COST AND PERFORMANCE REPORT

In situ Permeable Reactive Barrier for Contaminated Groundwater
at the U.S. Coast Guard Support Center
Elizabeth City, North Carolina

September 1998

EPA

Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information:

U.S. Coast Guard Support Center
Elizabeth City, North Carolina

CERCLIS #: Not applicable

ROD Date: Not applicable

Treatment Application:

Type of Action: Corrective Action

Period of operation: 7/1/96 - Ongoing (Data collected through September 1997).

Quantity of groundwater treated during application: 2.6 million gallons (estimated)

Background

Historical Activity that Generated Contamination at the Site: Electroplating Operations

Corresponding SIC Code: 3471 (Electroplating of metals)

Waste Management Practice That Contributed to Contamination: Spills and leaks to the subsurface through floor drains and holes in building floor

Location: Elizabeth City, North Carolina

Facility Operations: [1, 2, 5]

- The Support Center, Elizabeth City (SCEC) is a U.S. Coast Guard (USCG) facility providing support, training, operation and maintenance associated with USCG aircraft.

- The groundwater plume is adjacent to a former electroplating shop which operated for more than 30 years. Operation ceased in 1984.

- In December 1988, a release was discovered during demolition of the former plating shop. Soil excavated beneath the floor of the former plating shop was found to contain chromium at concentrations up to 14,500 mg/kg.

- The majority of the contaminated soil at the site was believed to have been excavated during the 1988 activities. Subsequent investigations indicated that the groundwater had been impacted by chromium.

- Additional investigations by the USCG indicated the presence of chlorinated compounds in the groundwater. Multiple sources were suspected of having contributed to the groundwater contamination.

- A pilot study was initiated at the site in 1994 to demonstrate the effectiveness of the permeable reactive barrier (PRB) (iron treatment wall) at this site. Two different types of iron were poured into 16 cm inside-diameter hollow stem augers. A total of 21 iron cylinders were installed from 3 to 8 meters below ground surface. The cylinders were installed in three rows. Groundwater samples were taken downgradient of the iron cylinders to test for reduced groundwater concentrations.

- A full-scale PRB was installed in June 1996. The iron wall was constructed using a trencher which excavated the soil and back-filled with iron in one pass. The wall was installed in seven hours.

Regulatory Context:

- The full-scale PRB was constructed as part of an Interim Corrective Measures (ICM) associated with a voluntary RCRA Facility Investigation (RFI). The electroplating shop is identified in the facility's RCRA Part B permit as Solid Waste Management Unit (SWMU) No. 9. Corrective actions at the site are regulated under 40 CFR Subpart F.

Remedy Selection:

- An *in situ* PRB was selected as the remedy for this site.

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: USCG-Lead

Oversight: State

USCG Project Manager:
Jim Vardy, P.E.*
U.S. Coast Guard
CEU Cleveland Environmental Engineer
Bldg. 19
Elizabeth City, NC 27909
919-335-6847

Remedial Project Manager:
Surabhi Shah
North Carolina Department of Environment and Natural Resources (DENR)
Hazardous Waste Section
401 Oberlin Rd., Ste. 150
Raleigh, NC 27605

*Indicates Primary Contact

Treatment System Vendor:
Design
University of Waterloo, Waterloo, Canada
Contractor Support
Parsons Engineering Science, Inc. Cary, NC
Licensing
Environmental Technologies, Inc. Ontario, Canada
Installation
Horizontal Technologies, Inc.

Additional Contact:
Robert Puls
USEPA
Robert S. Kerr Environmental Research Center
Subsurface Protection and Remediation Division
National Risk Management Research Laboratory
P.O. Box 1198
Ada, OK 74821
580-436-8543

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [1, 5]

Primary Contaminant Groups: Halogenated volatile organic compounds (VOC) and metals

- Contaminants of concern at the site are trichloroethene (TCE) and hexavalent chromium (Cr^{+6}).
- Maximum concentrations detected during initial investigations included TCE (>4,320 µg/L) and Cr^{+6} (>3,430 µg/L).
- Figure 1 is a contour map which depicts total chromium concentrations detected during a July/August 1994 sampling event. At least two overlapping plumes were identified at the site. A plume consisting of Cr^{+6} and minor amounts of halogenated VOCs began near the north end of the former electroplating shop and migrated north with the general groundwater flow direction. A second plume of primarily halogenated VOCs emanated from unknown sources. Most of these sources were suspected to be associated with old sewer drain lines. This plume also migrated north and overlaped the first plume. The plume discharged to the Pasquotank River.
- According to the site contact, the presence of dense non-aqueous phase liquid (DNAPL) at this site is likely based on elevated concentrations detected in groundwater samples and processes known to have occurred in the electroplating shop.
- The contaminant plume was estimated to be up to 5-6 feet thick and cover a 34,000 square foot area. The volume of contaminated groundwater was estimated to be 1.3 million gallons.

MATRIX DESCRIPTION (CONT.)

