SUCCESSFUL REMEDIATION OF GASOLINE SPILLS ON LONG ISLAND BY APPLICATION OF A COMBINATION OF TECHNOLOGIES — TWO CASE STUDIES

by

Ravi K. Korlipara, Ph.D., P.E.
Korlipara Engineering
315 Walt Whitman Road, Suite 316
Huntington Station, NY 11746

Mostafa El Sehamy, P.G., C.G.W.P.
Fenley & Nicol Environmental, Inc.
445 Brook Avenue
Deer Park, NY 11729

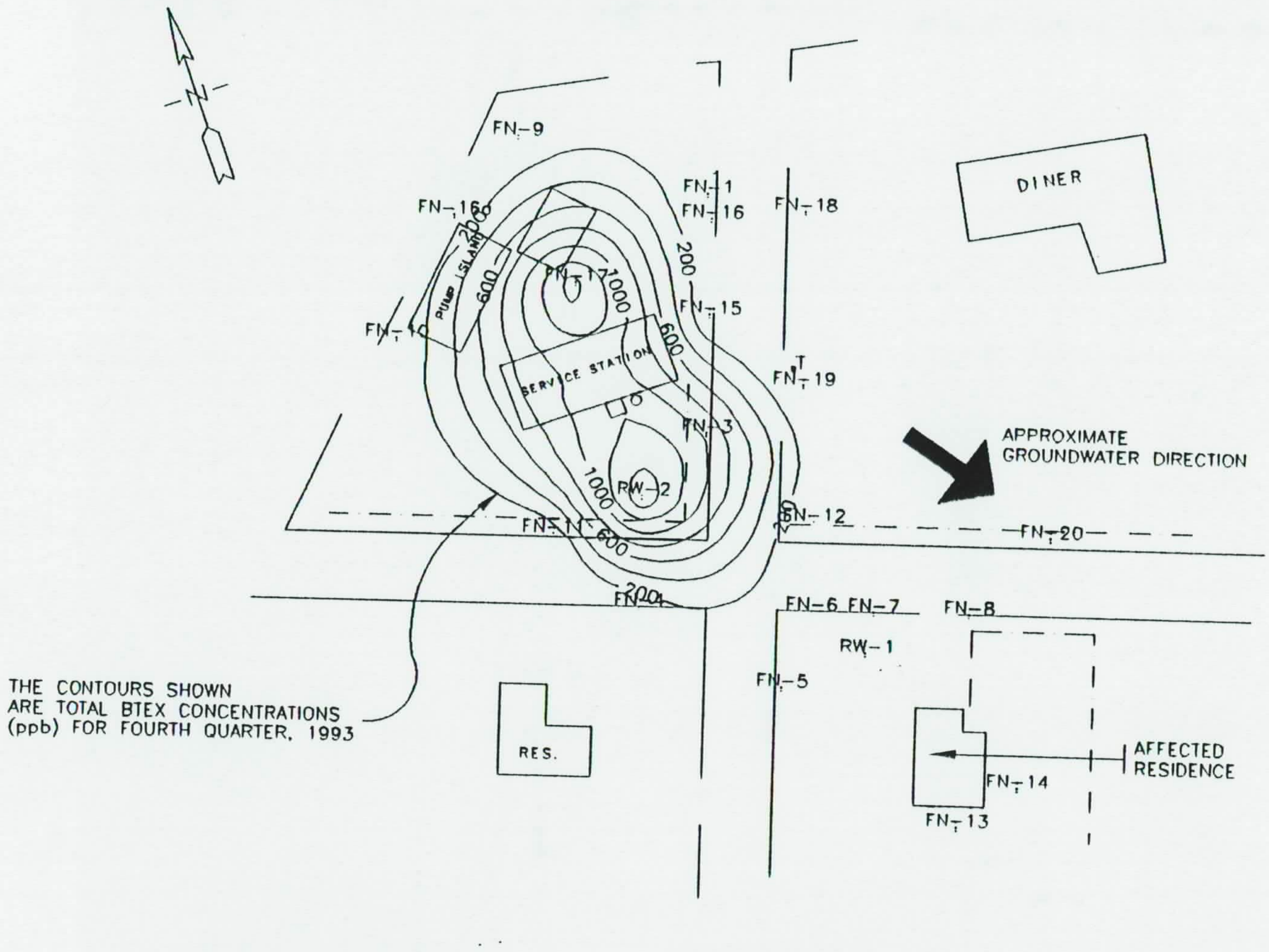
ABSTRACT

Gasoline spills and leaks from underground storage tanks (USTs) are among the more common causes of contaminated sites on Long Island and elsewhere. Due to the high frequency of occurrence of such sites and the potentially high mobility of gasoline through the soils and groundwater of the sole-source Long Island aquifers, it is important that the remediation efforts are expeditious and cost-effective. In this extended abstract, two (2) case studies of such remediation of gasoline contaminated sites are briefly described, followed in each instance by a summary of the successes and lessons learned. Case Study 1, the Massapequa Site, is discussed by adopting an approach intended to highlight the methodological and project management aspects of a remediation project. Case Study 2, the East Farmingdale Site, is discussed by adopting an approach more intended to highlight the design aspects of a remediation project. Between the two case studies, several issues which are frequently encountered in successfully remediating gasoline contaminated sites on Long Island are illustrated.

CASE STUDY 1: THE MASSAPEQUA SITE

The Massapequa Site is located in Massapequa, Long Island and includes a former service station and an "Affected Residence" as shown in Figure 1.

The groundwater at the site is 3.5 to 5.5 feet below ground level depending on the location. In particular, at the Affected Residence the groundwater is about one inch (1") below the basement floor during dry periods and at about the same elevation as the basement floor after a 2" rain. The local groundwater flow direction is approximately southeast and the Affected Residence is directly downgradient of the service station. The underlying shallow soils belonging to the Upper Glacial Aquifer are highly permeable with a hydraulic conductivity of



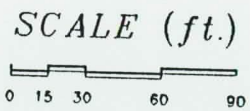


FIGURE 1

SITE PLAN FOR CASE STUDY 1

about 100 feet/day and a porosity of about 0.25-0.30. The groundwater gradient is approximately 0.0045 under natural conditions.

