COST AND PERFORMANCE REPORT

Pump and Treat and *In Situ* Chemical Treatment of Contaminated Groundwater at the Odessa Chromium II South Plume Superfund Site Odessa, Ector County, Texas

July 2005

Prepared by:

EPA

U.S. Environmental Protection Agency
Office of Superfund Remediation and Technology Innovation (OSRTI)

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Odessa Chromium II Superfund Site – South Plume, Operable Unit 2 (OU2)

Location: Odessa, Texas

Site ID No.: 0602703

EPA CERCLIS ID No.: TXD980697114

ROD Date: March 18, 1988

ESD Date: October 25, 1999

TECHNOLOGY APPLICATION

Type of Action: Remedial

Period of Operation:

- Electrochemical Groundwater Pump and Treat – December 1993 to December 1997
- In Situ Chemical Treatment – December 1998 to April 1999

Quantity of Material Treated During Application [11]:

- 121 million gallons of groundwater treated at the completion of remedial activities in December 1997 and 141 pounds of chromium removed from the groundwater.

BACKGROUND

Historical Activity that Generated Contamination at the Site: Radiator repair

Corresponding Standard Industrial Classification (SIC) Code: 7538

Waste Management Practice That Contributed to Contamination: Unlined wastewater-holding ponds and waste drum burial

Location: Odessa, Ector County, Texas. The site is bounded by 50th Street to the South, U.S. Highway 385 or Andrews Highway to the East, 54th Street to the North and Washington Avenue to the West.

Facility Operations [1, 2, 3, 9, 10, 11, 14]:

- The site is located in a mixed residential, commercial, and industrial area. The Basin Radiator & Supply, formerly located in the 5300 block of Andrews Highway, operated from 1960 to the early 1970s. Wastewater containing chromium was discharged to unlined ponds and waste radiator sludge containing chromium corrosion inhibitors was buried on the site. Also located in the 5300 block of Andrews Highway was Wooley Tool and Manufacturing which had a chromium plating operation.

- In 1977, the Texas Natural Resource Conservation Commission (TNRCC) discovered elevated levels of chromium in the groundwater during investigations in response to citizen complaints of contaminated well water. The TNRCC concluded that the two facilities, Wooley Tool and Manufacturing and Basin Radiator & Supply, were the source of chromium in the groundwater. The former became known as the Odessa II North site and the latter as the Odessa II South site. The Odessa II South site is the subject of this report.

- In 1978, the TNRCC removed drums, onsite buildings, and contaminated soils from the site.

- In 1986, the Remedial Investigation/Feasibility Study (RI/FS) was completed. On June 10, 1986, Odessa II was placed on the National Priorities List (NPL).

- The site included two operable units; OU1 provides an alternative water supply to the area, and OU2 addresses the groundwater contamination.

- Two groundwater plumes were identified at the site – the North plume and the South plume. Initially, EPA indicated that these plumes were to be remediated jointly because both plumes had similar characteristics and were located within 1,000 feet of each other. However, after additional hydrogeological investigations showed that the plumes were distinctly separate and not commingled, the site was divided into the North Plume Site and the South Plume Site.

- This report addresses the South Plume Site and includes the use of in situ ferrous sulfate to treat residual chromium contamination in the Ogallala Formation (perched zone). In addition, the report includes information about the completion of remedial activities at the site, including shut-down of the pump and treat system; site closeout; and the deletion of the site from the NPL in July 2004. This report updates a previous Cost and Performance Report for Pump and Treat of Contaminated Groundwater at the Odessa II South Superfund Site, Odessa, Texas, published in September 1998.

Regulatory Context [1, 11, 12, 13, 16]:

- The record of decision (ROD) for OU1 was signed in 1986 to provide an alternative drinking water supply. On March 18, 1988, the ROD for OU2 was signed to address groundwater remediation at the site. Source control was not required by the ROD.

- On October 25, 1999, an ESD was signed, adding in situ chemical treatment to address residual contamination at the site.

- The first five-year review for this site was signed on September 25, 2001.

- A second ESD was issued on September 10, 2003 to eliminate the 30-year monitoring of site after completion of the remedial action

- The Closeout Report for this site was prepared on September 18, 2003.

- The site was deleted from NPL on July 19, 2004.

Ground Remedy Selection:

- Groundwater extraction followed by treatment to remove chromium contamination and injection of the treated water back to the aquifer was determined by the FS to be the most appropriate methodology for site remediation. The results of a pilot study confirmed the basic approach.

- In situ ferrous sulfate was used to treat remaining chromium contamination in the two wells that had not achieved the cleanup goals as of December 1998.

SITE LOGISTICS/CONTACTS

Site Lead: State. The Texas Natural Resource Conservation Commission (TNRCC), now known as the Texas Commission on Environmental Quality (TCEQ), was the lead agency.

Oversight: EPA

Remedial Project Manager:
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Treatment System Vendor:
Design and Management: IT Corporation (ITC)
Construction and Operation: WATEC

MATRIX DESCRIPTION

MATRIX IDENTIFICATION

Type of Matrix Processed Through the Treatment System: Groundwater

CONTAMINANT CHARACTERIZATION [1, 3]

Primary Contaminant Groups: Chromium

- The contaminant of concern at the site was chromium, with hexavalent chromium identified as the species of concern. Two hydraulically connected chromium plumes were identified in OU2 – the Ogallala Formation, or Perched Zone plume, and the Trinity Aquifer plume.

- The maximum concentration of chromium in the groundwater in the Trinity Aquifer, detected during a 1985 sampling event, was 2.8 mg/L. The maximum chromium concentration in the Perched Zone groundwater, detected in 1986, was greater than 50 mg/L.