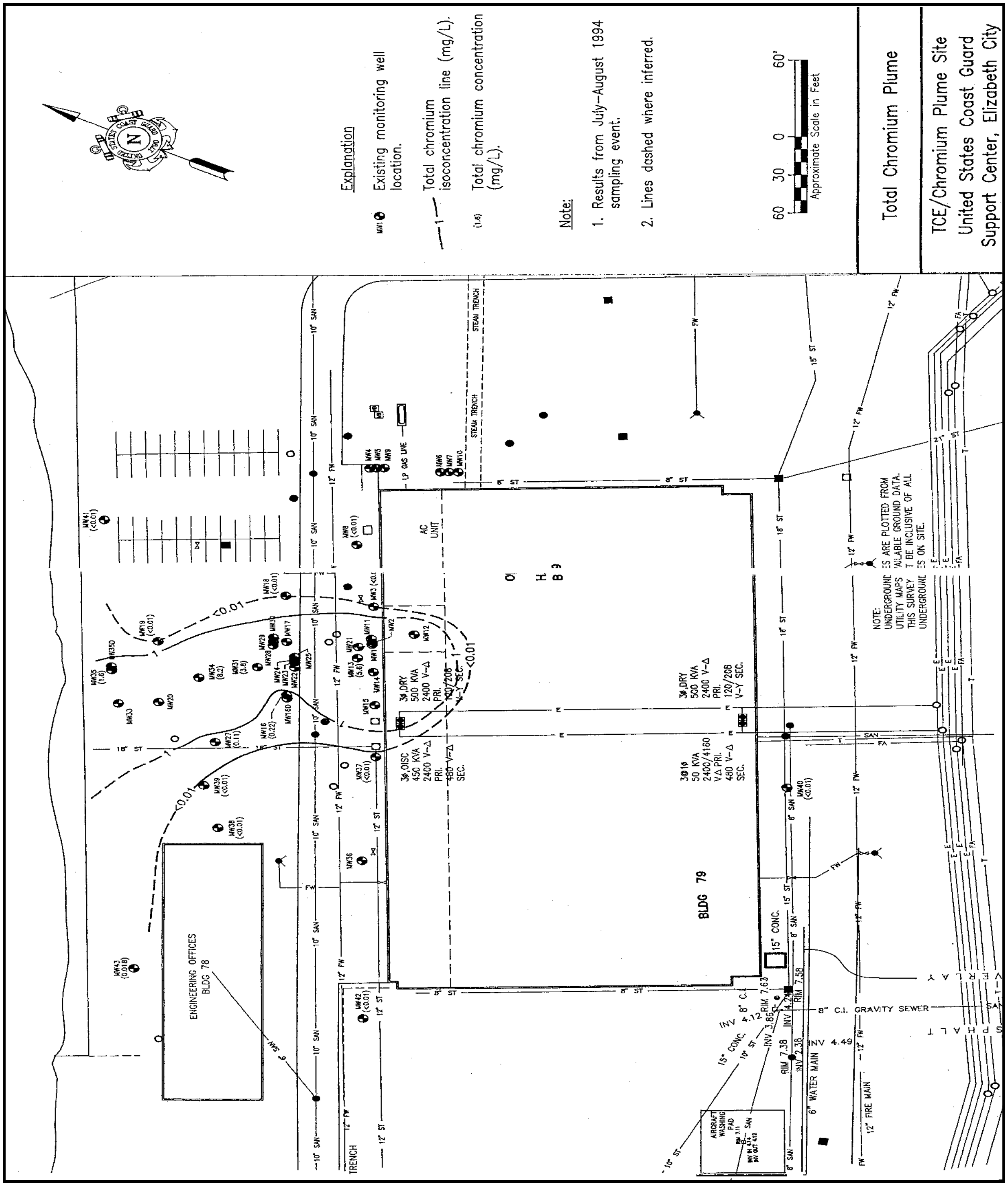

Figure 1. Plume Map Depicting Total Chromium Concentrations (detected in July/August 1994) Modified From [2]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology: [1, 2]

Four distinct hydrogeological units have been identified beneath this site. Groundwater begins approximately six feet below ground surface and a highly conductive zone is located between 16-20 feet below ground surface. This conductive layer coincides with the highest aqueous concentrations of chromate and chlorinated organic compounds found on site. Groundwater flows in a north direction toward the Pasquotank River. A low conductivity layer of clayey fine sand to silty clay is located at a depth of approximately 22 feet. This layer acts as an aquitard to the contaminants located immediately above. This information was used when designing the treatment wall depth to end in a low conductivity layer to prevent contaminants from flowing under the treatment zone.

Unit 1	Surficial Sediments	Brown to yellow-brown sandy to silty clay. This is a non water-bearing unit.
Unit 2	Surficial Sediments	Medium to fine sand or silty to clayey sand, with interbedded sandy clays ranging from stiff to loose and brown to tan. This is the upper water-bearing unit at the site.
Unit 3	Surficial Sediments	Dense gray to green clay or silty clay. This unit acts as a major aquitard between the upper aquifer and the Yorktown Formation.
Unit 4	Yorktown Formation	Fine to medium clayey and silty sand. This unit is a major water-bearing formation. Groundwater in this unit has not been impacted by site contamination.

Tables 1 and 2 present technical aquifer information and well data, respectively.

Table 1. Technical Aquifer Information

Unit	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
1	6-8	NA	NA	NA
2	50-60	11.3 - 25.5	0.3 - 0.6	North
3	25	Not characterized	Not characterized	Not characterized
4	>100	Not characterized	Not characterized	Not characterized

Source: [1, 5]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

PRB

Supplemental Treatment Technology

None

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation [1, 2, 5]

Table 2. Technical Wall Data

Unit	Flow-Through Thickness	Conductivity (ft/day)	Material	Vertical Thickness
Continuous Treatment Wall	2 feet	1,000	Granular Iron	18 feet

Source: [1, 5]

System Description

- The PRB is a passive, *in situ* treatment technology which makes use of natural groundwater velocity and transport mechanisms to carry contaminants through the reaction zone.

