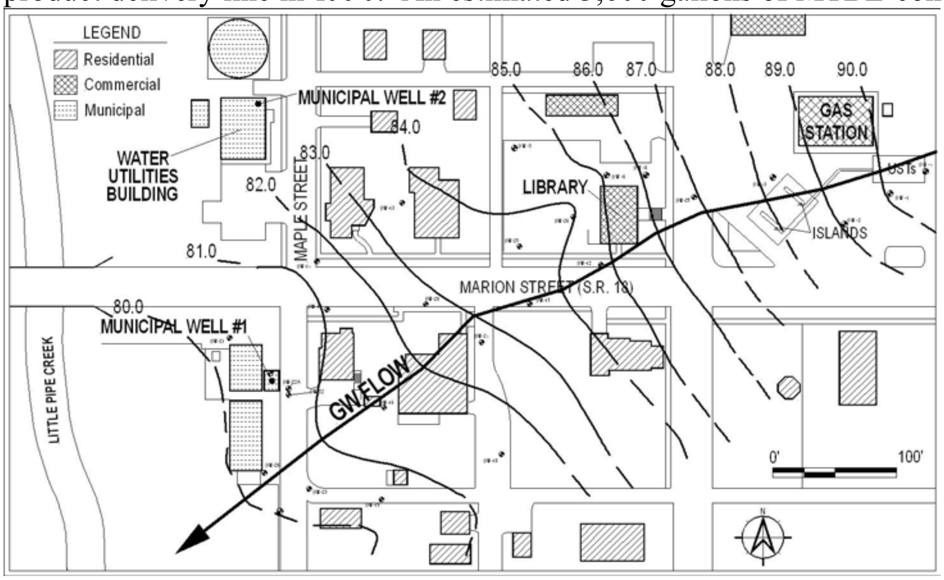

Figure 3 Preremediation groundwater flow direction (relative elevation in feet)

The failure of the product delivery line caused the owner of the site to remove the existing gasoline underground storage tanks (USTs) on the west side of the site and replace them with new USTs on the east side of the site. Early in the investigation process, in 1991, the environmental consultant used a soil gas survey to identify the extent of the product plume, as shown in Figure 4. The highest concentration of separate-phase hydrocarbon was located on the west edge of the site, near the area of the product line failure. At this point the dissolved plume had started to spread out radially from the release area but had not moved significantly downgradient.

Initial Remedial Efforts

Initial efforts removed a large portion of the separate-phase hydrocarbon on the Site. However, despite these early recovery efforts, a significant portion of the plume migrated to the west and southwest, in the direction of groundwater flow. As a result of this shift in the area of highest concentration, the focus of the remediation was relocated from the Site to Library property west of the Site and nearer to the then downgradient edge of the plume.

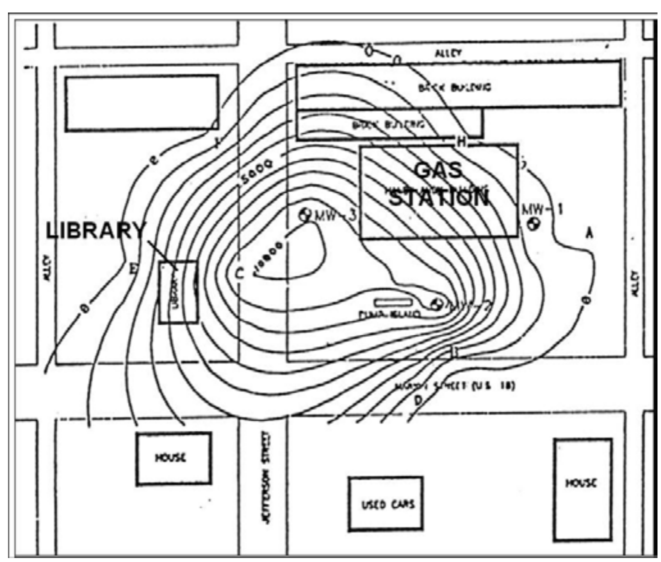

Figure 4 Soil gas survey readings showing the distribution of hydrocarbons in February 1991.

The initial groundwater treatment system used at the Site was a traditional groundwater pump-and-treat system, which began operation in 1994. When this treatment technology proved less effective than anticipated, a dual phase vacuum-enhanced recovery groundwater treatment system was installed and the previous groundwater recovery system removed. The extent of separate-phase and dissolved petroleum at and downgradient of the Site in November of 1994 is shown on Figure 5.