- The initial volume of the chromium plume in the Perched Zone was estimated in the 1986 RI/FS at 980,000 gallons. The aerial extent of the initial plume was estimated to be approximately 105,000 square feet. The initial volume of the chromium plume in the Trinity Aquifer was estimated in the 1986 RI/FS to be 79,000,000 gallons. The aerial extent of the initial plume was estimated to be approximately 585,000 square feet.

MATRIX DESCRIPTION (CONT.)

CONTAMINANT CHARACTERIZATION [1, 3]

- The ROD required the site to be remediated to meet the Maximum Contaminant Level (MCL) for chromium. The initial MCL of 0.05 mg/L was changed by EPA in 1991 to 0.1 mg/L. The plume size estimates were originally calculated based on the 0.05 mg/L contour.

- Figures 1 and 2 delineate the 0.1 mg/L chromium contours in the Perched Zone and Trinity Aquifer, respectively, as observed during a September 1994 sampling event.

- In the Project Status Draft Report, the plume volumes in the Perched Zone and Trinity Aquifer were calculated based on the revised 0.1 mg/L clean-up goal and data that were nine years more current than the original RI data. A significant change in the aquifer water level and the chromium concentration had occurred between 1985 and 1994 because of lower water withdrawal rates in the area.

- The Perched Zone plume was found to be 61,270 square feet in area and 690,000 gallons in volume, compared to the 1986 plume estimate of 105,000 square feet in area and 980,000 gallons in volume. The Trinity Aquifer plume was found to be 210,385 square feet in area and 44,000,000 gallons in volume, compared to the 1986 estimate of 585,000 square feet and 79,000,000 gallons. The reduction in the size of the plumes was in part a result of the change in the MCL from 0.05 mg/L to 0.10 mg/L issued by EPA in January 1991.

MATRIX CHARACTERISTICS AFFECTING TREATMENT COSTS OR PERFORMANCE

Hydrogeology [1, 3]:

Two distinct hydrogeologic units have been identified beneath this site. Soil and sandy caliche overlie the water-bearing formations. The first water-bearing unit is encountered at approximately 30 to 45 feet below ground surface.

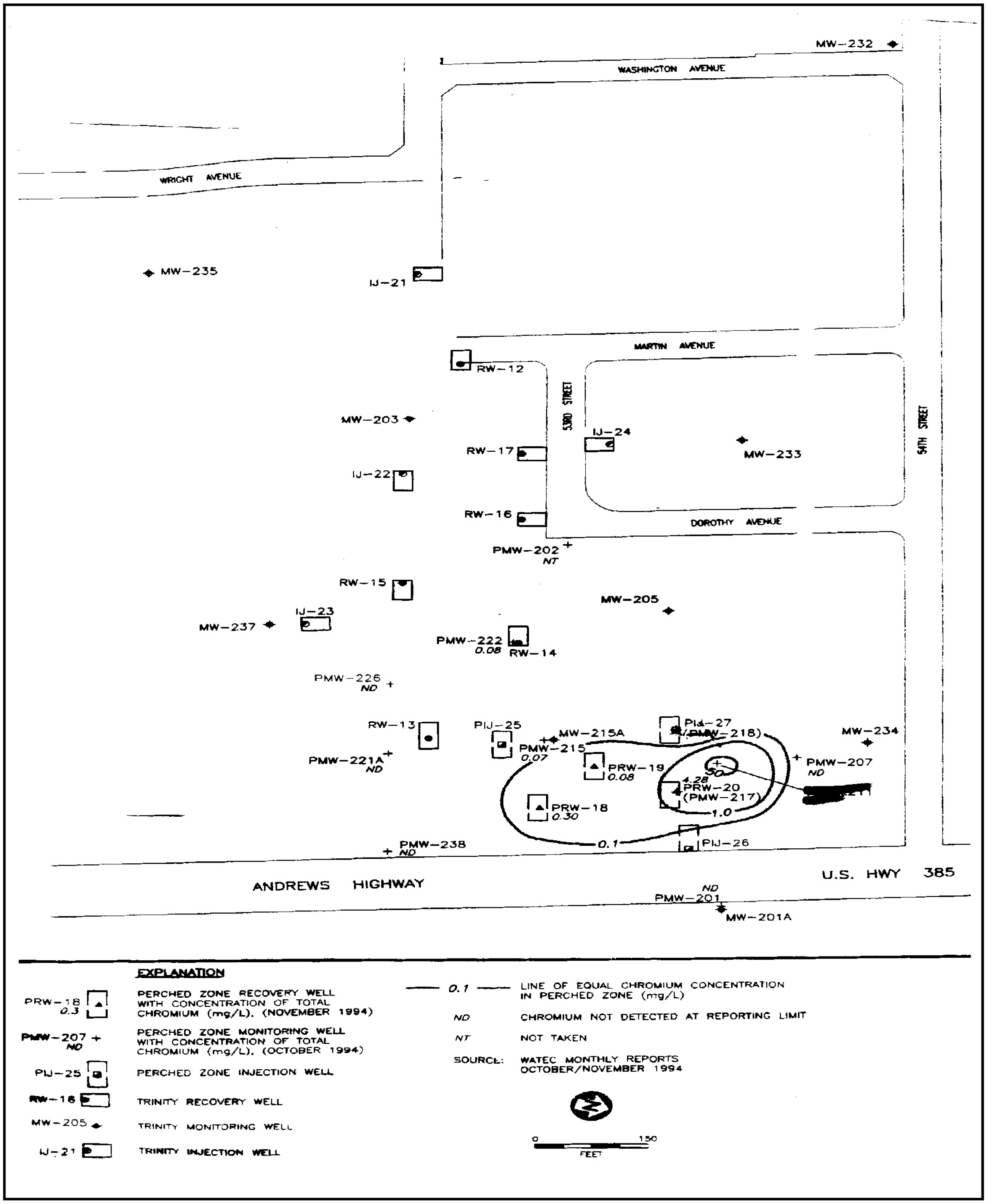
Unit 1 - Ogallala Formation (Perched Zone). This unit is formed of fluvial plastics consisting of fan deposits of fine to coarse grained sands, silt, clay, and occasional strings of gravel. A few miles to the south, the Ogallala has been removed by erosion. It is present in some parts of the site with a saturated thickness of approximately 5 to 15 feet, and is referred to as the Perched Zone. It is hydraulically connected and discharges to the underlying Trinity Sand Formation under natural conditions. The Ogallalla does not exist as a continuous aquifer and thus flow direction could not be measured.