- The full-scale PRB consists of 450 tons of granular zero-valent iron. The reactive zero-valent iron to dechlorinate TCE to chloride and ethylene, and reduce hexavalent chromium to trivalent chromium. Trivalent chromium forms an insoluble hydroxide compound and precipitates. The physical dimensions of the wall are 152 feet long by 2 feet wide. The reactive media begins 4 to 8 feet below ground surface and extends to 24 feet below ground surface.

- The PRB is keyed into an underlying low conductivity layer within Unit 2, which is comprised of clayey fine sand to silty clay and is found at a depth of approximately 22 feet. This material is not classified as an aquitard; however, chromium and TCE contamination is primarily found in a highly conductive zone directly above this unit at a depth of 16 to 20 feet.

- The required residence time in the treatment zone for the dechlorination and reduction reactions has been estimated to be approximately 21 hours based on the highest concentration scenario.

- Ten compliance monitoring wells are used to monitor the treatment wall performance. Six wells (MW46, MW47, MW49, MW50, MW52, MW35D) are located downgradient of the treatment wall. Well MW48 is located within the treatment wall. Three wells (MW38, MW48, MW13) are located upgradient of the treatment wall. Monitoring well MW52 was added between June 1997 and September 1997 to further monitor contaminant concentrations downgradient of the wall. Fifteen additional multi-level sampling points (135 total sampling points) have also been installed upgradient and downgradient of the treatment wall for research purposes.

System Operation

- Quantity of groundwater treated (gal):

	Approximate Volume Treated
1996-1997	2.6 million gallons

Based on average groundwater velocity of 0.4 ft/day and dimensions of 152 feet wide and 16 feet flow-through thickness [2].

- Since July 1996, the PRB has been 100% operational.

- Compliance monitoring wells and research sampling points are monitored for piezometric head to evaluate groundwater velocity and flow direction through the PRB.

Operating Parameters Affecting Treatment Cost or Performance

A major operating parameter affecting cost and performance for this technology is the groundwater flow rate through the treatment wall. The average flow rate through the wall and the required remedial goals are included in Table 3. In addition, a minimal residence time is required to treat the contaminants to the cleanup goal levels. For this application, the residence time is 21 hours.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance (Cont.)

Table 3: Performance Parameters

Parameter	Value
Average Velocity through Treatment Wall	0.2 - 0.4 ft/day
Remedial Goal (Aquifer downgradient of the wall)	TCE (5 µg/L) Cr^{+6} (0.1 mg/L)

Source: [1, 5]

Timeline

A timeline for this remedial project is shown in Table 4.

Table 4: Project Timeline

Start Date	End Date	Activity
9/90	6/95	Remedial system designed
9/94	on-going	Pilot study initiated
6/96	---	Construction of full-scale PRB completed (1 day)
6/96	---	Full-scale PRB begins operation
11/96	---	Date for initial quarterly monitoring round
11/97	---	Quarterly monitoring conducted

Source: [1]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1, 5]

- Cleanup goals for this site are Primary Drinking Water Standards. Specific concentrations for target compounds are included in Table 3. These goals are applied in monitoring wells downgradient of the treatment wall.

Treatment Performance Goals [1, 5]

- The primary goal of the PRB is to reduce contaminant concentrations in the groundwater downgradient of the reactive zone to cleanup goals.
- The secondary goal of the PRB is to contain the contaminated part of the plume upgradient of the reactive zone.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment [2,7,8,9]

- As shown in Figures 2 and 3, Cr^{+6} concentrations were below the cleanup goal of 0.1 mg/L in all six downgradient monitoring wells in both the November 1996 and September 1997 sampling events. Cr^{+6} concentrations were reported below the quantification limit (BQL) of 0.0041 mg/L in all cases.

- As shown in Figures 4 and 5, TCE concentrations remain above the cleanup goal of 5 µg/L in four of the six downgradient wells (MW46, MW49, MW50, MW52) as of September 1997. In addition, these figures show that the concentrations had increased in two of these four wells (MW49, from 2.8 to 5.5 µg/L and MW50, from 41 to 548 µg/L; both of these wells are located adjacent to the wall) over the period of November 1996 to September 1997. The other two downgradient wells (MW35D and MW47) remained below the cleanup goal of 5 µg/L during this time.

- The TCE concentration in MW50 has fluctuated from the November 1996 (baseline) concentration of 41 µg/L to 3.4 µg/L for the first quarter (of operation), 156 µg/L for the second quarter (of operation), and 548 µg/L during the September 1997 sampling event. This fluctuation may be attributed to large amounts of rainfall that washed into the open trench during construction. The heavy infiltration rate may have pushed the organic plume down or residual contamination in the soils downgradient of the wall may be leaching TCE into the aquifer [10].

- Monitoring wells MW13, MW18, MW38, MW47, MW48, MW49, MW50, MW35D, MW46 and MW52 are monitored quarterly for compliance purposes. TCE results from MW15, MW48, MW50 and MW46 are shown in Figure 6, and Cr^{+6} results from the same wells are shown in Figure 7.