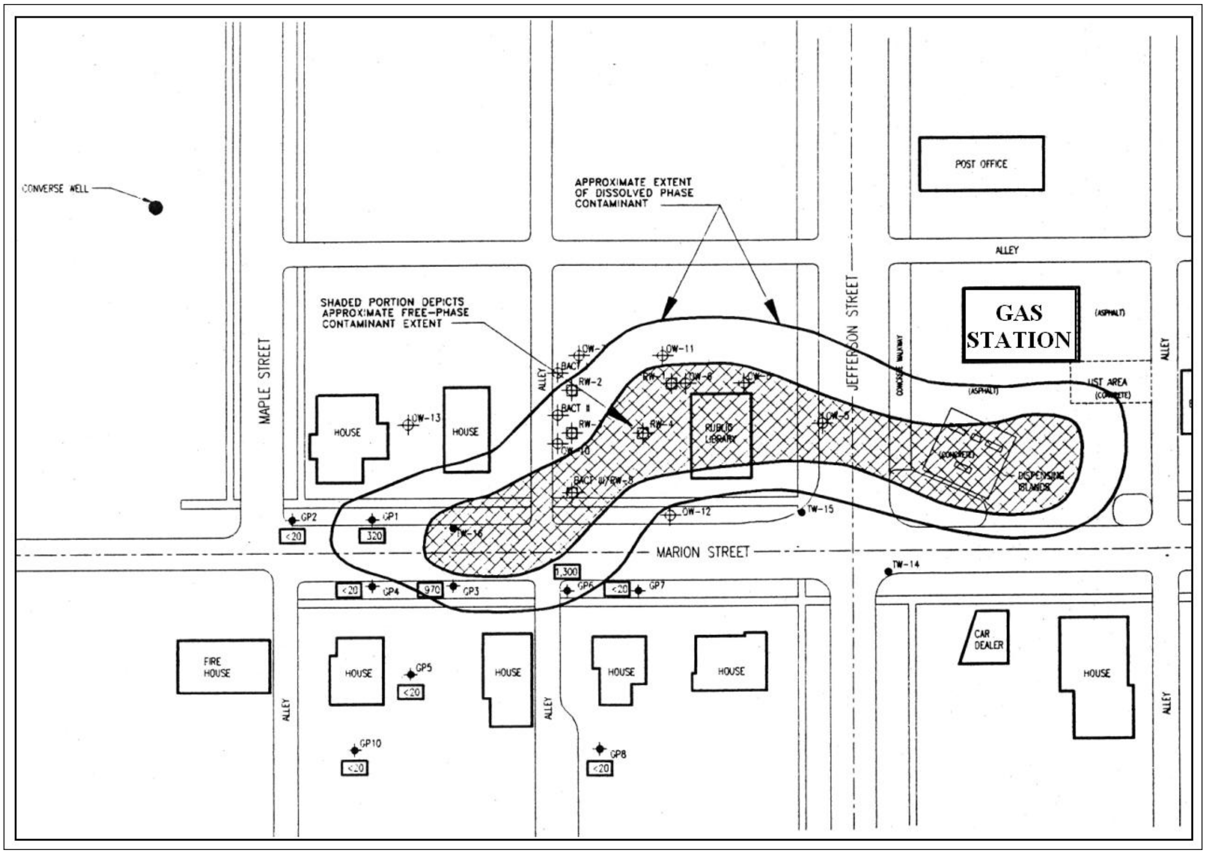

Figure 5 Petroleum plume extent in November 1994 - hatched area is separate-phase hydrocarbon.

In 1997, at the time of the implementation of the dual-phase vacuum-enhanced recovery system, the overall remedial strategy for this plume changed. It was believed that the Town of Converse only operated a single municipal groundwater supply well (Municipal Well #2), as shown in Figure 6 (labeled "Converse Well) and designated "Municipal Well #2" in Figures 2 and 3. The focus of the remedial strategy shifted from complete recovery of all dissolved hydrocarbons to the recovery of all separate-phase hydrocarbons and reduction of the concentration of dissolved phase hydrocarbons. All homes within the plume area and downgradient of the plume were known to be connected to the municipal water supply; therefore it was assumed that there were no downgradient receptors of the impacted groundwater. It was believed that with removal of the separate-phase hydrocarbon and reduction of the dissolved hydrocarbon concentration that natural attenuation would adequately reduce the dissolved hydrocarbon concentrations before the groundwater reached the Municipal Well #1 or discharged to Little Pipe Creek.

From 1994 to 2002 the dual-phase vacuum-enhanced recovery system operated on the Library property. During this interval, almost all of the separate-phase hydrocarbon was removed and the upgradient end of the plume moved downgradient to the middle of Jefferson Street, east of the Library. During this same period, the dissolved hydrocarbon plume continued to migrate downgradient toward Little Pipe Creek as shown in Figure 6.