Unit 2 - Trinity Sand Aquifer. This unit consists of sands and ferragiorous calcite cemented sandstones. Settled lenses of gravel, clay, and siltstone occur at irregular intervals. This unit is the primary groundwater supply for municipal and private residences in the area. It is underlain by the Chinle Formation, which acts as an aquitard. Groundwater flow in this unit has been observed to flow north to northeast; however, changes in water levels have altered groundwater flow direction.

The water level in the Trinity Aquifer has risen over 25 feet from 1986 to 1993. The rise in the water table is attributed to the decrease of public and private wells in the aquifer and to increased precipitation during this period. Table 1 presents technical aquifer information.

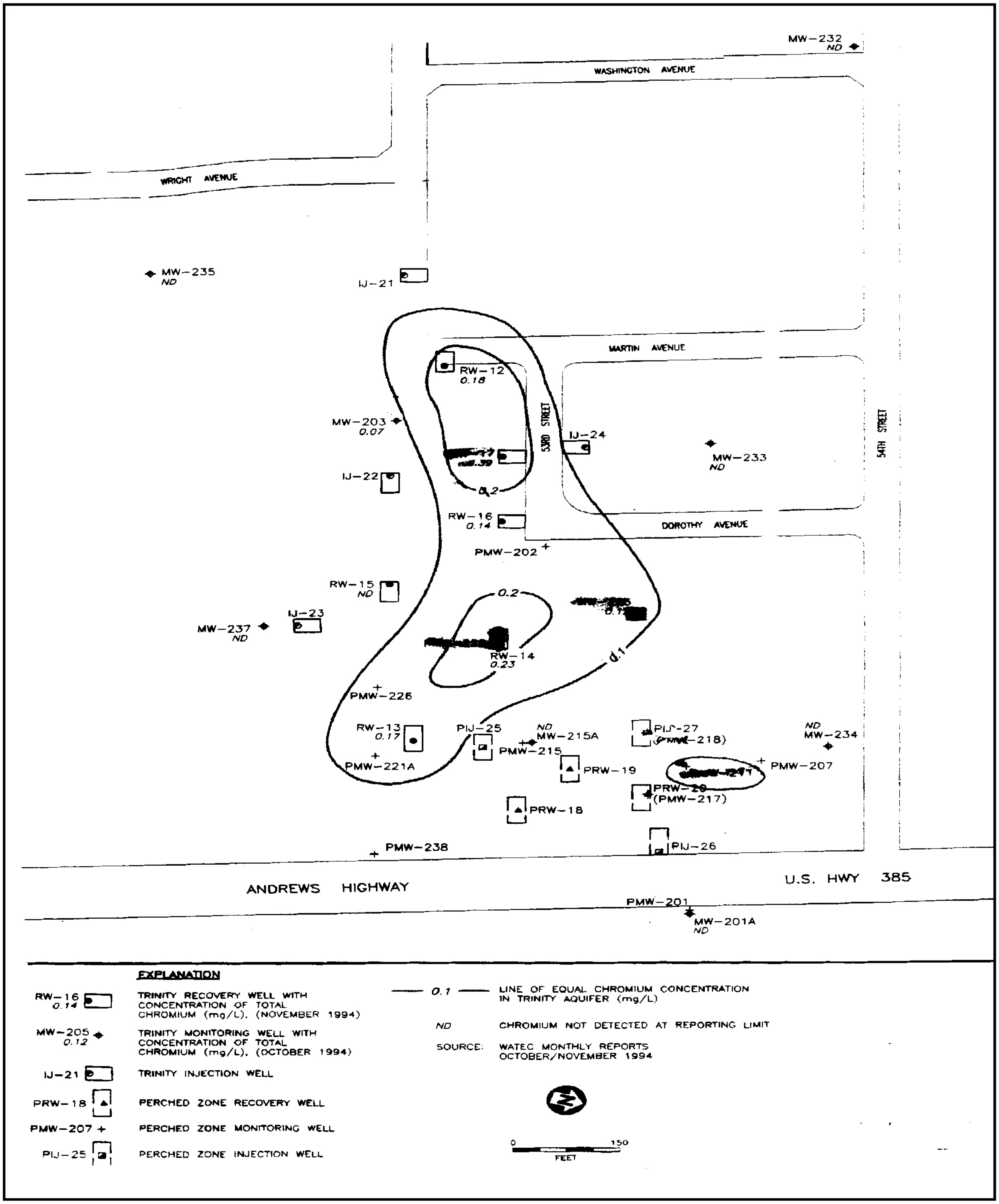
MATRIX DESCRIPTION (CONT.)

Figure 1. Perched Aquifer Chromium Contour Map (1994, Best Copy Available) [3]



MATRIX DESCRIPTION (CONT.)