- Figure 6 shows that TCE concentrations have decreased in MW48 and MW46 to approximately 100 µg/L (MW48) and 10 µg/L (MW46), respectively. TCE concentrations remained relatively constant at approximately 20 µg/L in MW13, and increased in MW50 to about 800 µg/L. Because well MW52 was installed between the June 1997 and September 1997 sampling event, only one data point is available. TCE concentrations were measured at about 500 µg/L for MW52 in September 1997. Well MW52 is screened at the same interval as well MW50, and is located adjacent to the river similar to well MW46.

- Figure 3 shows that Cr^{+6} concentrations in MW48, within the treatment wall, remained relatively constant at approximately 1.0 mg/L. Cr^{+6} concentrations in MW13, upgradient of the wall, were higher than the cleanup goal of 0.1 mg/L, at approximately 3 mg/L.

- The pilot study performed in 1994 and 1995 was successful at demonstrating the effectiveness of the iron treatment wall technology at this site. The results from the pilot study led to the selection of a full-scale reactive wall as the remedy for this RCRA corrective action.

- With respect to the secondary treatment performance goal of plume contaminant upgradient of the reactive zone, the data indicate that the TCE plume may not be contained. An explanation for the TCE concentrations found in MW50 and MW52 has not been confirmed.

Performance Data Completeness

- Ten compliance monitoring wells are sampled quarterly.

- Analyses were performed by the EPA NRMRL Laboratory and the University of Waterloo.

TREATMENT SYSTEM PERFORMANCE (CONT.)

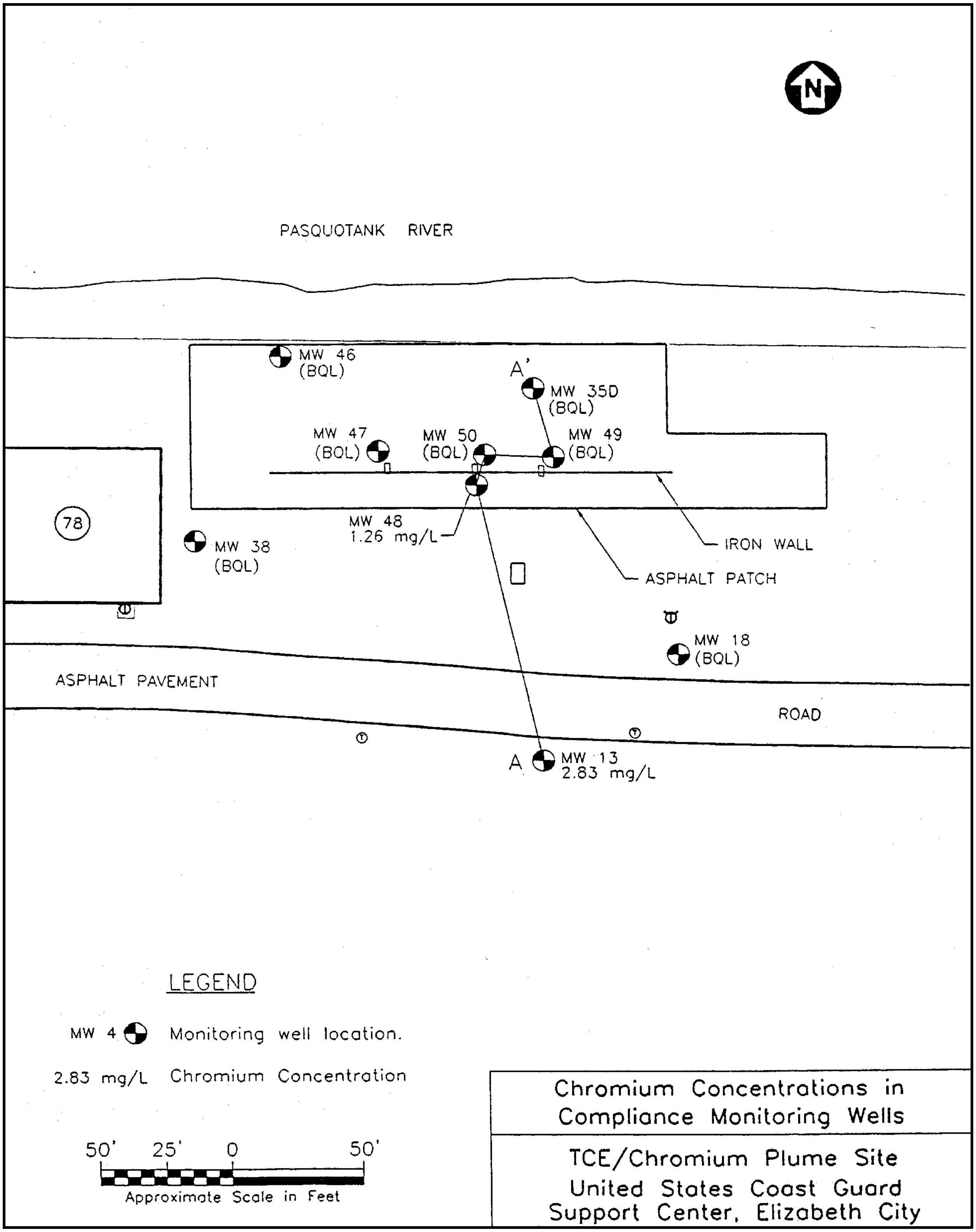

Figure 2. Cr^{+6} Concentrations in November 1996 [1]

TREATMENT SYSTEM PERFORMANCE (CONT.)