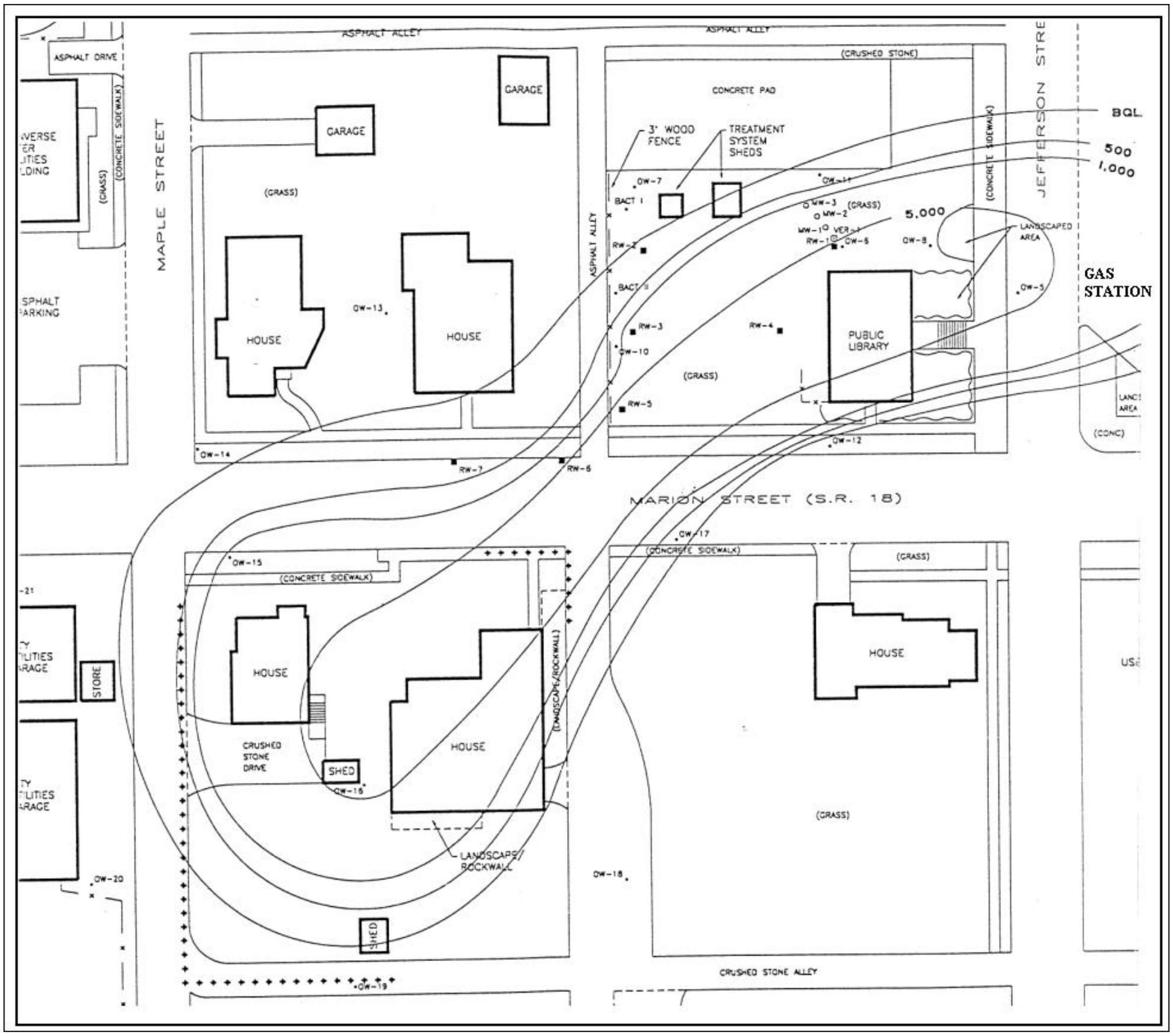

Figure 6 Extent of dissolved benzene plume in April 1998 - concentrations are in ug/l

By early 2002 the active remediation system installed on the Library property had removed enough dissolved hydrocarbon to cause the downgradient portion of the plume to detach from the portion on the Library property. Since it was anticipated that monitored natural attenuation would be adequate to deal with the downgradient portion of the plume, the remedial effort continued to focus on the Library property (see Figure 7).

