Chemical Oxidation Remediation Project Wins Environmental Award, Saves Time and Cost

NSB KINGS BAY

In-Situ Chemical Oxidation was used to treat groundwater contaminated with high concentrations of PCE at a landfill located on the Naval Submarine Base, Kings Bay Georgia. This effort allowed the Navy to accelerate the estimated time for cleanup of the site and shut off the existing pump and treat system. Due to the effectiveness and innovation of the treatment approach, the project received the State of Georgia Chamber of Commerce Environmental Excellence Award. The State of Georgia Environmental Protection Division submitted the nomination.

Project Summary

- The site is a 25-acre municipal landfill that operated between 1974 and 1980.
- The Remedial Investigation identified Perchloroethylene (PCE) and its degradation products in groundwater emanating from the landfill towards a residential subdivision 500 feet away.
- Over 600 homes are located in the subdivision and many use groundwater for irrigation purposes.
- Groundwater extraction wells with an air-stripping treatment system were installed in 1992 to prevent migration of contaminants into the subdivision.
- The source of PCE contamination was identified on the perimeter of the landfill with concentrations of over 9000 µg/l.
- Natural Attenuation of the groundwater was found to be highly efficient but there was not enough distance prior to reaching the subdivision to complete the process due to the relatively high source area concentrations.
- In-situ Chemical Oxidation was selected to reduce the source of contamination such that the natural attenuation processes could efficiently treat the residual concentrations.
- The oxidation process utilized Fentons Chemistry. This process uses hydrogen peroxide and a ferrous sulfate catalyst to generate hydroxyl radicals. These radicals are strong non-specific oxidizers that transform the chlorinated hydrocarbons to carbon dioxide, water, and chlorides without any intermediate products.
- Injection of chemical reagents and catalyst was implemented by the placement of 23 injection wells.
- Two injection treatments were used for this site. One treatment began in November 1998 and lasted for a period of approximately 3 weeks. A follow-up treatment was conducted in February 1999 and lasted for 1 week.
- The initial source area treated consisted of a 175 x 50 ft^2 area and a 5 ft thick horizon. The horizon treated was approximately 37 feet below land surface.
- Treatment achieved over a 98% destruction of chlorinated hydrocarbons.
- Modeling predictions indicate that the remaining residual concentrations will degrade within 5 years.
- The natural attenuation of the plume will be monitored at the site until the residual concentrations meet the Federal groundwater Maximum Contaminant Levels (MCLs).
- Two additional nearby source areas in the landfill have been targeted for cleanup using this approach.

Site/Location:	Old Camden County Landfill, Site 11 NSB Kings Bay, GA
Site Description:	25-acre municipal landfill, which required investigation of Perchloroethylene (PCE) and its degradation products in groundwater emanating from the landfill towards a residential subdivision 500 feet away
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Technology:	In-Situ Chemical Oxidation Monitored Natural Attenuation
Contaminant:	Perchloroethylene (PCE), and its degradation products in groundwater
Action Levels:	Perchloroethylene (PCE) 5 µg/L Trichloroethene (TCE) 5 µg/L Dichloroethene (DCE) 70 µg/L Vinyl Chloride (VC) 2 µg/L
Legal Driver:	Resource Conservation and Recovery Act (RCRA) Permit No. HW-014
Decision Document:	RFI Report Recommendations Corrective Action Plan (CAP)

Regulatory Requirements/Community Involvement

The landfill is a Solid Waste Management Unit subject to corrective action as part of a RCRA Part B Permit. Cleanup requirements for groundwater specify action levels of federal MCLs. The remedy approach was communicated to the community through the Restoration Advisory Board and has been well received.

Construction Challenges

A remedy utilizing a combination of chemical oxidation and Monitored Natural Attenuation posed some early concerns regarding how quickly the microbial community would rebound from the treatment process. This was determined to be a relatively short period of time. Within 6 weeks of treatment, the source areas that had been saturated with dissolved oxygen returned to anoxic conditions indicative of anaerobic microbial activity.

Cost Avoidance Measures

The success of the chemical oxidation of the source area precluded the need to install new recovery wells and a new expensive off-gas treatment system (UV oxidation) to ensure containment of the plume. It is expected that long term monitoring cost will be substantially diminished at this site as the time for residual concentrations to meet MCLs through Monitored Natural Attenuation is predicted to be complete within less than 5 years. Net present value of life cycle cost savings exceeds $3.3 million.