Following the detection of hydrocarbon fumes in the basement of the Affected Residence in June 1990, the existing sump pit was sealed air-tight and a vapor abatement system (VAS) was installed. These fumes were caused by the volatilization of the dissolved hydrocarbons in groundwater, which migrated from the vicinity of the pump island at the service station. The installed VAS was designed to capture the vapors trapped in the soil and the volatilized contaminants from the groundwater by inducing a negative pressure in the subsurface. Five (5) 2" diameter PVC (2" PVC) vapor well points were optimally installed to sufficiently capture the fumes. The wells consisted of approximately eight feet (8') of slotted screen and one foot (1') of solid pipe near grade. The vapor wells were manifolded together and piped approximately 6" below grade to a sound-proof blower shelter, including a vent pipe from the sump pump. The vapor effluent was exhausted through a 2" PVC stack, guide wired to approximately 20' above grade. Extreme care was maintained to minimize disruption of the property or home owner.

Periodic testing of the vapor emissions was performed using a portable Photovac Gas Chromatograph. By December 1990, except for some slight odors no gasoline fumes were being recorded in the basement of the residence. The VAS was eventually shutdown in February 1995.

Investigations for the remediation of groundwater were conducted and a groundwater pump and treat system was installed in 1991. The system consisted of one (1) 6" diameter, 25' deep recovery well RW-1, which was located about 30' upgradient of the Affected Residence (Figure 1) so as to remove the dissolved hydrocarbons prior to their reaching the house. The design pumping rate was 40 to 60 gpm. Piping consisted of a 2" sch. 80 PVC pipe trenched below grade and across to the recovery shelter behind the service station building. The pumped water was passed through a 3' diameter, 20' tall air stripper, with two blowers producing 1,000 cfm. The discharge water was piped to the back of a catch basin and discharged to Massapequa Creek via an existing 24" storm drain. In anticipation of the need for a second recovery well on the gas station property itself, the air stripper was over designed for the proposed 40 - 60 gpm from the recovery well. The air stripper was designed such that effluent limitations will be met under flow conditions from both wells. The air stripper was cleaned quarterly with steam.