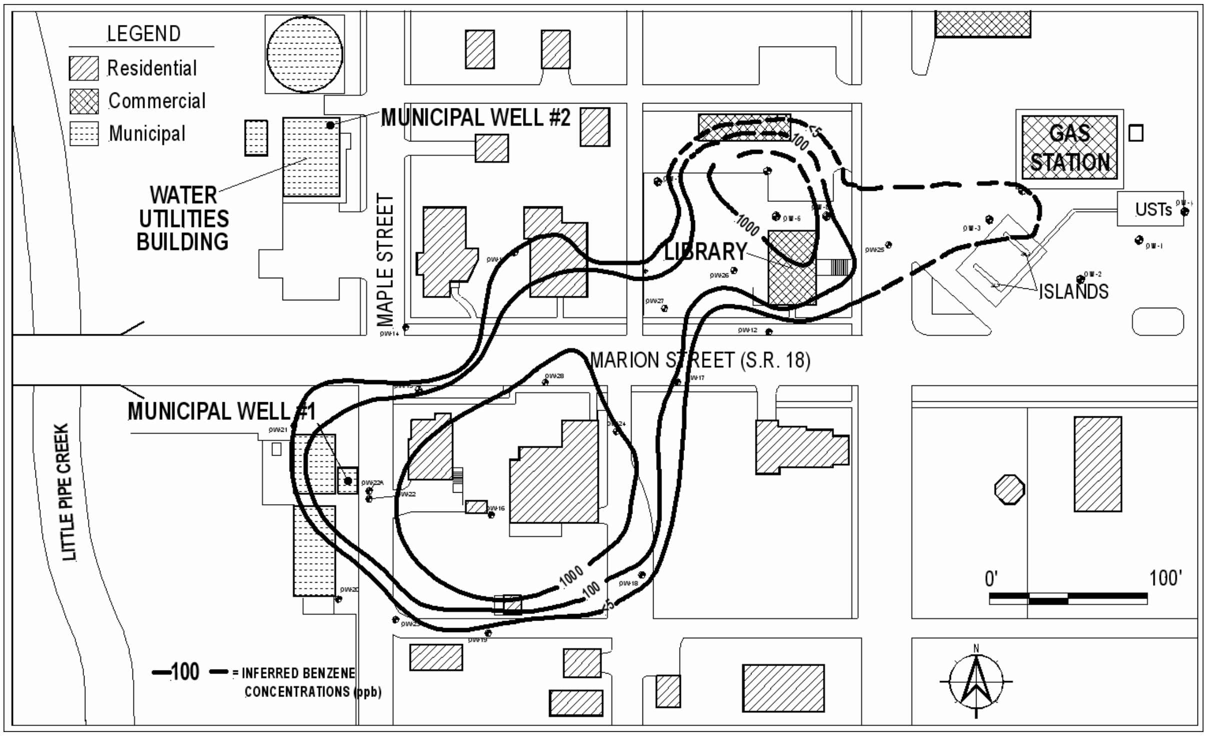

Figure 7 Extent of dissolved benzene plume in January 2002 - concentrations are in ug/l

In 2002 the environmental consultant discovered that the Town of Converse had two water supply wells, not one well as previously supposed. Further more, the second municipal well (Designated "Well 1" by the Town) was immediately downgradient of the leading edge of the dissolved hydrocarbon plume as shown in Figure 7. Up to this point, most of the emphasis in remediation had been focused on remediation of benzene. However, with the discovery of the second municipal well, additional monitoring wells were installed that indicated that MTBE was detectable in the groundwater within 15 feet of the municipal well. Municipal Well #1, located approximately 500 feet from the Site, did not have detectable concentrations of benzene or MTBE in the drinking water supply in mid-2002, but it was obvious that it was only a matter of time before the higher concentration portion of the downgradient portion of the plume reached the municipal well.

Final Remedial Design

It was at this point in the investigation that a new environmental consulting firm was brought into the project and asked to develop a new remedial plan and direct the ongoing remediation. The Town of Converse minimized pumping from Well #1 to reduce the advance of the MTBE and benzene plumes. The new remediation system was designed to accomplish the following primary objectives:

1. Protect the municipal water supply from contamination;

2. Efficiently recover impacted groundwater from the downgradient plume area;

3. Establish hydraulic control of the dissolved plume; and,

4. Remove dissolved hydrocarbons and MTBE from the recovered groundwater, making the water suitable to discharge to Little Pipe Creek.

Pumping Test

A pumping test well was installed on the edge of Maple Street near Well #2 to evaluate the sustainable yield of a well screened in the impacted sand and gravel aquifer. This test indicated that while the aquifer formation readily yielded water, the formation was not thick enough for significant yield from a vertical well screen. During the course of the test, the maximum sustainable yield was between 10 and 20 gallons per minute (gpm).