Figure 2. Trinity Aquifer Chromium Contour Map (1994, Best Copy Available) [3]



MATRIX DESCRIPTION (CONT.)

MATRIX CHARACTERISTICS AFFECTING TREATMENT COSTS OR PERFORMANCE (CONT.)

Table 1. Technical Aquifer Information [1, 3]

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Flow Velocity (ft/day)	Flow Direction
Unit 1	5 – 15	1.6	0.0190	Not Characterized
Unit 2	70	1.7 – 5.1	0.0262 – 0.0782	North-Northeast[1]

[1] Flow observed during the 1986 remedial investigation was towards the north-northeast. However, the water table rose from 1986 to 1993 by 25 feet and could have resulted in a change in groundwater flow direction.

TECHNOLOGY SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY

- Pump and treat (P&T) with electrochemical precipitation of chromium using ferrous ion
- In situ ferrous sulfate addition

SUPPLEMENTAL TREATMENT TECHNOLOGY

Solids removed by flocculation and filtration

SYSTEM DESCRIPTION AND OPERATION

Table 2 presents the extraction well data

Table 2. Extraction Well Data [1, 3, 4]

Well Name	Unit Name	Depth (ft)	Design Field (gal/day)
PRW18	Ogallala Formation	70	4,070
PRW19	Ogallala Formation	70	4,070
PRW20	Ogallala Formation	70	4,070
PRW28	Ogallala Formation	70	4,070
RW12	Trinity Aquifer	165	21,600
RW13	Trinity Aquifer	165	21,600
RW14	Trinity Aquifer	165	21,600
RW15	Trinity Aquifer	165	21,600
RW16	Trinity Aquifer	165	21,600
RW17	Trinity Aquifer	165	21,600

TECHNOLOGY SYSTEM DESCRIPTION (CONT.)

SYSTEM DESCRIPTION AND OPERATION (CONT.)

This report addresses the groundwater P&T system used for remediating the South Plume site and the use of in situ ferrous sulfate addition to treat remaining chromium contamination in the Ogalla Formation (perched zone).

System Description [3, 5, 8, 9, 11]:

Groundwater P&T

- The extraction system for the South Plume consisted of six recovery wells in the Trinity Aquifer and four recovery wells in the Perched Zone. ITC used Random Walk to model solute transport (an in-house model by Reed & Associates) and Geoflow to model groundwater flow (an in-house model by IT). Model results were used to determine well placement based on projected pumping rates.

- The metals treatment system was designed to treat the collected groundwater at a rate of 60 to 90 gallons per minute (gpm). An influent tank regulated flow through the treatment system.

- Water from the extraction wells was sent to a dual chamber reaction tank (initially single chamber), into which ferrous ion was fed and mixed with the contaminated well water. Ferrous ion was produced on site in an electrochemical cell. The ion reduced the hexavalent chromium to trivalent chromium to facilitate subsequent hydroxide precipitation. In the second chamber of the reaction tank, pH was adjusted in the range of 8.5 to 8.8 to achieve minimum solubility for chromium hydroxide. Also, in the second chamber, excess ferrous ion was oxidized by aeration to insoluble ferric ion and converted to ferric hydroxide. The ferric and chromium hydroxide precipitate was mixed with a polyelectrolyte in the second chamber to aid settling.

- The treated water was clarified through a flocculation and precipitation tank, then polished through a multimedia and cartridge filter for reinjection. The multimedia filters were backwashed with treated water based on pressure drop and the cartridge filters were replaced when a specified pressure differential is exceeded. The sludge from the clarifier and the cartridge filters were disposed off site as non-hazardous waste.

- Chromium concentrations in the influent to and the effluent from the system were monitored continuously. If the level of chromium exceeded 0.05 mg/L in the effluent, the effluent was recycled through the treatment system. Treated water with chromium concentrations less than 0.05 mg/L was injected through a network of six injection wells in the Trinity Aquifer and three injection wells in the Perched Zone.

- The recovery wells were monitored on a monthly basis for water quality parameters. A network of wells was used to monitor plume containment on a semiannual basis: 10 monitoring wells and the recovery wells in the Trinity Aquifer, and two monitoring wells and the recovery wells in the Perched Zone.

TECHNOLOGY SYSTEM DESCRIPTION (CONT.)

SYSTEM DESCRIPTION AND OPERATION (CONT.)

In Situ Ferrous Sulfate Treatment

As discussed in more detail in the performance section of this report, as of December 1997, the cleanup goal for chromium had been met in all but two wells in the South Plume – PRW-20 and PRW-28, located in the Perched Zone. In situ ferrous sulfate addition was used to treat the residual chromium in these two wells. The wells were first injected with hydrochloric acid to prevent plugging and to lower the pH of the groundwater to promote the reduction of hexavalent chromium to trivalent chromium, followed by ferrous sulfate addition. On December 4, 1998, a concentrated solution of ferrous sulfate was injected into each well, and the wells were restarted on December 10, 1998. No information was provided about the volume or concentration of the ferrous sulfate solution.

System Operation [3, 4, 5, 8, 9, 11, 14]:

Groundwater P&T

- Quantity of groundwater pumped from aquifer by year:

Year	Volume Pumped (gal)
11/93 to 12/93	4,269,133
1994	29,660,519
1995	29,118,867
1996	31,257,749
1997	26,320,000

- Initial startup began in July 1992. However, after a few days of operating, the multimedia polishing filter and injection wells began to clog with iron and calcium and treated water could not be reinjected. The extraction and treatment systems were shut down and the following modifications were made:

  - The reaction tank was altered from a single-chamber to a two-chamber tank, separated by a baffle. The second chamber allowed for precipitation of the excess iron, the main clogging problem.