Project Successes

- Treatment of the source area ensured that there would be protection of downgradient receptors.
- Reduction of the source area concentrations and utilization of MNA minimized the life cycle remediation costs.
- An existing RCRA consent order was rescinded upon treatment of the source area and the hydraulic containment wells and treatment system was shut off.
- The remedy for the contamination was changed from hydraulic containment to both an active and passive treatment
- On June 9, 1999 the State of Georgia Chamber of Commerce recognized the project for the State Award for Environmental Excellence. The Georgia Department of Environmental Protection submitted the nomination for this award.

Lesson Learned

The application of In-situ Chemical Oxidation at NSB Kings Bay was successful due to several factors. The source of the contamination was well defined both laterally and vertically. The geology at the site was sufficiently permeable that injection of the reagents into the aquifer was capable of contacting and destroying the contaminants.

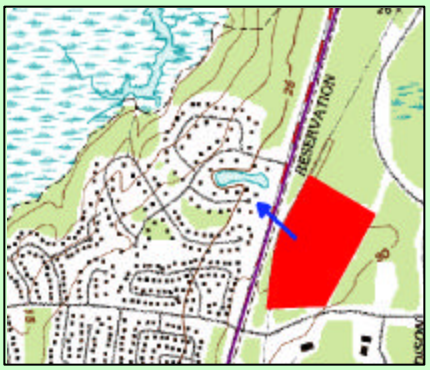

Figure 1: ***Location of landfill relative to subdivision and direction of groundwater flow.***

Figure 2: ***Process controls and catalyst in tractor-trailer and hydrogen peroxide in tanker truck.***

Figure 3*: In-situ chemical oxidation injection wells (background) monitoring well (foreground).*

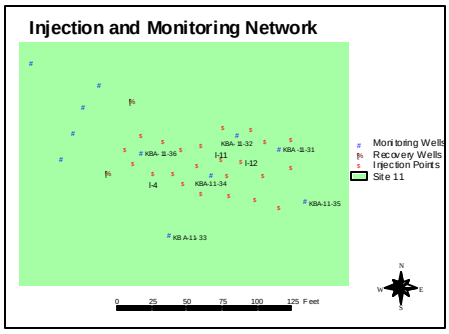

Figure 4*: Layout of monitoring and injection wells.*

SUMMARY REPORT

Site 11, Old Camden County Landfill Remedial Action Operation

Remedial Action Operation Optimization

Summary

During the early 1990s, a plume of chlorinated aliphatic compounds (CACs) was discovered in groundwater moving toward a residential area located near Site 11, Old Camden County Landfill, Naval Submarine Base (NSB) Kings Bay. The major contaminants of the groundwater plume included tetrachloroethene (PCE), and its breakdown products, trichloroethene (TCE), and cis-1,2-dichloroethene (DCE). To prevent further offsite contamination from reaching the residential area, a pump and treat (P&T) system was designed and installed to hydraulically contain the plume at the perimeter of the landfill and adjacent to the residential area.

During the early stages of the RCRA Facility Investigation, the P&T system was expected to be the final remedy for the site. Further investigation of the landfill identified a source of contamination near the edge of the landfill. In addition, the natural attenuation capacity of the aquifer was determined to be very effective at this site. Instead of relying solely on the P&T approach, *in-situ* chemical oxidation was implemented to reduce contaminant concentrations at the source areas and monitored natural attenuation (MNA) was to be implemented to address residual concentrations.

After two *in-situ* chemical oxidation treatments, contaminant concentrations were observed at levels below cleanup objectives. A third treatment is expected to address additional sources of contamination. As a result of the success of the *in-situ* chemical oxidation treatments, the P&T system was shut down, and MNA was implemented. Based on predictions from a numerical model, MNA at the site is expected to meet MCLs within 5 years.

The modification of remedial action operations (RAO) reduced long-term P&T for hydraulic containment from a period that was expected to exceed many decades to less than two months after the chemical oxidation treatments. Additionally, this modification resulted in savings in excess of several million dollars over the life of the remedy.

1.0 Site Background

1.1 *Site Description*

NSB Kings Bay occupies 16,168 acres in Camden County, GA. Site 11 is identified as the Old Camden County Landfill, which is now incorporated into the NSB. The Old Camden County Landfill was used for municipal waste disposal from the early to mid-1970s until 1980. Waste was disposed by digging trenches, filling with waste, and covering with fill. PCE was disposed in the landfill at some point during waste disposal operations, resulting in groundwater contamination at the site.