Horizontal Well System Design

In examining the location of the downgradient portion of the plume (beneath several residences) and the relative thinness of impacted sand and gravel aquifer, it was determined that a horizontal recovery well would be the most effective means of removing impacted water, maintaining hydraulic control of the plume and minimizing intrusion onto private property. While a horizontal well is relatively expensive compared to a vertical well on a per foot of screen basis, the screen of a horizontal well is much more efficient in that the entire screen generally remains saturated under normal pumping conditions. When compared with the five or six vertical wells and the associated access to private property that would have been needed to establish the same hydraulic control, the horizontal well proved to be a more cost-effective and efficient means of recovering groundwater.

Most horizontal wells use an entrance hole, where the drill tooling is located, and an exit hole, where the casing comes back up to the surface at the end of the well. Access limitations prevented the use of this design, as there was no suitable exit hole location. Because of this limitation, the drilling contractor Mears/HDD (Mears) used an innovative technology to drill a blind horizontal well. In other words, the well had no exit hole. A plan-view of the horizontal well location is shown on Figure 8. A cross-sectional view of the horizontal well location in the aquifer is shown on Figures 9A and 9B.

Initial yield testing of the horizontal well indicated that the well, with 100 feet of screen should be able to sustain a yield of 30 gallons per minute (gpm). This yield was slightly lower than the initially estimated yield of 50 gpm, but has proven to be adequate to maintain hydraulic control of the plume.

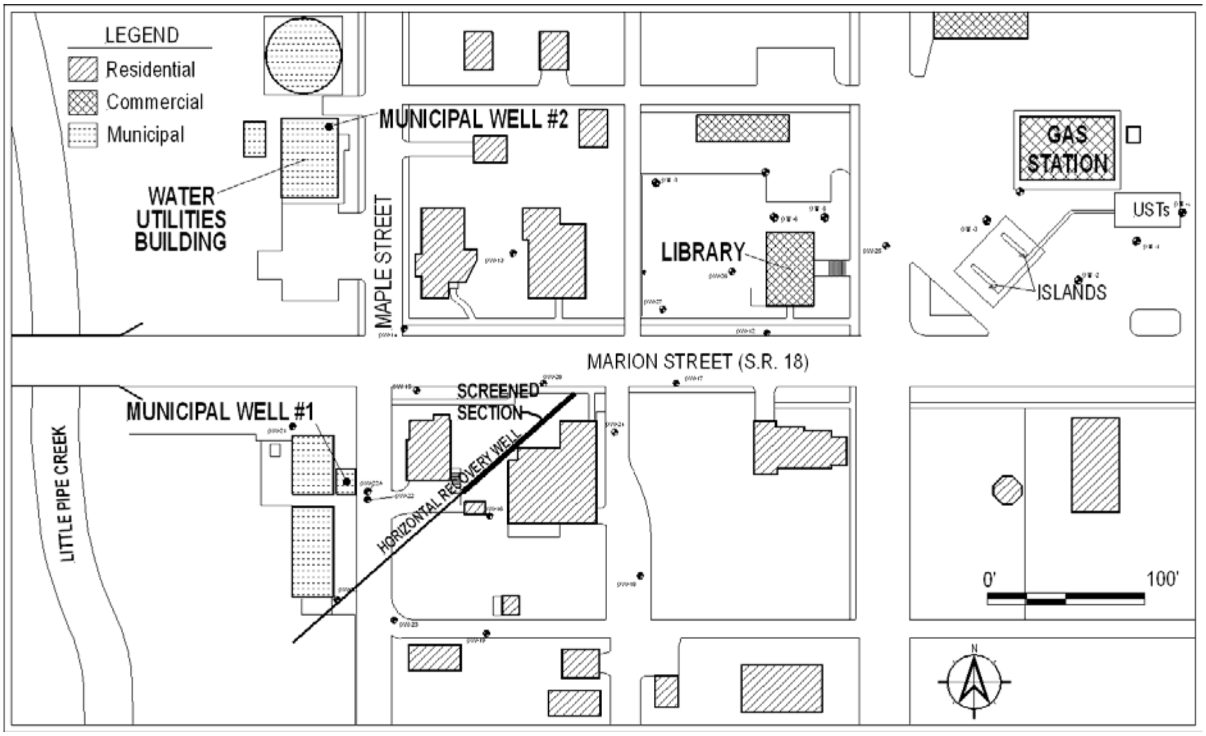

Figure 8 Plan-view of horizontal well location.