The groundwater remediation system with recovery well RW-1 began operation in October, 1992. By the end of 1992, concentrations of dissolved BTEX were in the 30-40 ppb range in the pumped water from RW-1, about 6,400 ppb in a monitoring well at the eastern boundary of the gas station (MW-15), and less than 1 ppb on the Affected Residence property downgradient of RW-1. These results indicate that the recovery well was preventing significant concentrations of dissolved hydrocarbons from reaching the groundwater beneath the Affected Residence. Water level monitoring results and groundwater modeling suggested, however, that while the main part of the plume was within the capture zone of RW-1, as was anticipated during the initial design phase hydraulic control of the entire plume was not achieved.

To improve the recovery rates, a second recovery well RW-2 was installed on the southeast corner of the service station (Figure 1) and put into operation in March 1993. Five (5) new monitoring wells were also installed at this time, bringing the total number of monitoring wells to 20 (Figure 1). In addition, a vapor extraction system (VES) was installed in the service station to remove hydrocarbons from the unsaturated zone near the pumps and the USTs. The VES consisted of the newly installed 2" PVC wells FN-16a and FN-17, and the existing 4" PVC well FN-15. The wells were manifolded by a 2" PVC piping and connected to a 2-HP blower. (The wells FN-16a, FN-17, and FN-15, which are located close to the center of the plume, were also used for monitoring groundwater quality.) The VES was put into operation in March 1993 at a vapor extraction rate of about 115 cfm.

The two wells RW-1 and RW-2 pumped equally for a total of 90 gpm through the end of 1993. As was anticipated from groundwater modeling during the design phase, water level monitoring results showed that full hydraulic control of the plume was achieved by this combined pumpage, with the second well RW-2 acting as a first line of defense and RW-1 as a second line of defense against plume migration towards the Affected Residence. The addition of monitoring well RW-2 greatly improved the recovery of dissolved hydrocarbons in groundwater. For example, prior to the start of RW-2, the concentrations of total BTEX in the groundwater from RW-1 were in the 30-40 ppb range. With the addition of RW-2 in March 1993, the concentration of total BTEX in RW-1 quickly fell below 25 ppb, rapidly decreased further over time, and was non-detectable within less than three (3) months. During this time, the average concentration of total BTEX in the water from both wells increased to 75-150 ppb range, primarily due to recovery of hydrocarbons from RW-2. Based on monitoring data, it is estimated that a total of approximately 65 lbs of total BTEX were removed through recovery of contaminated groundwater from the start of the system operation in October 1992 to the eventual shutdown of the system in May 1995 (RW-1 in January 1995 and RW-2 in May 1995). Of this amount, only about 2.5 lbs of total BTEX is attributable to recovery from RW-1, with the rest 62.5 lbs recovered from RW-2. It is evident that locating RW-2 about 110' closer to the center of the plume than RW-1 had a significant impact in shortening the time of cleanup (due to higher rates of recovery at RW-2 before further dilution occurred while reaching RW-1) and in expeditiously restoring the quality of groundwater under the Affected Residence [in about six (6) months from start of cleanup]. In addition, total hydraulic capture of the plume was achieved.

Negligible amounts of emissions occurred from the VES during March 1993 when the system was started. However, high concentrations of total BTEX occurred in the emissions from the VES during the Second Quarter of 1993 – 825,730 ppbv in April, 707,300 ppbv in May, and 1,714,080 ppbv in June, 1993. A stack emissions study was performed in April 1993, from which it was determined that emissions from the VAS at the Affected Residence and from the air stripper were below short-term guideline concentrations for the BTEX compounds but that emissions from the VES at the service station were in exceedence for benzene. An activated carbon canister system was therefore installed on the VES stack in June 1993.