Sampling of groundwater conducted in October 1998 indicated that CACs were present in groundwater and that the impacted zone was primarily restricted to between 30 and 40 ft. below ground level (bgl). The CACs reported maximum concentrations were 8,500 µg/L for PCE, 550 µg/L for TCE, and 24 µg/L for cis-1,2-DCE. The average total concentration of CACs within the treatment area, taken as the sum of

PCE, TCE, and cis-1,2-DCE concentrations, is estimated to be 9,074 µg/L.

The Crooked River Plantation subdivision is located adjacent to and downgradient from the landfill (Figure 1). A private well survey conducted in the subdivision indicated that just one well was found to contain concentrations of a contaminant of concern at or above the federal maximum contaminant levels (MCLs). A total of 25 private wells were located within the survey, ranging from 10 to 40 ft. bgl. None of the wells were being utilized for drinking water purposes.

The ultimate goal of RAO at the landfill is to treat groundwater within the contaminated plume to concentration levels below the MCLs established by the Georgia Environmental Pollution Department (GEPD). Modeling results indicate that source area reduction of CACs to a cleanup objective of 100 µg/L for each compound would be sufficient for natural attenuation to achieve compliance levels in the groundwater plume prior to leaving the base boundaries and reaching offsite monitoring points.

1.2 *Site Geology and Hydrogeology*

The shallow soils in the region of NSB Kings Bay are typified as fine sands interbedded with silty and/or clayey fine sands and some medium sands, with water encountered at approximately 6 feet bgl. An unconfined surficial aquifer is approximately 90 ft. thick in the vicinity of the landfill. Within the landfill, the lithology of the surficial zone is described as gray to light brown, fine to medium quartz sand with intermittent gray clay lenses, extending to a depth of at least 50 ft. bgl. Depth to water is approximately 6 ft. bgl. The direction of groundwater flow is generally northwest. Hydraulic conductivity is reported as 30 ft/day in the 30 to 40 ft. depth interval.

2.0 Initial Remedial Action Operation

2.1 *Pump and Treat*

In September 1993, a groundwater pump and treat (P&T) system was designed and installed as a measure to control offsite migration of contaminated groundwater. Startup of the P&T system occurred in March 1994. The first stage of the remedial effort included the installation of five groundwater recovery wells and their associated conveyance system, a diffused aeration tank (DAT) for groundwater treatment, and vapor-phase carbon drums for off-gas air treatment. The recovery wells were positioned in the areas with the highest known concentrations of contaminants. The second stage of the remedial effort included the addition of a new recovery well, which was centrally located within the existing recovery well network. The recovery well network is shown in Figure 2. In July 1998, five recovery wells were operating at a combined flow rate of approximately 55 gallons per minute. The recovered groundwater was treated to concentrations below MCLs and discharged into the NSB Kings Bay Land Application System (LAS); however, the treatment system did not meet the GEPD requirement to eliminate emissions in the air discharge.

To improve the effectiveness of groundwater treatment, an ultraviolet (UV) oxidation unit was approved as a replacement for the existing treatment system. UV oxidation is a technology that uses ultraviolet light in conjunction with standard oxidants, such as hydrogen peroxide and ozone, to destroy the contaminants.

2.2 *Remedial Action Performance*

The P&T system is periodically tested for CAC concentration in the water influent to the DAT.

Historical operating data was collected from March 1994 to January 1997. This data demonstrates a rapid decrease in CAC concentrations during the initial startup of the P&T system; however, since startup, CAC concentrations have stabilized and have remained relatively constant. Table 1 details the CAC concentrations in the water influent.

Table 1. Water Stream CAC Concentrations (Reported during 03/94 – 01/97)

Parameter	Concentrations (ppb)	
	MCL	Avg. Influent
PCE	5	21.71
TCE	5	31.27
1,2-DCE	70	157.95

To meet the cleanup goals established by GEPD, operation of the P&T system is projected for at least fifty (50) years. This projection is based on the high concentrations of CACs within the site, the low solubilities of the CACs, and the performance data. The time frame is representative of the extended remedial duration required for alternatives that rely solely on groundwater pumping.