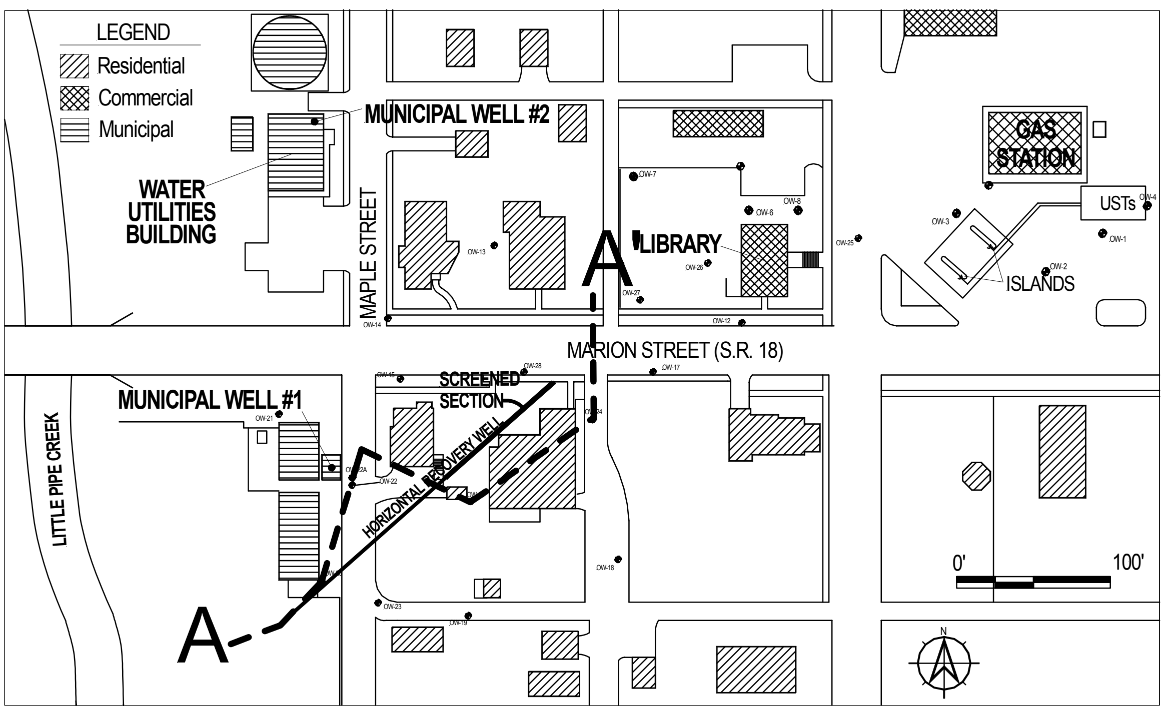

Figure 9 Location of cross-section A-A'