Recovery of total BTEX by the VES averaged 1.9 lbs/hr during April-June 1993 for an estimated total recovery of 4,150 lbs of total BTEX during this period. Similar levels of recovery occurred during July-September 1993, i.e, approximately 4,150 lbs of total BTEX were additionally removed during this period. Thereafter, the concentrations of total BTEX in the extracted vapors dropped steeply from 1,000 ppbv in October 1993 to less than 1 ppbv by the end of Third Quarter of 1994, and the amounts recovered were negligible compared to the April-September 1993 period. From a study of the monitoring results, the extracted vapors appear to have been primarily from the unsaturated soils during April and May 1993. Due to natural causes, the water table elevation was lowered by about 2' during June-September 1993 and recovered during the Fourth Quarter of 1993. While concentrations of total BTEX in the groundwater plume prior to the water table drop were generally high with the highest concentration of 10,580 ppb recorded at monitoring well FN-17, the concentrations in the recovered water table in the Fourth Quarter of 1993 (shown in Figure 1) were much lower with the highest concentration of 1,542 ppb recorded at monitoring well FN-17. This indicates that the bulk of the contamination in groundwater was retained by the newly exposed soils when the water table dropped in elevation, resulting in high concentrations of total BTEX in the extracted vapors (in addition to vapors from unsaturated soils).

Whereas less than 100 lbs of total BTEX were removed by the groundwater extraction system, about 8,300 lbs of this material was removed by the VES at the service station. [In addition to total BTEX, the Methyl tert-butyl ether (MTBE) plume, which generally mirrored the BTEX plume, was also remediated in this project.] It is evident that without the removal of the contaminants source (unsaturated soils and shallow groundwater near the pump stations) by the VES, the cleanup of the system by groundwater treatment alone would have taken a significantly longer time with great adverse impact on costs. At the same time, source remediation alone by the VES would not have been sufficient because the groundwater needed remediation. The combination of pump and treat and SVE technologies which were adopted for this project achieved both groundwater and source cleanup expeditiously and cost-effectively.

Considering the magnitude of this project (about 8,400 lbs of total BTEX and additional MTBE), the entire project was accomplished within a very reasonable budget of $292,000 dollars. This amount included the soil and groundwater remediation, investigations, monitoring, and the vapor abatement system at the Affected Residence. The fortuitous 2' drop in the water table during June-September 1993, which resulted in exposing contaminated soils for easier recovery by the VES (which otherwise would have remained submerged in the groundwater and, hence, would have taken longer to remediate), helped towards mitigating the costs. In the absence of this water level drop, installation of an additional recovery well in the center of the plume near the pump stations (with RW-2 continuing to operate and RW-1 shutdown) would have been the next logical step that would have been considered for expediting the cleanup, with a modest increase in costs.

The successes and lessons of this case study can be summarized as follows:

- Contamination problems impacting receptors (e.g., fumes in the basement and contaminated groundwater underneath the Affected Residence) are critical, should be addressed first, and should be responded to with great speed, as was done here.

- The remediation system should be designed such that hydraulic control of the plume is maintained and cleanup of the source is achieved quickly.

- The location of the various components of the remediation system relative to the contamination has a significant impact on cleanup times and costs. Thus, the placement of recovery wells, vapor extraction systems, and other remediation system components should be chosen with extreme care. To the extent possible, these components should be placed as close to the hot spots as possible, while also placing additional components (if necessary) to assure total capture (e.g., a well at the center of a plume to capture the high concentrations and another at the toe of the plume to assure hydraulic control).

- Employing an appropriate combination of technologies rather than a single technology will greatly reduce cleanup times and costs and will achieve cleanup goals with greater success because the problem can be solved through different and non-overlapping mechanisms.

- Project management is very important for a successful and expedited cleanup. During remediation, the management approach should have the flexibility and, in fact, should seek to recognize developing opportunities and potential problems and to act appropriately.

- The Massapequa Site project involving a vapor abatement system in the basement of the house and remediation of soil and groundwater gasoline contamination was accomplished in less than three (3) years. The remediation itself (about 8,400 lbs of total BTEX plus additional amounts of MTBE in soil and groundwater) was accomplished to a significant extent in less than a year (October 1992 - September 1993) with additional two (2) years for project management, investigations, remediation of residuals, and monitoring. The site was cleaned to groundwater standards. The total project costs incurred were a modest $292,000. This was accomplished by a judicious choice of treatment system locations and pumping schedules, application of a combination of technologies (pump and treat and vapor extraction), and a project management approach on the part of both the contractors and agencies (NYSDEC) that took advantages of arising opportunities for quicker cleanup and solved problems immediately.