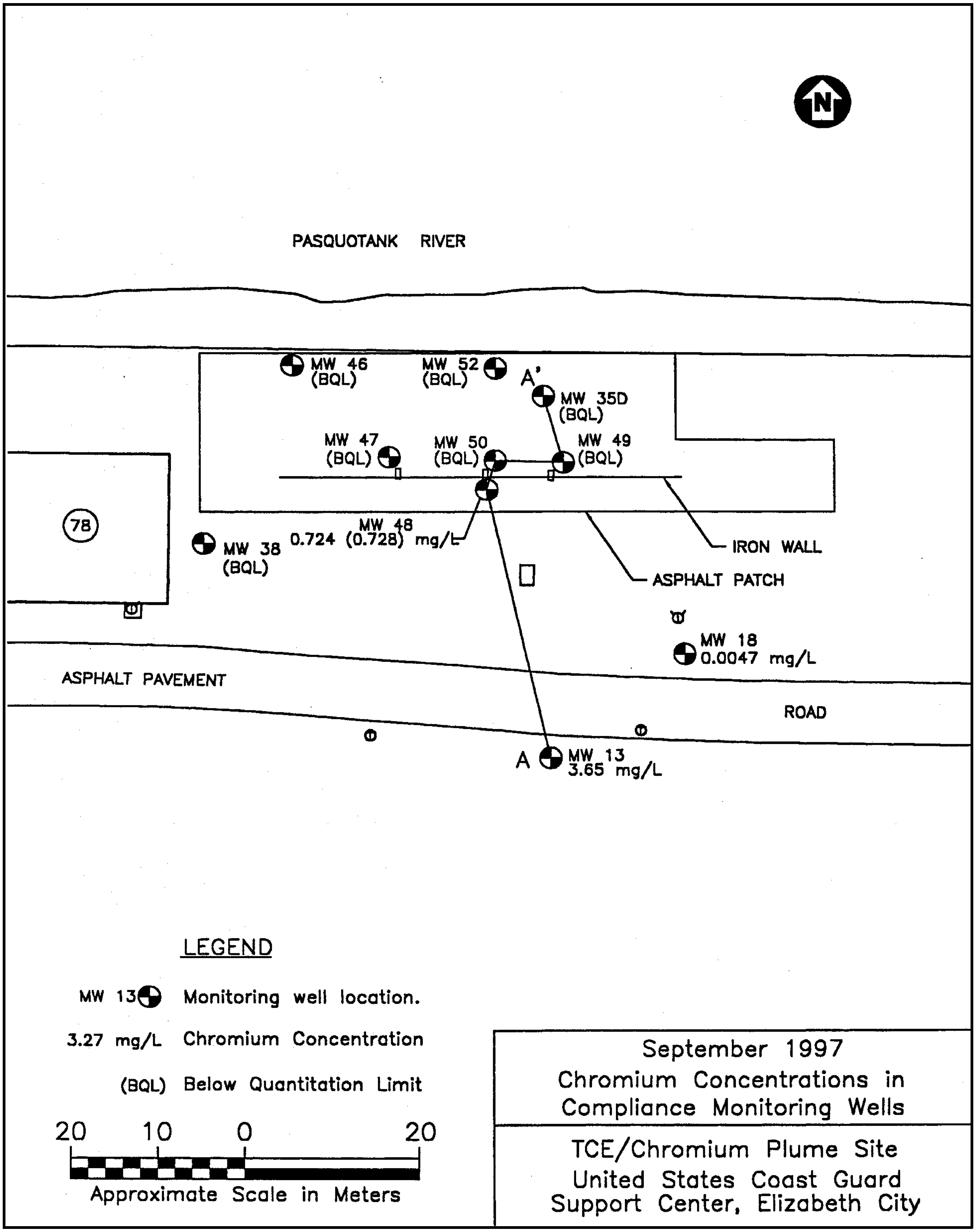

Figure 3. Cr^{+6} Concentrations in September 1997 [9]

TREATMENT SYSTEM PERFORMANCE (CONT.)