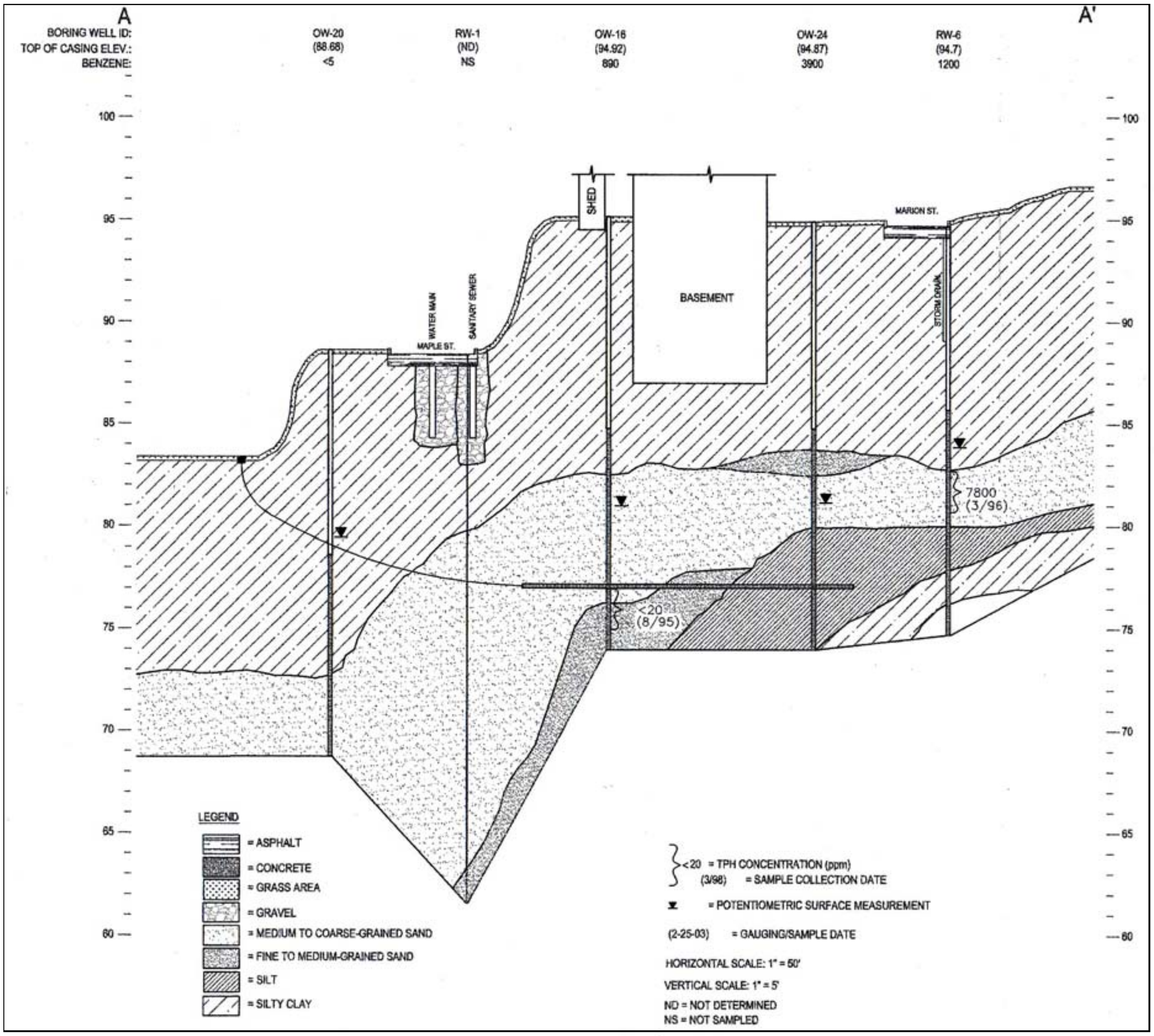

Figure 10 Cross-section A-A' showing the position of the horizontal screen relative to the aquifer.

Vertical Well

In addition to the horizontal well, a small recovery well was also installed in Maple Street, immediately upgradient of the Municipal Well #1. The purpose of this well was to act as a secondary hydraulic control barrier to prevent BTEX and MTBE from reaching the drinking water well. This vertical well discharges between about 10 to 14 gpm on an average basis.

Groundwater Treatment System

A wide variety of groundwater remediation technologies were considered for this site. It was estimated that the influent water to this system would contain approximately 3,900 ug/l of benzene and 250 ug/l of MTBE. The surface water discharge permit for this system required benzene concentration less than 5 ug/l and an MTBE concentration of less than 45 ug/l. To reach these discharge goals, the groundwater would require a treatment system that was approximately 99.9% efficient in the removal of benzene and 96.5% efficient in the removal of MTBE from the groundwater. After reviewing the performance and design of other operating systems, it was determined that a tray air stripper should be adequate to reach the desired discharge goals. Since the actual influent concentrations were not known for certain at the time the system was designed, the remediation system was designed with the option of installing granular activated carbon (GAC) filters as a secondary treatment technology if needed at some later date. A general isometric of the system is shown on Figure 11.