CASE STUDY 2: THE EAST FARMINGDALE SITE

The East Farmingdale Site includes a former gasoline service station located in East Farmingdale, Long Island (Figure 2) and the gasoline contamination caused by this station. The groundwater contamination problem at this site consisted of a large dissolved hydrocarbon plume that was present on-site and had migrated with the groundwater flow approximately 400' southwest from the service station's storage tanks. The proposed remediation activities consisted of a groundwater pump and treat system and a soil vapor extraction system (VES).

The site geology is characterized by unconsolidated glacial till and moraine deposits. The groundwater table is approximately 25' below grade. Under natural flow conditions, the groundwater gradient at the site is approximately 0.002. The site soils are highly permeable with a hydraulic conductivity of about 100 ft/day and a porosity of about 0.25-0.30.

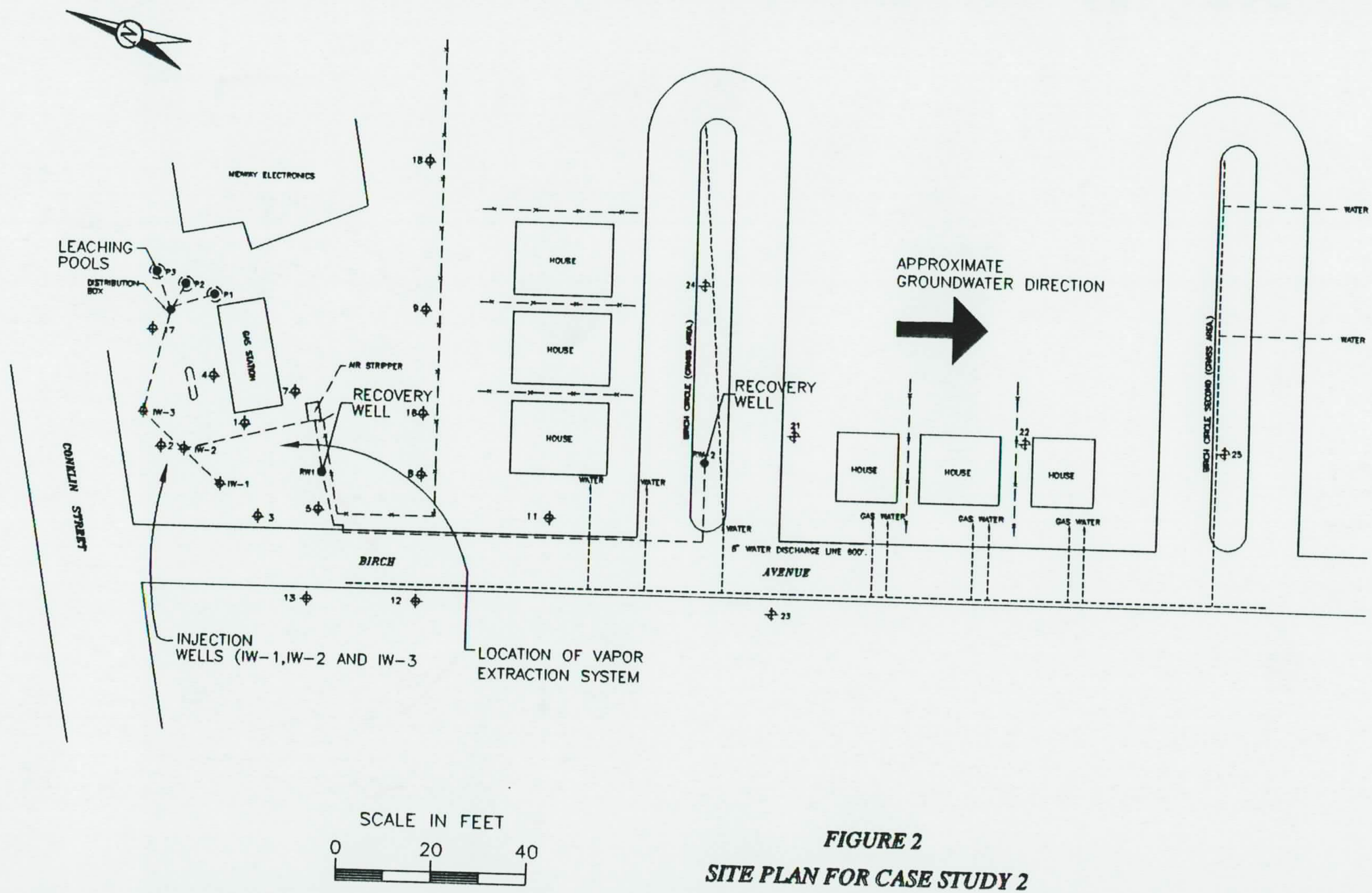


FIGURE 2

SITE PLAN FOR CASE STUDY 2

Drawn By: J.L.

