

# **Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2007-November 2008**

---

**Environmental Science Division**



**United States Department of Agriculture**

Work sponsored by Commodity Credit Corporation,  
United States Department of Agriculture

**About Argonne National Laboratory**

Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357. The Laboratory's main facility is outside Chicago, at 9700 South Cass Avenue, Argonne, Illinois 60439. For information about Argonne and its pioneering science and technology programs, see [www.anl.gov](http://www.anl.gov).

**Availability of This Report**

This report is available, at no cost, at <http://www.osti.gov/bridge>. It is also available on paper to the U.S. Department of Energy and its contractors, for a processing fee, from:

U.S. Department of Energy

Office of Scientific and Technical Information

P.O. Box 62

Oak Ridge, TN 37831-0062

phone (865) 576-8401

fax (865) 576-5728

[reports@adonis.osti.gov](mailto:reports@adonis.osti.gov)

**Disclaimer**

This report was prepared as an account of work sponsored by an agency of the United States Government. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of document authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, Argonne National Laboratory, or UChicago Argonne, LLC.

# Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2007-November 2008

---

by  
Applied Geosciences and Environmental Management Section  
Environmental Science Division, Argonne National Laboratory

January 2009



United States Department of Agriculture

Work sponsored by Commodity Credit Corporation,  
United States Department of Agriculture

## Contents

Notation.....	v
1 Introduction.....	1-1
2 Overview of the Aquifer Restoration Facilities at Utica .....	2-1
2.1 Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units.....	2-1
2.2 Well GWEX4 and the Conventional Air Stripper .....	2-1
2.3 Monitoring Well Network.....	2-1
3 Overview of System Operations .....	3-1
3.1 Operation of Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units ....	3-1
3.2 Operation of Well GWEX4 and the Conventional Air Stripper .....	3-2
4 Groundwater Production Results .....	4-1
4.1 Production by Wells GWEX1-GWEX3 .....	4-1
4.2 Production by Well GWEX4 .....	4-2
5 Groundwater Treatment Results .....	5-1
5.1 Results for Wells GWEX1-GWEX3, with Treatment by Spray Irrigation .....	5-2
5.2 Results for Well GWEX4, with Treatment by Air Stripping.....	5-3
5.3 Estimated Removal of Carbon Tetrachloride from the Utica Aquifer.....	5-4
5.4 Sampling of Monitoring Wells and Apparent Carbon Tetrachloride Concentration Trends in the Utica Groundwater.....	5-4
5.5 Evaluation of Groundwater Inorganic Geochemistry .....	5-5
6 Operation, Maintenance, and System Modifications .....	6-1
6.1 Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units.....	6-1
6.2 Well GWEX4 and the Air Stripping Unit.....	6-2
6.3 Operating and Maintenance Costs .....	6-2
7 Summary .....	7-1
8 References.....	8-1

## Figures

2.1 Locations of the restoration facilities, contaminant plume, and permanent monitoring wells at Utica.....	2-3
2.2 Spray irrigation unit in operation at Utica .....	2-4
3.1 Servicing of extraction well GWEX1, March 2008.....	3-3

### Figures (cont.)

3.2	Corrosion and perforation identified in the steel riser pipe of well GWEX1, March 2008.....	3-4
5.1	Carbon tetrachloride concentrations at monitoring wells MW1-MW4, November 2004 to November 2008.....	5-11
5.2	Carbon tetrachloride concentrations at extraction well GWEX1, November 2004 to November 2008.....	5-12
5.3	Carbon tetrachloride concentrations at extraction well GWEX2, November 2004 to November 2008.....	5-13
5.4	Carbon tetrachloride concentrations at extraction well GWEX3, November 2004 to November 2008.....	5-14
5.5	Carbon tetrachloride concentrations at extraction well GWEX4, November 2004 to November 2008.....	5-15
6.1	Location proposed by the Nebraska Game and Parks Commission for the surveying of topographic elevations and the installation of permanent water level gauging staffs at the North Lake Basin Wildlife Management Area.....	6-4

### Tables

2.1	Summary of construction details for GWEX wells at Utica.....	2-2
4.1	GWEX operation and groundwater production data in December 2007-November 2008.....	4-3
4.2	Comparison of actual well production rates and target rates.....	4-4
5.1	Analytical results for carbon tetrachloride in untreated groundwater samples and treated effluent samples in December 2007-November 2008.....	5-6
5.2	Values for pH in untreated groundwater samples and treated effluent samples in December 2007-November 2008.....	5-7
5.3	Estimation of carbon tetrachloride removed from the Utica aquifer in December 2007-November 2008.....	5-8
5.4	Well construction data and analytical results for carbon tetrachloride in groundwater samples from the permanent monitoring wells.....	5-9