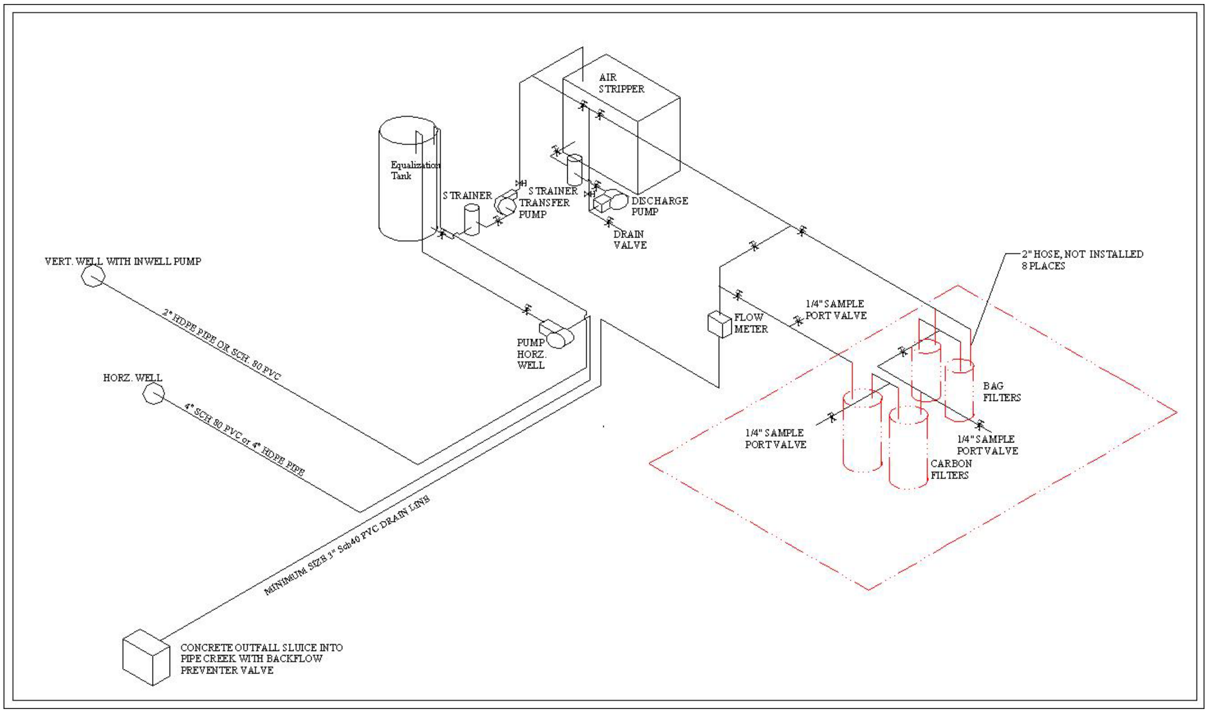

Figure 11 Remediation system plumbing isometric.

Since there was no history of separate-phase hydrocarbon in the downgradient portion of the plume, this remediation system did not include an oil/water separator. A separate/phase hydrocarbon sensor was installed in the equalization tank to protect the remediation system and the Little Pipe Creek from unexpected separate-phase hydrocarbon entering the system.

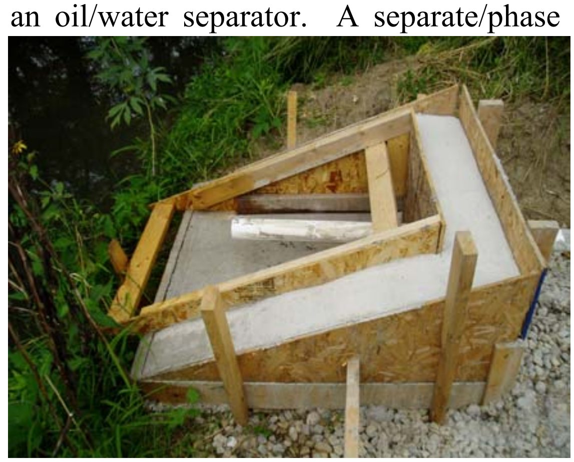

Figure 12 Construction of the remediation system outfall

Remediation System Performance

Testing of the remediation system began in August of 2004 and the system became fully operational in October of 2004. The system flow rate has varied between 27 and 37 gpm. Influent concentrations of MTBE and benzene have varied from less than 5 ug/l to 27 ug/l for MTBE and from 120 ug/l to 840 ug/l for benzene. The system effluent has consistently been less than the laboratory method detection limit for all organic compounds.

While the total system flow rate and influent concentrations are both lower than anticipated, the remediation system has responded well. The changes in MTBE and benzene concentrations in surrounding monitoring wells since the remediation system began operation are summarized in Table 1.

Table 1
Changes In The Concentration of Benzene and MTBE
In Monitoring Wells After 5 Months of Treatment
Converse Indiana Site

Well ID	Distance From Recovery Well (feet)	Direction To Recovery Well (gradient)	Before Treatment System Operation Began		After 5 Months of Treatment System Operation	
			Benzene	MTBE	Benzene	MTBE
			ug/L	ug/L	ug/L	ug/L
OW-16	21	Cross-Gradient	2,100	<5	<5	<5
OW-22	62	Down-Gradient	<5	19	<5	12
OW-22A	60	Down-Gradient	<5	12	<5	<5
OW-24	34	Cross-Gradient	2,400	10	640	4.2
OW-27	75	Upgradient	91	<5	120	<5
OW-28	17	Cross-Gradient	9,300	25	7,100	15

After only 5 months of operation, several wells in the heart of the downgradient plume are showing dramatic reductions in concentrations of MTBE and benzene. The rise in the concentration of OW-27 may be due to the horizontal well pulling some of the upgradient plume further downgradient.

Figure 13 Tray air stripper in operation

Ongoing Operation

At this point in the system's operational life it has not been necessary to install GAC filters or an oil/water separator to meet the system discharge standards. Fouling of the air stripper with calcium carbonate deposits has been an ongoing maintenance concern. The installation of an acid wash recirculation loop has significantly decreased the amount of time required to maintain the stripper. The stripper is simply isolated from the rest of the system, acid wash solution is added to the stripper sump and the acid wash solution is recirculated through the stripper until the stripper is clean. The acid wash solution is then neutralized with sodium bicarbonate and discharged with the system effluent.

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Biographical Sketches

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