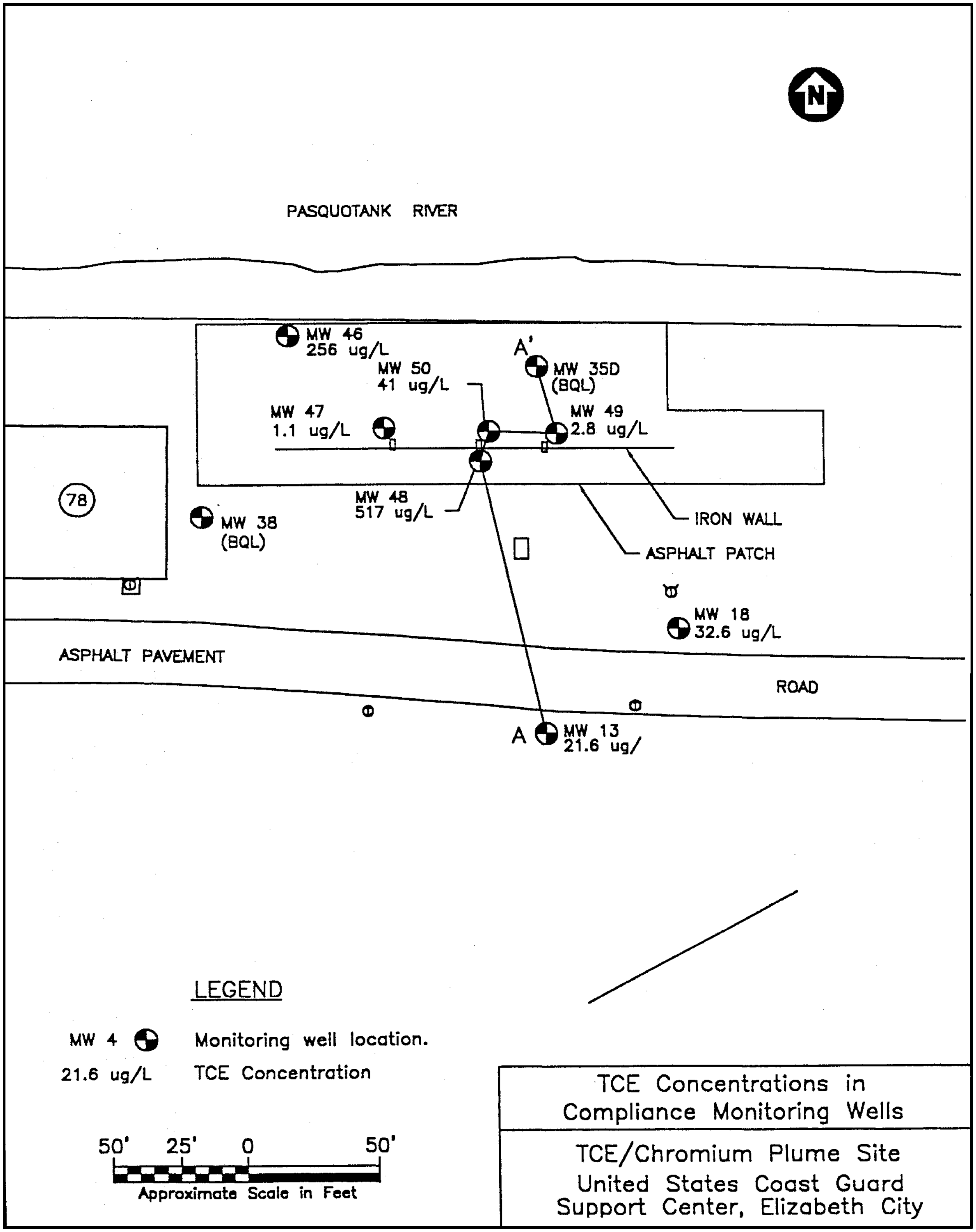

Figure 4. TCE Concentrations in November 1996 [1]

TREATMENT SYSTEM PERFORMANCE (CONT.)