**Tables (cont.)**

5.5	Comparison of inorganic geochemical results for untreated groundwater samples and treated effluent samples.....	5-10
6.1	Summary of operating and maintenance costs for the Utica restoration project .....	6-3
7.1	Summary of performance of the groundwater restoration systems at Utica.....	7-3

## Notation

BGL	below ground level
CCC	Commodity Credit Corporation
°F	degree(s) Fahrenheit
ft	foot (feet)
gal	gallon(s)
gpm	gallon(s) per minute
GWEX	groundwater extraction
hr	hour(s)
in.	inch(es)
kg	kilogram(s)
L	liter(s)
µg/L	microgram(s) per liter
mph	mile(s) per hour
mg/L	milligram(s) per liter
MW	monitoring well
NDEQ	Nebraska Department of Environmental Quality
NGPC	Nebraska Game and Parks Commission
NPDES	National Pollutant Discharge Elimination System
USDA	U.S. Department of Agriculture
VOC	volatile organic compound

## **Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2007-November 2008**

### **1 Introduction**

This document summarizes the performance of the groundwater restoration systems installed by the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) at the former CCC/USDA grain storage facility in Utica, Nebraska, during the fourth year of system operation, from December 1, 2007, until November 30, 2008. Performance in earlier years was reported previously (Argonne 2005, 2006, 2008).

In the project at Utica, the CCC/USDA is cooperating with multiple state and federal agencies to remove carbon tetrachloride contamination from a shallow aquifer underlying the town and to provide supplemental treated groundwater for use in the restoration of a nearby wetlands area. Argonne National Laboratory assisted the CCC/USDA by providing technical oversight for the aquifer restoration effort and facilities during this review period.

This document presents overviews of the aquifer restoration facilities (Section 2) and system operations (Section 3). The report then describes groundwater production results (Section 4); groundwater treatment results (Section 5); and associated maintenance, system modifications, and costs during the review period (Section 6). Section 7 summarizes the present year of operation.

## **2 Overview of the Aquifer Restoration Facilities at Utica**

The principal components of the groundwater restoration systems at Utica are shown in Figure 2.1. The facilities consist of two main operating units, as described below. The facilities include four groundwater extraction (GWEX) wells. Table 2.1 summarizes construction details for these wells.

### **2.1 Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units**

Extraction wells GWEX1-GWEX3, located in the northern portion of the town, are used to extract contaminated groundwater from the upgradient portion of the contaminant plume. These wells are linked by a distribution system that selectively carries untreated groundwater to either of two discharge points in the northern and southern subbasins of the North Lake Basin Wildlife Management Area (Figure 2.1). At each discharge point, the water is treated to remove carbon tetrachloride by using a custom spray irrigation treatment unit (Figure 2.2). The three extraction wells are operated simultaneously to maintain a critical operating pressure at each treatment unit.

Wells GWEX1-GWEX3 are operated intermittently during the year, subject to local weather conditions and in consultation with the Nebraska Game and Parks Commission (NGPC). The NGPC owns most of the property occupied by the wetlands and has administrative and technical responsibility for management of the wildlife area.

### **2.2 Well GWEX4 and the Conventional Air Stripper**

Extraction well GWEX4 is located near the downgradient toe of the carbon tetrachloride plume and is operated continuously as a containment well. Groundwater produced from GWEX4 is treated by using a conventional (shallow-tray) air stripping technique, and the effluent is discharged to the surface for reinfiltration into the shallow Utica aquifer.

### **2.3 Monitoring Well Network**

A network of seven permanent monitoring points has been established at Utica (Figure 2.1). Wells SB48, SB71, and SB72 were constructed during the early phases of the

investigations at Utica. These wells were intended primarily for the measurement of groundwater levels; they do not penetrate the more contaminated zones of the groundwater column identified in detailed vertical-profile sampling (Argonne 2000). To improve monitoring coverage, additional wells MW1-MW4 were installed at strategic locations along the plume migration pathway in August 2005.

TABLE 2.1 Summary of construction details for GWEX wells at Utica.