  - A tank was added to receive backwash from the multimedia filters. The backwash tank acted as an equalization tank to prevent shock change to the system influent tank when the filters were backwashed. The pH of the water was set to between 7.0 and 7.5 pH beyond the clarifier to prevent precipitation of calcium carbonate.

  - Two additional injection wells were constructed to allow for higher reinjection rates.

  - Backwash water was stored in the modified backwash unit and was slowly added to the influent tank to avoid upsetting the pH balance in the influent.

  - Modifications were completed in August 1993, and the system was restarted on November 11, 1993. The 30-day trial period was completed on December 11, 1993; the treatment phase of the project began upon successfully completion of this 30-day trial period.

TECHNOLOGY SYSTEM DESCRIPTION (CONT.)

SYSTEM DESCRIPTION AND OPERATION (CONT.)

- In September 1996, a low-flow test was performed in case future extraction would be from the Perched Zone, as remediation was progressing more slowly than the Trinity Aquifer. The treatment system was tested for ability to operate at 20 gpm, and was successful at low flow rates.

- In March 1997, an additional recovery well was installed in the Perched Zone to expedite cleanup of the suspected source area. The additional well expanded the extraction network to a total of four recovery wells in this zone.

- During this time, the system was operational 95% of the time, with downtime primarily due to shutdowns for local brown outs and routine system maintenance.

- By December 1997, all of the recovery wells had met the cleanup goal with the exception of PRW-20 and PRW-28, located in the Perched Zone. WATEC began the Partial Closure Phase and plant modification on December 11, 1997. These activities, completed on February 14, 1998, included disconnecting of the treatment system, and modifying the recovery piping to allow groundwater recovery from wells PRW-20 and PRW-28 only.

- The equipment that was not needed in the modified plant was either disposed off site or disconnected and stored on site for future use. All of the Trinity Aquifer recovery wells with the exception of RW14 were plugged, as were Perched Zone wells PRW-18 and PRW-19. RW-14 supplied injection water to the Perched Zone aquifer to help move contaminated water toward PRW-20 and PRW-28.

In Situ Ferrous Sulfate Treatment

- Ferrous sulfate was injected into PRW-20 and PRW-28 on December 4, 1998. The wells were restarted on December 10, 1998, and sampled on a regular basis. Based on the results of the samples showing chromium concentrations below the cleanup goal, well PRW-20 was shut off on February 20, 1999. After 90 days of data showed chromium concentrations remained below the cleanup goal, the well was treated with ferrous sulfate a second time, then plugged and abandoned.

- In Well PRW-28, chromium concentrations initially decreased to levels below the cleanup goal, then increased to levels above the cleanup goal. On April 30, 1999, the well was treated a second time with ferrous sulfate. The 90-day period where chromium concentrations remained below the cleanup goal in this well was met on December 10, 1999.

Plant Shutdown and Closure

On December 10, 1999, after all wells in the Perched Zone and Trinity Aquifer had met the cleanup goals, the Closure Phase began. This phase included decommissioning and pressure washing the treatment building; plugging the remaining wells, and disconnecting the utilities. The closure phase was completed in March 2001. The Remedial Action Final Report was prepared in January 2002, and the site was removed from the NPL in July 2004.

TECHNOLOGY SYSTEM DESCRIPTION (CONT.)

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE

The operating parameter affecting cost or performance for this technology is the extraction rate. Table 3 presents the average pump rate and other performance parameters.

Table 3. Performance Parameters [3, 4]

Parameter	Value
Average Pump Rate	84,200 gpd*
Performance Standard (effluent)	0.05 mg/L total chromium
Remedial Goal (aquifer)	0.10 mg/L total chromium

* The average system extraction rate from November 1993 until December 1996 was approximately 84,200 gpd, based on a total volume of 94 million gallons extracted and a 95% operation rate.

TIMELINE

Table 4 presents a timeline for this application.

Table 4. Timeline [1, 4]

Start Date	End Date	Activity
January 1992	July 1992	Remediation system constructed
July 1992	August 1992	Trial run conducted and injection wells clogged with iron and calcium
August 1992	May 1993	Redesign and pilot studies performed
May 1993	August 1993	Alterations made to remedial system
November 1993	---	Continuous operation of remediation system begun. Monthly monitoring of groundwater began
September 1996	---	Treatment system tested for effectiveness during low flow
March 1997	---	Recovery Well PRW-28 constructed in Perched Zone
December 1997	---	Plant shut down and modified for collection of Perched Zone water only (PRW-20 and PRW-28)
February 1998	June 1998	Continuous operation of remediation system collecting water from PRW-20 and PRW-28 only
December 4, 1998	---	PRW-20 and PRW-28 treated with ferrous sulfate
December 10, 1998	---	PRW-20 and PRW-28 restarted following treatment
February 1999	---	End of PRW-20 90-day standby period
April 1999	---	PRW-28 was treated with ferrous sulfate, (PRW-20 also retreated as a preliminary step to P&A)
December 1992	---	End of PRW-28 90-day standby period. Plant operated in standby mode
February 2001	---	Plant closure phase (building decontaminated and utilities disconnected)
March 2001	---	Completion of Closure Phase

TECHNOLOGY SYSTEM PERFORMANCE

CLEANUP GOALS/STANDARDS [1]

The cleanup goal as established by the EPA and TNRCC was to lower the chromium levels in the groundwater to less than the maximum contaminant level (MCL), or Primary Drinking water standard of 0.10 mg/L. This goal is applied throughout the aquifer, as measured in all on-site monitoring wells.

Additional Information on Goals:

The original MCL for chromium was 0.05 mg/L. In January 1991, EPA revised the standard to 0.10 mg/L.