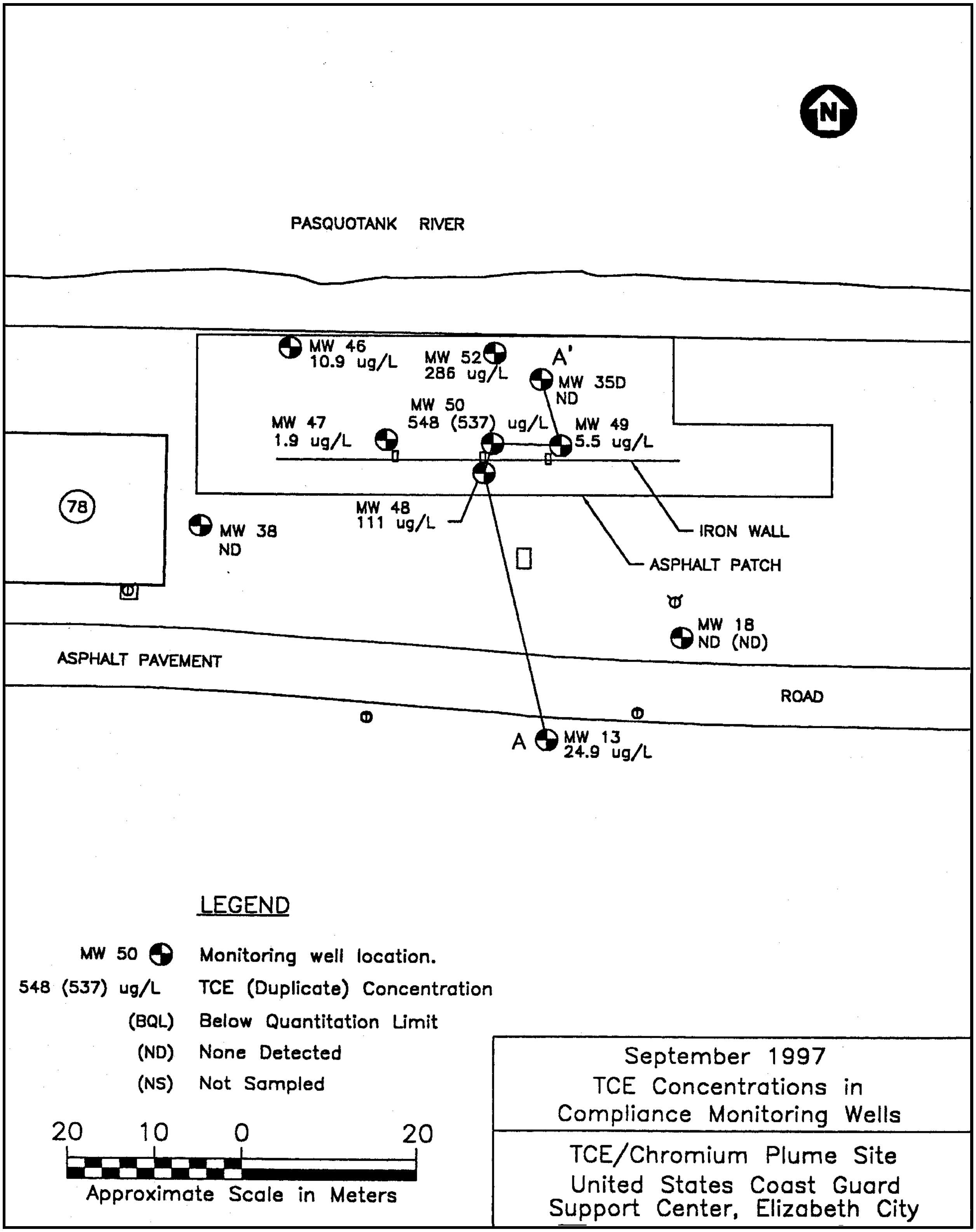

Figure 5. TCE Concentrations in September 1997 [9]

TREATMENT SYSTEM PERFORMANCE (CONT.)

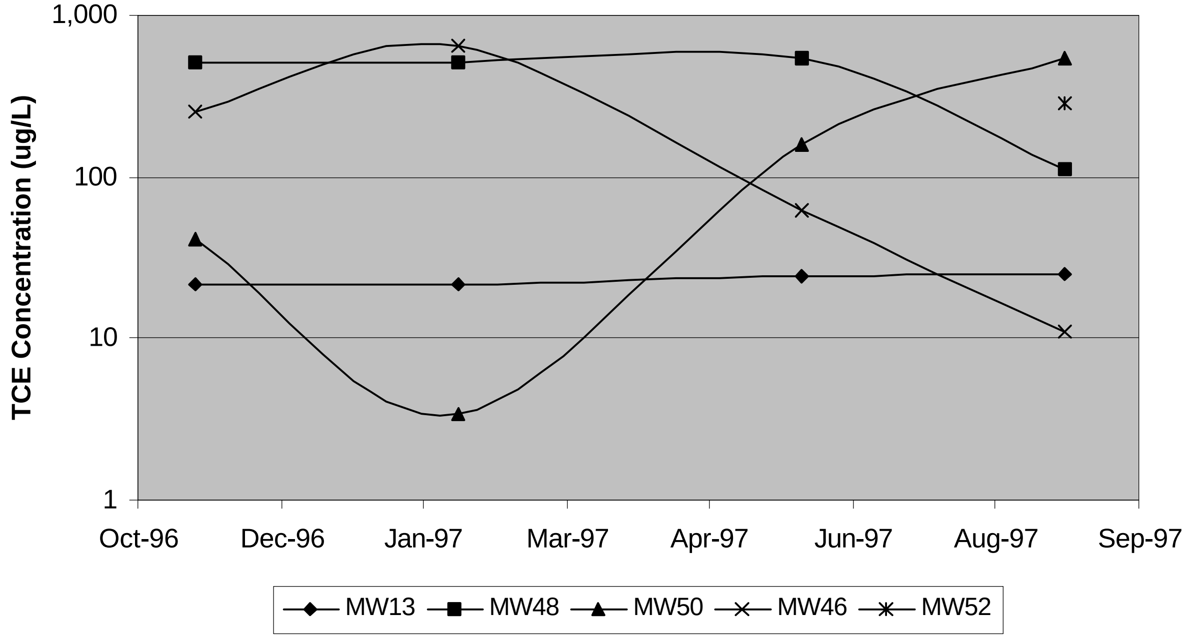

Figure 6. TCE Concentrations in Five Compliance Wells (1996 - 1997) [1,7,8,9]