2.3 Remedial Action Costs

The initial capital cost of the P&T system was $1.5 million. An additional $400,000 has been incurred annually for operations and maintenance (O&M) costs. Should this remediation approach continue until cleanup objectives are achieved, a $12 million total cost cap is expected to be negotiated.

In addition to existing P&T operation costs, the total first year cost for implementation of the UV oxidation treatment system is estimated at $525,000. This cost estimate includes an implementation cost of $425,000. Additional annual costs include $65,000 for operations and maintenance, $25,000 for monitoring, and $10,000 for reporting.

3.0 Remedial Action Optimization

3.1 *In Situ Chemical Oxidation*

In July 1998, a corrective action plan proposed containment of the plume at the Navy property and reduction of the source of contamination followed by attenuation of the residual compounds. The containment of the plume to Navy property was to be facilitated by extraction wells at the perimeter of the installation and treatment of the extracted water by UV Oxidation. The extraction wells were to operate until concentrations were sufficiently lowered that MNA would be effective for any offsite contamination. The source area was to be treated by in-situ chemical oxidation to 100 ppb total VOC's. MNA was to remediate concentrations of 100 ppb or lower based on an evaluation of the Natural Attenuation Capacity of the aquifer.

The *in-situ* chemical oxidation process is intended to reduce organic contaminant concentrations in groundwater. The process is an aggressive, pressurized injection of concentrated hydrogen peroxide and ferrous iron catalyst in a location where high levels of contamination are known to exist. The process uses Fenton's Chemistry to create hydroxyl radicals, which are powerful, effective and nonspecific oxidizing agents, within the groundwater. The hydroxyl radicals react with chlorinated compounds in the groundwater to form water, carbon dioxide, and hydrogen and chloride ions, which are all non-toxic at the levels produced.

A two-phase treatment was completed at NSB Kings Bay in February 1999. Phase I treatment focused primarily on the central part of the contaminant plume. Phase II treatment focused primarily on the downgradient areas that were not the focus of the Phase I treatment. Figure 2 details the areas of concern for Phase I and II treatment. Further treatment of the downgradient area, as well as an adjacent, upgradient source area will be the focus of Phase III, scheduled for completion in July 1999.

As part of the *in-situ* chemical oxidation treatment program, twenty-three injectors distributed in two vertical levels were installed at the locations indicated in Figure 2. In addition to the injectors, six additional monitoring wells and two recovery wells were installed within or adjacent to the targeted treatment area. Monitoring of field data during injections includes collecting groundwater samples twice each day from monitoring wells. These samples were evaluated to determine if appropriate chemical conditions (e.g., pH, alkalinity and total iron) were established in the aquifer, reagents were dispersed effectively (e.g., hydrogen peroxide), and inert byproducts of CAC oxidation were generated. In addition to field data, pre-and post-treatment groundwater samples were collected to determine contaminant concentrations.

The P&T system was operational during the chemical oxidation treatments. With approval from GEPD, the UV oxidation treatment system was not installed during the treatments. The effectiveness of the chemical oxidation treatments was evaluated to determine whether the UV oxidation treatment system would be needed. If cleanup objectives were met after the chemical oxidation treatments, the P&T system would not be necessary and would be shut off.

3.1 *Remedial Action Performance*

The *in situ* chemical oxidation treatment has provided an effective and rapid solution to CAC contamination in the aquifer underlying the landfill. During Phase I treatment, sampling results indicate that the cleanup objective was achieved within the primary target area. Similar results were found during Phase II treatment. Table 2 details the analytical results of the pre- and post-Phase I and II treatment. Figure 3 provides a graphical representation of monitoring results at the landfill.

Table 2. Results of Phase I and II Treatment

	Total CAC (ppb)		
Well ID	Pre-injection	Post-injection Phase I	Post-injection Phase II
KBA-11-34	9074	93	9
KBA-11-36	512	416	6

Although cleanup objectives were achieved within the target areas, an additional source of contamination was discovered to the north of the treated area. Phase III treatment will address sources of contamination both up- and down-gradient of the previous target areas. As Phase III has not yet been completed, no performance information is currently available.

Results from Phase I and II treatments indicate that cleanup objectives have been achieved in the target areas. As a result, the P&T system was shut off two months after Phase II treatment. This shutoff eliminates the need for the UV oxidation treatment system. Also, MNA has been implemented as the RAO for the landfill.