As of December 1992, a preliminary remediation system existed at the site consisting of one (1) 8" diameter and 44' deep recovery well (RW-1), a 4' diameter and 24' high air stripper, and effluent discharge into a distribution box via a 6" PVC pipe from where the water is distributed to three (3) leaching pools.

An additional recovery well (RW-2 in Figure 2) was designed for installation in the first Birch Circle for containing and treating the highest portion of the dissolved hydrocarbon plume which migrated off-site. An 8" diameter, 45' deep well (30' screen in water, 10' additional screen, and 5' of solid PVC) was designed. The Johnson Continuous Wrap PVC well screen was chosen. The use of continuous wrap screen will increase the effective screen openings by approximately 50% over slotted screens. To reduce the turbidity of the water in order to prevent clogging of the treatment system and final discharge, a slot size of 0.05" which, based on sieve analysis of site soils, would allow only 50% of the formation to pass was chosen. The filter packing was minimum 2" thick Morie #2, which is large enough to be 100% retained by the well screen but small enough to reduce the entry of fines. The designed screen has a 12.7 gpm, 1' yield limit with an entrance velocity of 0.10 ft/sec. This recovery well will have a maximum yield of 300 gpm and, based on earlier investigations, will be pumped at 100 gpm during remediation. The existing air stripper was used for treating the pumped water from both wells RW-1 and RW-2. Pumped water from RW-2 was directed to the air stripper by a 4" PVC pipe located approximately 2' below grade.

The location and design of RW-2 was such that the downgradient portion of the plume is completely captured by this well. The upgradient portion of the plume on the site will be intersected by the existing recovery well on site (RW-1).

The disposal of treated water was a problem on site because of the refusal of the NYS Department of Transportation (NYSDOT) to allow discharge of treated water into a storm drain system. The request was denied due to the amount of flooding in the recharge basin. Therefore, a discharge system consisting of three (3) 8" diameter, 65' deep (60' screen and 5' solid PVC casing) injection wells was designed such that overflows from the injection wells are directed to the existing leaching pools via the distribution box (Figure 2). A slot size of 0.07" and Morie #3 gravel pack was used for the injection wells. The injection wells disposed the water into the subsurface under pressure. These wells were located upgradient of the plume so as to flush the contaminated soils and drive the plume towards the recovery wells at a faster rate, thereby reducing the cleanup time. A liability (problem of discharge to a storm drain) was thus converted into an asset (upgradient injection wells for reducing cleanup time). Maintenance of the injection system would be required since groundwater chemistry may dictate the use of chemical treatment of discharge water prior to injection in order to prevent biomass growth or clogging of the wells.

A vapor extraction system (VES) was designed and installed for remediating residual unsaturated zone contamination and for capturing volatilizing hydrocarbons from the groundwater. The installed VES consisted of nine (9) wells. Of these four (4) wells are existing monitoring wells MW-1, MW-3, MW-6, and MW-7 (Figure 2). The other five (5) are new 2" PVC wells installed in the tank area to a depth of 25' (22' screen and 3' solid). The pipes were manifolded approximately 2' below grade by a 2" PVC pipe. The enclosure for the VES equipment was located adjacent to the existing fence within easy access of overhead electrical lines for service drops. The system consisted of two (2) 2-HP Rotron blowers mounted inside an insulated wooden shed to reduce the noise output. The concentrations of contaminants in the vapors were very low and non-detectable by OVA on most occasions.

Monitoring and maintenance of equipment was conducted on a weekly basis, particularly in view of the special care needed for maintaining the injection wells in good working condition. The air stripper tower and injection and recovery wells were cleaned and chemically treated on a quarterly basis (primarily iron deposits).