Treatment Performance Goals [3]:

- Effluent injected into the aquifer from the treatment system must have levels of chromium below MCLs.
- As a secondary goal, the remedial system is designed to create an inward hydraulic gradient toward the site to contain the plume.

PERFORMANCE DATA ASSESSMENT [3, 4, 5, 6, 11, 13, 14, 15]

Groundwater P&T

- As of December 1997, all wells in the Trinity Aquifer and all but two wells in the Perched Zone had achieved the cleanup goals. In addition, based on the sampling results, the site operators concluded that the plume had been contained in both aquifers.
- Figure 3 shows the decrease in average chromium concentrations in the groundwater over time for the Trinity Aquifer, and shows a spiking of the average chromium concentrations in the Perched Zone in 1995. ITC has attributed this spike to desorption of possible chromium from the previously unsaturated zone that was affected by increased precipitation from 1986 to 1996.
- Effluent chromium levels met the required performance standard of 0.1 mg/L. Therefore, reinjection of effluent occurred throughout system operation.
- From 1993 to December 1997, the P&T system removed a total of 141 pounds of chromium from the groundwater, as shown in Figure 4. Figure 4 illustrates the decline in contaminant removal rate for the P&T system during the first three years of full-scale system operation (1993-1996). The chromium removal rate decreased from 0.18 pounds per day in December 1993 to 0.05 pounds per day in 1996.

TECHNOLOGY SYSTEM PERFORMANCE (CONT.)

Figure 3. Average Chromium Concentrations from March 1992 - January 1997 [3, 4]

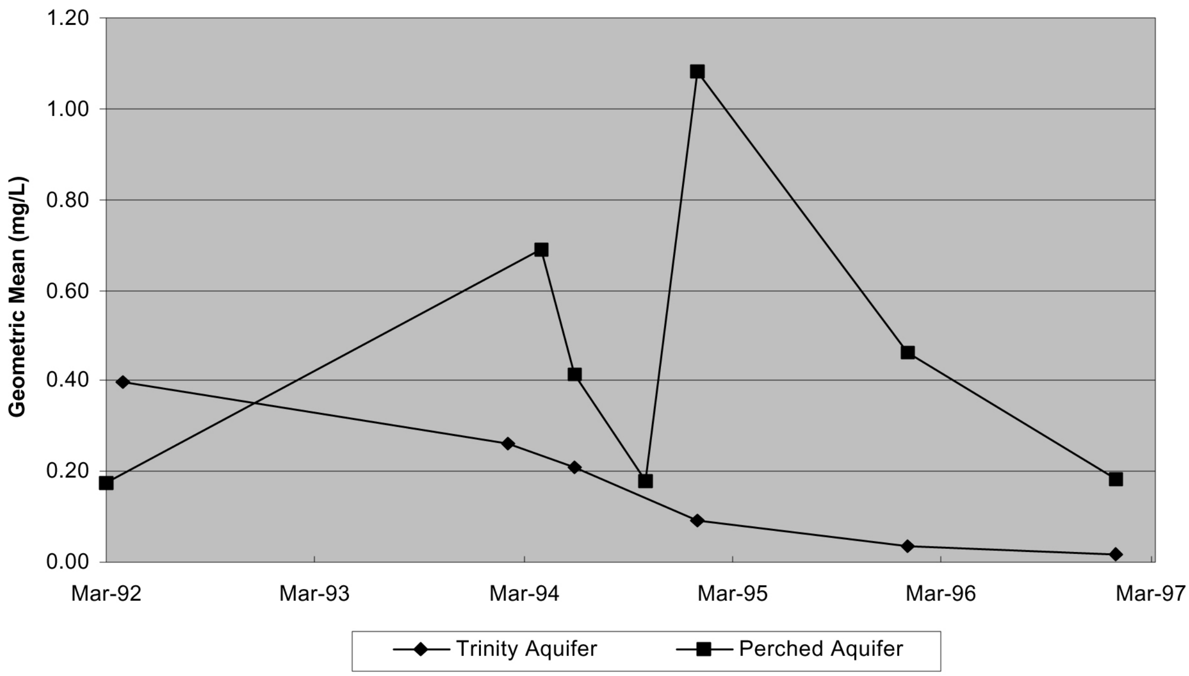
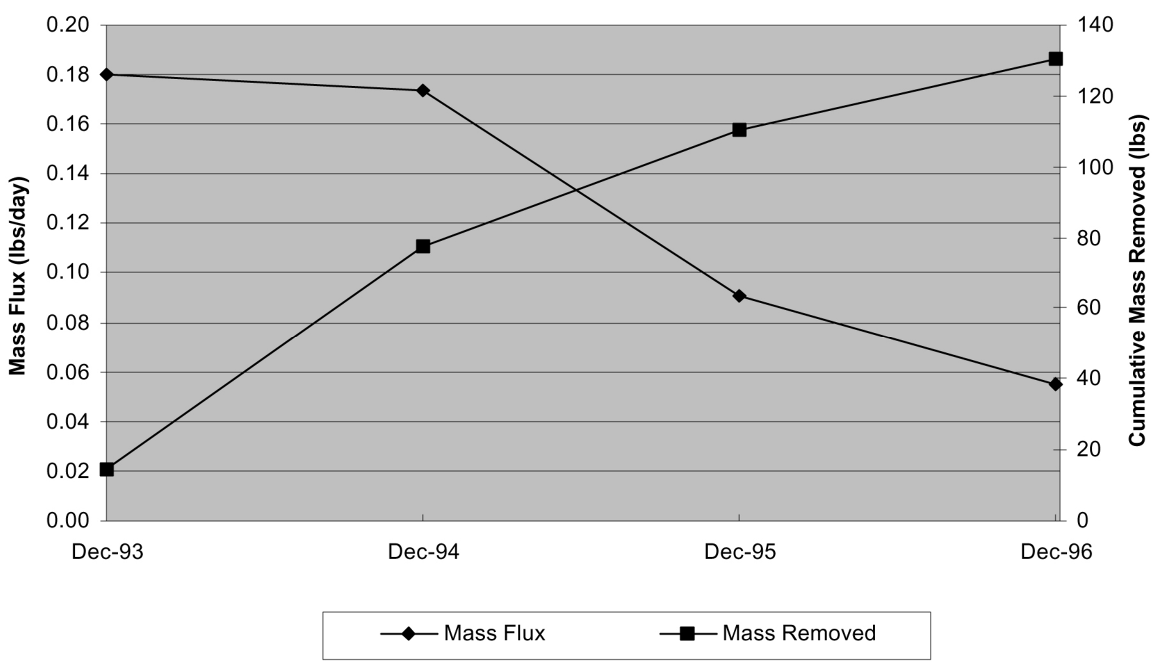