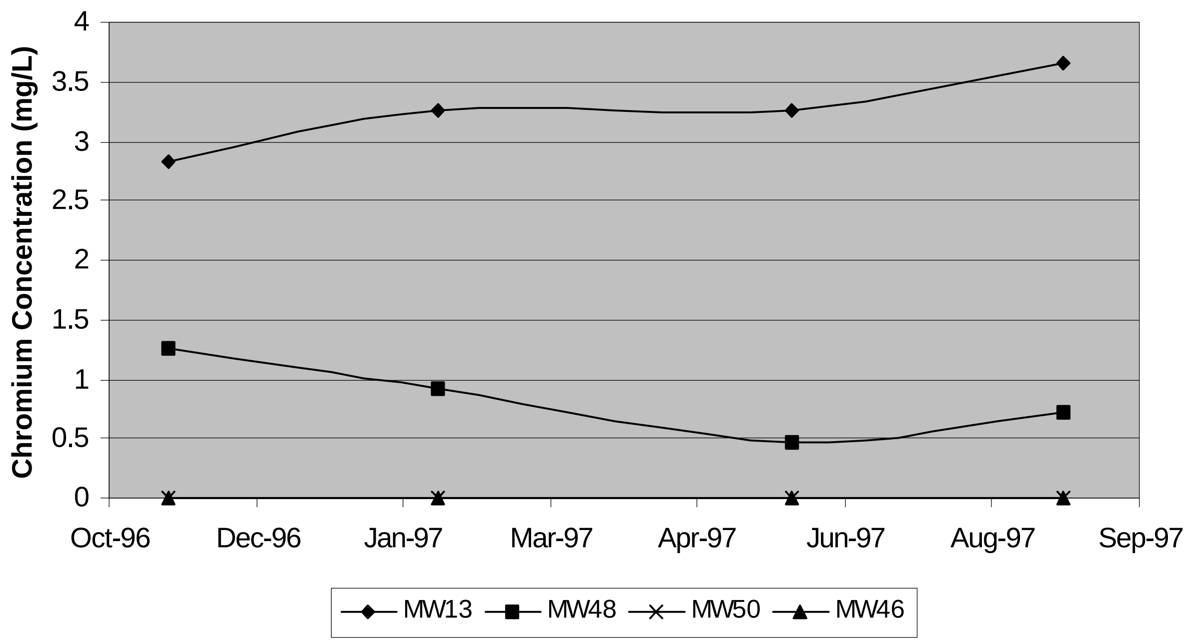

Figure 7. Cr^{+6} Concentrations in Four Compliance Wells (1996 - 1997) [1,7,8,9]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of North Carolina requirements. All monitoring was performed using EPA-approved methods, RSKSOP-102, RSKSOP-146, RSKSOP-147, RSKSOP-175, RSKSOP-179, RSKSOP-181, RSKSOP-183, RSKSOP-184, Method 353.1, Method N-601, SW-846 Method 8240, SW-846 Method 8020 and the vendor did not note any exceptions to the QA/QC protocols.

TREATMENT SYSTEM COST

Procurement Process

The USCG CEU-Cleveland is the lead for this site. SCEC is responsible for on-site activities and oversight. The State of North Carolina is responsible for RCRA activities within the state.

Cost Analysis

All costs for design, construction and operation of the treatment system at this site are borne by the USCG.

Capital Costs* [6]

	(Cost in 1996 dollars)
Remedial Construction	
System Installation	$200,000
Site Preparation	$100,000
Iron	$200,000
Total Remedial Construction	**$500,000**

*Estimated

Operating Costs [6]

Monitoring/Analytical	$40,000[1]
Report Preparation	$45,000[2]
Total	**$85,000**

[1]First annual monitoring and analytical contract.
[2]Baseline Report.

Other Costs [6]

Pilot Program	$150,000
Remedial Design	$60,000
State Oversight	$30,000

Cost Data Quality

Actual capital and operations and maintenance cost data provided by the USCG contact for this site. Some cost figures provided were estimated based on public sector industry standards.

OBSERVATIONS AND LESSONS LEARNED

- The cost for groundwater remediation at this site over one year was approximately $585,000 consisting of $500,000 in capital costs, and $85,000 in operating costs, corresponding to a unit cost of $225 per 1,000 gallons of groundwater treated.

- According to the USCG site contact, by using a treatment wall to remediate groundwater contamination, the USCG will save nearly $4 million in construction and long-term maintenance costs. This savings is based on a comparison with a typical pump and treat system with the following costs: $500,000 for installation, $200,000/year for monitoring and maintenance, and $500,000 for equipment replacement over a twenty-year operating life [6]. As this shows, construction and installation costs are similar in magnitude

OBSERVATIONS AND LESSONS LEARNED (CONT.)

for this technology when compared with a typical pump and treat application. However, operating costs are much less for the treatment wall technology.

- The results of sampling in November 1996 (after four months of operation) showed that Cr^{+6} had been reduced to below the cleanup goal of 1.0 mg/L in all downgradient compliance wells. Data from the September 1997 sampling event showed that Cr^{+6} levels remained below the quantification limit of 0.0041 mg/L.

- As of September 1997, TCE concentrations had been reduced to below the cleanup goal of 5 µg/L in two of the six downgradient compliance wells. While TCE concentrations were reported below the cleanup goal in three of these wells in November 1996, TCE concentration in well MW49 increased from 2.8 µg/L to 5.5 µg/L between sampling events. In addition, concentrations in well MW50 increased from 41 µg/L to 548 µg/L between November 1996 and September 1997. Possible reasons for the increase included ongoing leaching from residual contamination in the soil and infiltration caused by heavy rainfall.

- Because of the limited data available at the time of this report, mass flux and cumulative contaminant mass removal could not be calculated.

REFERENCES

1. *Interim Measures Baseline Report*, Parsons Engineering Science, Inc., Cary, NC. April 1997.

2. *Interim Measures Workplan*, Parsons Engineering Science, Inc., Cary, NC. December 1995.

3. Puls, Robert W., C.J. Paul and R.M. Powell, *Remediation of Chromate-Contaminated Groundwater Using Zero-Valent Iron: Field Test at USCG Support Center, Elizabeth City, NC*; Proceedings from HSRC/WERC Joint Conference on the Environment.

4. Puls, Robert W., C.J. Paul and R.M. Powell, *In Situ Immobilization and Detoxification of Chromate-Contaminated Groundwater Using Zero-Valent Iron: Field Experiment at the USCG Support Center, Elizabeth City, NC*; Proceedings from the Great Lakes Geotechnical and Geoenvironmental Conference.

5. Phone Conversations with Dr. Robert Puls, ADA Labs November 25, 1997.

6. Phone Conversations with Mr. James Vardy, USCG, April 18, 1997.

7. Interim Measures Quarter 1 Report, Parsons Engineering Science, Inc., Cary, NC. May 1997.

8. Interim Measures Quarter 2 Report, Parsons Engineering Science, Inc., Cary, NC. October 1997.

9. Interim Measures Quarter 3 Report, Parsons Engineering Science, Inc., Cary, NC. March 1998.

10. Correspondence between Jim Vardy, USCG, and Linda Fiedler, USEPA, July 1, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.