A three (3) day pump test was conducted in July 1993 to determine the drawdown induced by continuously pumping the existing recovery wells. Recovery well RW-1 was pumped at a rate of 65 gpm and recovery well RW-2 was pumped at a rate of 100 gpm. The test results showed that full hydraulic control and capture of the plume was achieved.

The groundwater remediation system included 25 monitoring wells (MWs). From the initial groundwater sampling conducted in September-October 1992, the highest concentrations were recorded as follows: 4,442 ppb total BTEX and 300 ppb MTBE at MW-6; 2,065 ppb total BTEX and 10 ppb MTBE at MW-8; 3,923 ppb total BTEX and 200 ppb MTBE at MW-16; 8,110 ppb total BTEX and 19 ppb MTBE at MW-17; 3,490 ppb total BTEX and 40 ppb MTBE at MW-20; 5,110 ppb total BTEX and <1 ppb MTBE at MW-21; and 1,415 ppb total BTEX and 2 ppb MTBE at MW-22.

The groundwater treatment system and the VES began operation in July 1993. By October 1993, the remediation system reduced the concentrations of dissolved BTEX and MTBE by approximately 90% from those detected in September-October 1992. In particular, in October 1993 the highest total BTEX concentrations were recorded as 1,500 ppb at MW-6 and 1,219 ppb at MW-16, and the highest MTBE concentration was 50 ppb at MW-24 with all other monitoring wells having MTBE concentrations below 10 ppb. Groundwater plume maps generated from the monitoring data indicate that the contaminants were being effectively prevented from further migration by the existing remediation system. As the project progressed, the pumping rates were varied between 55-110 gpm at RW-1 and 95-110 gpm at RW-2 such that hydraulic control of the plume was achieved and its movement was controlled to occur in desired directions.

Through the end of April 1994, recovery well RW-2 recovered significantly higher concentrations of total BTEX than RW-1 while the influent from RW-1 decreased below detection limits. As of March 1994, the highest total BTEX concentrations were 724 ppb at monitoring well MW-16 and 2,200 ppb at MW-17. Also, MTBE was undetectable in all monitoring wells.

Recovery well RW-1 was shutdown at the end of May 1994. By the end of June 1994 the highest total BTEX concentrations were centered at monitoring well MW-6 (859 ppb) which is closer to RW-1 (Figure 2). Therefore, RW-1 was turned on and RW-2 was turned off at the end of July 1994. This process of turning the two recovery wells on and off as necessary to capture the residual plume was continued until the First Quarter of 1995. During the Fourth Quarter of 1994 and the First Quarter of 1995 the highest concentrations were detected in MW-16 with the plume receding or exhibiting lower concentrations in the other upgradient monitoring wells. Therefore, beginning March 1995 RW-1 was shutoff and MW-16 was converted into a recovery well by installing a 2-HP submersible pump. An additional influent line to the air stripper was installed connecting MW-16 to the air stripper. From thereon to the completion of remediation in December 1995, the recovery wells MW-16 and RW-2 were pumped on and off as necessary to capture the residual plume.

The successes and lessons of this case study include:

- Expeditious cleanup in less than three (3) years, with the bulk of remediation accomplished in less than one (1) year, and with the remainder of the time utilized for investigations, residuals cleanup, monitoring, and closure. This was accomplished by a judicious choice of treatment system locations and pumping schedules, application of a combination of technologies (pump and treat, vapor extraction, and re-injection), and a project management approach that took advantages of arising opportunities for quicker cleanup and solved problems immediately. In particular, the inability to discharge treated water to a storm sewer (a liability) was converted into an asset by installing and successfully operating a re-injection well system upgradient of the plume which provided a solution to the water disposal need and also contributed to reducing the cleanup time. The costs incurred for this project are of the same order of magnitude as those for Case Study 1.

- Successful maintenance of the remediation system, in particular the injection system which causes great difficulties if not handled correctly.

ACKNOWLEDGMENTS

The authors thank Ms. Karen J. Gomez, P.E., New York State Department of Environmental Conservation (NYSDEC), Building 40, SUNY, Stony Brook, NY, for her suggestions and contributions to this manuscript. Ms. Gomez was the NYSDEC Project Manager for Case Study 1.