Figure 4. Mass Flux Rate and Cumulative Chromium Removal (1993 - 1996) [3, 4]



TECHNOLOGY SYSTEM PERFORMANCE (CONT.)

PERFORMANCE DATA ASSESSMENT [3, 4, 5, 6, 11, 13, 14, 15] (CONT.)

In Situ Ferrous Sulfate Treatment

- The two wells, PRW-20 and PRW-28, that had not met cleanup goals during the initial shutdown of the P&T system, were treated with ferrous sulfate, as described on page 10 of this report, *System Description and Operation, In Situ Ferrous Sulfate Treatment*. Table 5 shows data for total chromium concentrations in these wells before and after treatment. Following the first treatment with ferrous sulfate, chromium concentrations in well PRW-20 decreased to below the cleanup goal. To meet the cleanup criteria, the concentration of chromium had to remain below the cleanup goal for 90 days. PRW-20 was shut off on February 20, 1999 and chromium concentrations remained below the cleanup goal for 90 days. The well was treated with ferrous sulfate a second time prior to plugging.

- In well PRW-28, chromium concentrations initially decreased to below the cleanup goal following treatment, then increased to levels as high as 0.88 mg/l. After a second treatment in April 1999, chromium concentrations decreased to below the cleanup goal. Well PRW-28 completed the 90-day period of chromium concentrations below the cleanup goal in December 1999.

Table 5. Total Chromium Concentrations (mg/L) Following In Situ Ferrous Sulfate Treatment [13]

Date	PRW-20	PRW-28
12/1/98	0.38	1.6
12/4/98 (1st treatment of both wells)		
12/16/98	0.01	0
12/28/98	0.02	0.12
1/1/99	0.04	0.39
1/15/99	0.03	0.36
2/2/99	0.6	0.88
2/16/99	0.02	0.3
Well PRW-20 Shut off and PRW-28 Received Second Injection of Ferrous Sulfate		
3/2/99	0.07	2.4
4/1/99	0.05	1.2
4/30/99 (2nd treatment of PRW-28)		
7/5/99	--	0.08
8/3/99	--	<0.05
9/7/99	--	<0.05
10/12/99	--	<0.05
11/2/99	--	<0.05
12/8/99	--	<0.05

Dates of Plugging and Abandonment of Groundwater wells

Table 6 shows the dates when cleanup goals were met in each well and the date the wells were plugged and abandoned.

Table 6. Dates of Plugging and Abandonment of Groundwater Wells [11]

Well	Date Cleanup Goal Met	Date of Plugging and Abandonment
RW-12	January 1995	February 1998
RW-13	November 1995	February 1998
RW-14	March 1996	April 29, 2004
RW-15	April 1994	February 1998
RW-16	February 1995	February 1998
RW-17	December 1995	February 1998
PRW-18	February 1996	February 1998
PRW-19	June 1996	February 1998
PRW-20	December 1998	January 30, 2002
PRW-28	July 1999	January 31, 2002

Post Closure

- The Closure Phase for the South Plume was completed in March 2001, and the operation and monitoring phase (O&M) phase began, which included inspection and maintenance activities and groundwater monitoring. The first O&M groundwater sampling event was completed on February 18, 2002. Total chromium concentrations for all samples were below the cleanup goal of 0.10 mg/L. Results of the first five year review completed by EPA in July 2001 showed that current operation and maintenance procedures had proven to be effective at maintaining the protectiveness of the remedy at the South Plume and no deficiencies were noted. The final remedial action report was prepared in January 2002. The closure report was prepared in September 2003, and the site was deleted from the NPL in July 2004.

- As part of the NPL deletion notice, EPA noted that after an evaluation of sampling data for the site, the 30-year monitoring period requirement could be discontinued.

PERFORMANCE DATA COMPLETENESS

- Data on mass flux and mass removed were reported on a monthly basis, and were available from the TNRCC. Annual monitoring data were used for Figure 3.

- A geometric mean was used for average chromium concentrations detected in the groundwater in Figure 4 to show the overall trend of chromium levels in the groundwater on an annual basis.

- Annual data on chromium mass removed were provided by the TNRCC and were used for Figure 4 analyses.

- For concentrations below detection limits, half of the detection limit was used for evaluation purposes.

PERFORMANCE DATA QUALITY [4, 15]

The QA/QC program used throughout the remedial action met the EPA and the TNRCC requirements. All monitoring was performed using EPA Method 218.1 and EPA-approved methods for pH, total suspended solids, and other water quality parameters. The vendor did not note any exceptions to the QA/QC protocols.