3.2 *Remedial Action Costs*

The total first year cost for implementation of Phase I and II *in-situ* chemical oxidation and UV oxidation treatment is estimated at $1,050,000. This cost estimate includes an implementation cost of $900,000. Additional annual costs include $65,000 for operations and maintenance, $40,000 for monitoring, and $15,000 for reporting. Phase III chemical oxidation treatment is estimated at $282,000.

Since cleanup objectives were achieved by chemical oxidation, and the UV oxidation treatment system is not needed, a $525,000 savings was realized, based on the implementation costs of the UV oxidation system presented in Section 2.3. Additionally, the shut down of the P&T system eliminates the associated costs of the system, resulting in several million dollars (up to $12 million) of cost savings.

4.0 Contact Information

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Figure 1. Location of Landfill Relative to Subdivision and Direction of Groundwater Flow

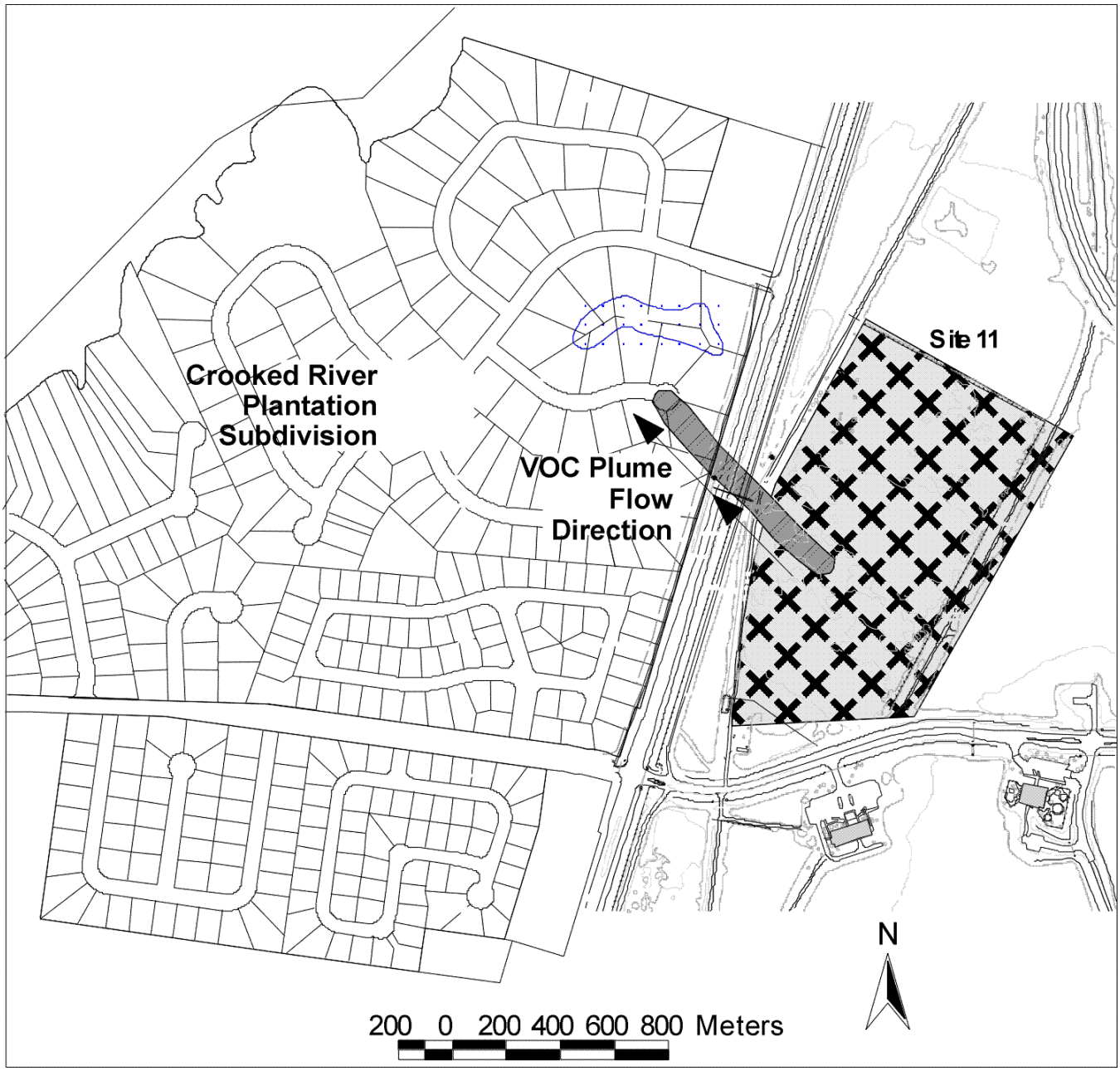

Figure 2. NSB Kings Bay Site Map

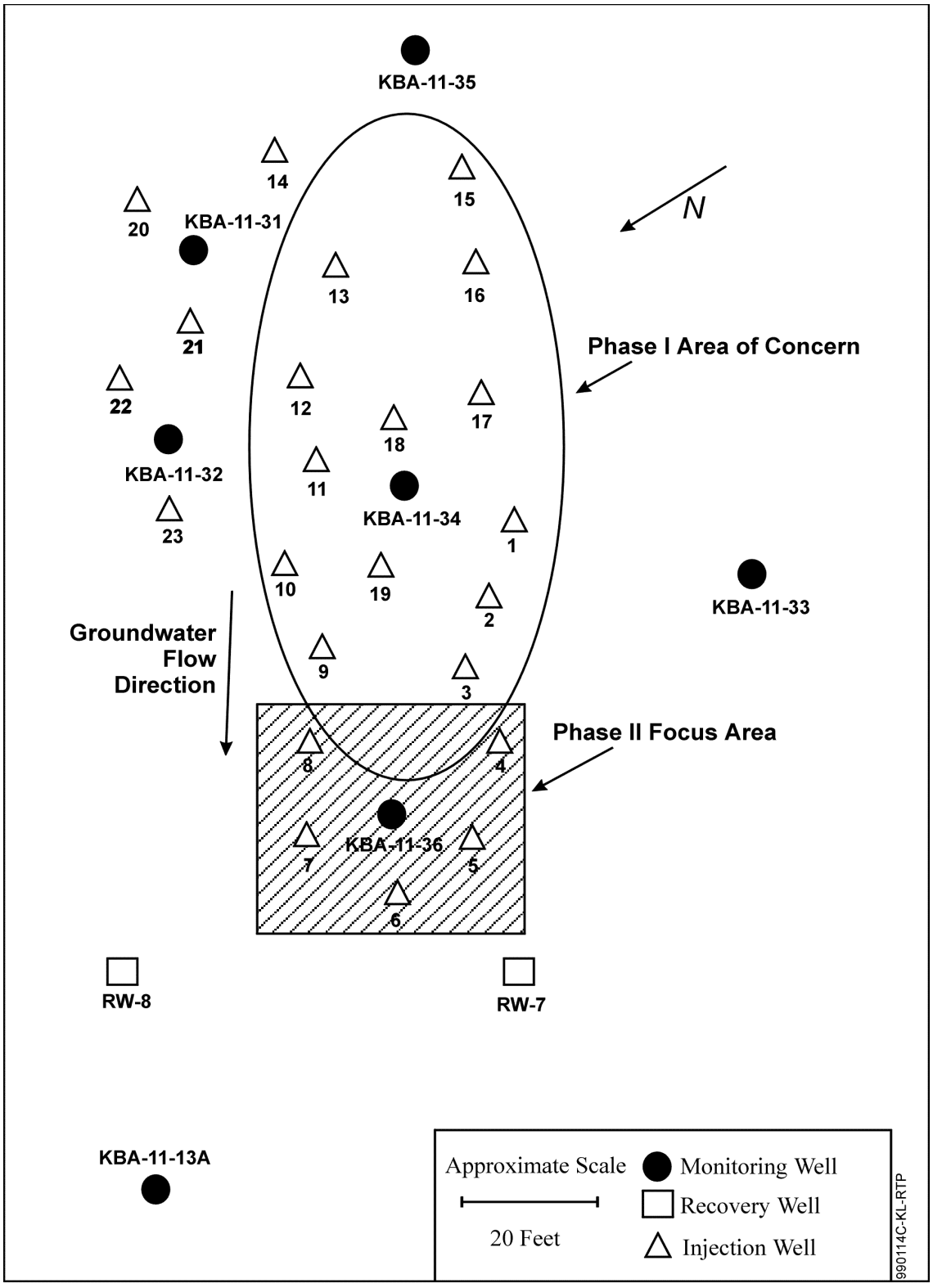

Figure 3. Monitoring Results at Site 11, NSB Kings Bay