COST OF THE TECHNOLOGY SYSTEM

PROCUREMENT PROCESS

The TNRCC is the lead authority on this site. WATEC was awarded the construction and operations contract for the site. IT Corporation was awarded the oversight contract for the site.

COST DATA

The costs for design, construction, and operation of the treatment system at this site were split 90:10 by the EPA and the TNRCC, respectively. Table 7 lists the remediation costs associated with the groundwater P&T.

Table 7. Groundwater P&T Remediation Costs [4]

Type of Cost	Technology Cost ($)	Cost for Calculating Unit Cost ($)
1. Capital costs for remedial construction		
Mobilization Work	$334,723	
Monitoring Wells Sampling/Testing Analysis	$43,500	
Groundwater Collection & Control	$330,944	
Installation of Treatment Plant	$884,962	
Site Restoration	$13,542	
Site Security	$3,298	
Construction Management	$316,533	
Total Remedial Construction	**$1,927,502**	**$1,927,502**
2. Operation and Maintenance Costs		
1993 Operating Costs (11/93-12/93)	$13,060	
1994 Operating Costs (1/94-12/94)	$146,260	
1995 Operating Costs (1/95-12/95)	$232,416	
1996 Operating Costs (1/96-12/96)	$168,506	
1993 – 1996 Monitoring: Sampling and Analysis	$35,466	
Total Operation and Maintenance Costs	**$560,232**	**$560,232**
3. Other Project Costs		
Engineering Design	$417,452	
Oversight	$48,154	
EPA Oversight	$113,978	
Total Other Project Costs	**$579,584**	
Total Costs	**$3,067,318**	**$2,487,734**

Remediation system construction was from January 1992 to August 1993.

ADDITIONAL COST INFORMATION [11, 14]

- According to the *Remedial Action Final Report*, two contracts were issued to support the work at the South Plume – an engineering contract (issued to IT Corporation) and a remediation contract (issued to Waste Abatement Technologies). The final total cost for the engineering contract was $1,022,814, including all amendments. The final total cost for the remediation contract was $2,596,158. The *Remedial Action Final Report* includes details of the specific modifications to each contract.

COST OF THE TECHNOLOGY SYSTEM (CONT.)

- According to the Closeout Report for the Odessa Chromium II Superfund Site (September 2003), the total original contract amount was $727,734.19. The original contract included $89,195.81 for procurement and $178,227.97, $408,145.03, and $52,165.38 for oversight of the construction, treatment and closure phases respectively. The final amended contract amount was $1,022,814.12.

- The combined cost of two treatments with ferrous sulfate and plant operations for three moths was approximately $42,600(cost in 1999 dollars).

COST DATA QUALITY [6, 14]

The costs listed above include the system modifications performed in 1993 and in 1995. Actual capital and operations and maintenance cost data were obtained from the TNRCC and from the *Remedial Action Final Report*.

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

- Actual costs for the P&T application at Odessa II South were approximately $2,487,700. The capital costs were $1,927,500 (January 1992 to August 1993). The operations and maintenance costs were $560,200 (1993 to 1996). This corresponds to $26 per 1,000 gallons of groundwater treated and $19,000 per pound of chromium removed.

- The ROD specified that the ferrous ion used to reduce the chromium would be electrochemically produced. This requirement limited the on-site system to two vendors and potentially increased the cost of the treatment unit.

- The in-situ treatment using ferrous sulfate at wells PRW-20 and PRW-28 accelerated the achievement of remediation goals at the site. Using the P&T system, the remediation goals at the site would not be achieved before February 2000 and the projected cost of treatment would be $123,200 (cost in 1999 dollars). The combined cost of two treatments with ferrous sulfate and plant operations for three moths was approximately $42,600. This resulted in cost savings of $80,600.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED [2, 3, 16]

- The original estimated time for all recovery wells in the South Plume to meet the cleanup goal for chromium was four years. At the end of four years of operation of the P&T system, December 1997, all of the recovery wells had met the cleanup goal except for two well in the Perched Zone. In situ ferrous sulfate was used to treat the two wells, and by December 1998, all wells in the South Plume met the cleanup goal.

- Average concentrations of chromium in the Perched Zone spiked between 1993 and 1995. The increase may be a result of aquifer recharge through chromium- containing soil. ITC determined that the chromium in the Perched Zone was the source for chromium in the Trinity Aquifer. Because of the hydraulic connection, water within the Perched Zone was expected to continue to move downward over time, adding additional contaminated water to the Trinity Aquifer.

- There were several startup problems with the P&T, including clogging of injection wells and encrustation of the multimedia polishing filter by iron and calcium carbonate that delayed full-scale operations. These problems were accommodated through system modification, and no longer interfere with operations. ITC suggested that one potential approach to identifying problems earlier would be to increase the length of pilot operations. At this site, pilot tests were conducted in hourly increments, and the results were used to simulate full cycle operations. Had the pilot operations been conducted for a full 24-hour cycle, it is likely that the iron fouling problems that led to clogging could have been identified [2].

- Full-scale operations were delayed by iron and calcium encrustation in injection wells and the filter. Future effluent standards set for iron could prevent such delays.

- ITC found monthly monitoring of chromium levels in influent wells helpful. However, this was not the case for continuous monitoring. The continuous chromium monitors installed at this site could not detect levels above 1.0 mg/L [2].

- During system operation, ITC determined that backwash from the filter system should be equalized and added slowly to the influent tank to avoid large changes in the influent chemistry. During early system operations, backwash water was introduced directly into the influent tank. The differences between the pH levels in the backwash and the influent reduced the effectiveness of the reaction tank. The backwash storage unit allowed gradual addition of backwash to the influent. Addition of an equalization tank alleviated the earlier problems in the reaction tank [2].

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