Well	Depth (ft BGL)			Casing Diameter (in.)
	Depth	Screen Interval	Gravel Pack Interval	
GWEX1	132	106-126	97-132	8
GWEX2	148	110-145	106-148	8
GWEX3	146	105-140	101-146	8
GWEX4	150	115-145	110-150	6

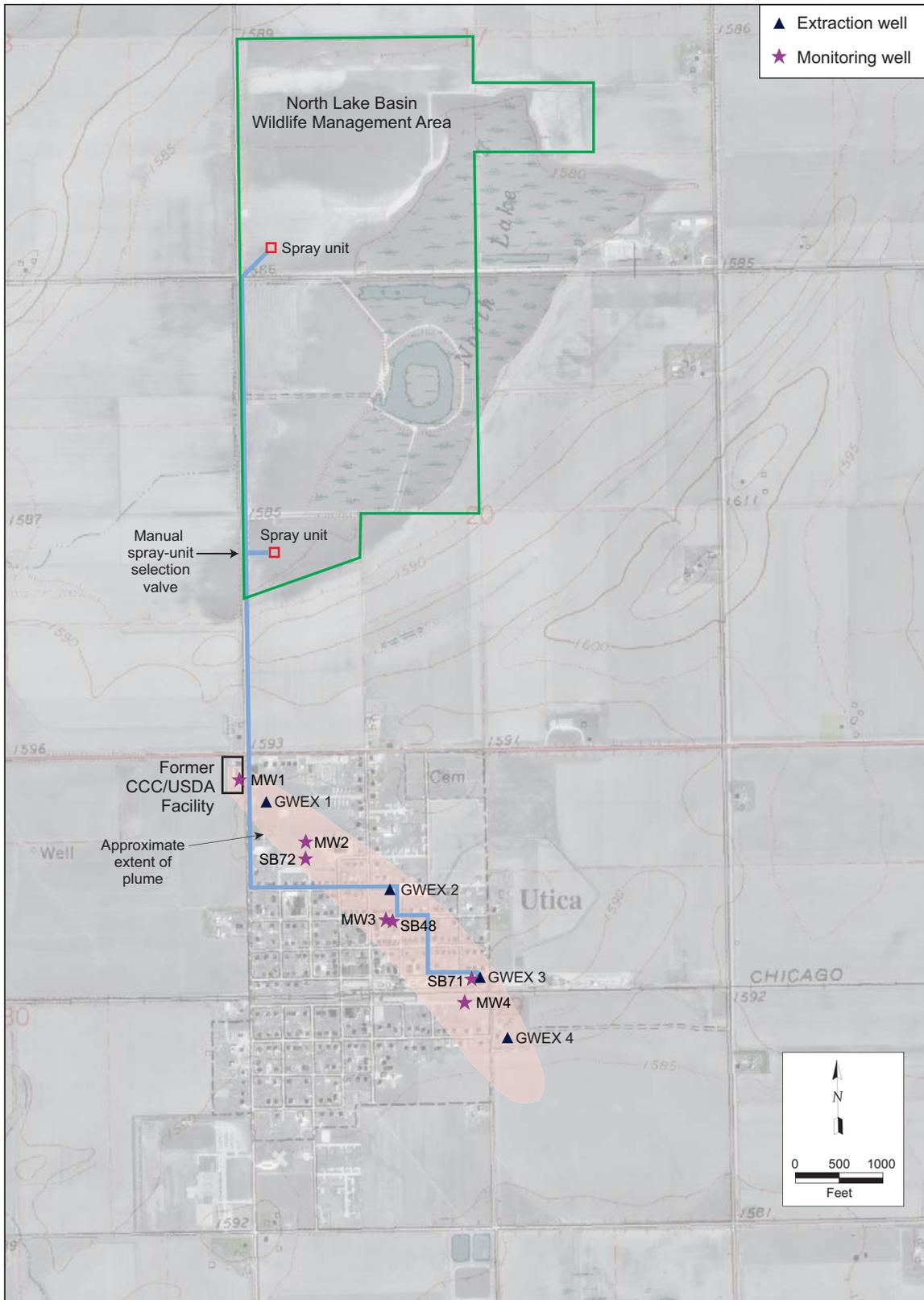


FIGURE 2.1 Locations of the restoration facilities, contaminant plume, and permanent monitoring wells at Utica.



FIGURE 2.2 Spray irrigation unit in operation at Utica.

### **3 Overview of System Operations**

The groundwater restoration program at Utica is conducted in accordance with a National Pollutant Discharge Elimination System (NPDES) permit (No. NE0137456) granted by the State of Nebraska, Department of Environmental Quality (NDEQ). As part of the compliance requirements for this permit, the Utica treatment operations were reviewed by the NDEQ on September 29, 2008. The review included an inspection of the on-site remedial facilities by an NDEQ representative, an evaluation of Argonne operation and maintenance procedures for the facilities, and a review of permit-related records. The NDEQ indicated that a brief report of the inspection would be prepared and provided to the CCC/USDA (as the designated permittee). Argonne representatives were verbally informed, however, that all elements of the Utica operations were found to be satisfactory and in compliance with the NPDES requirements.

#### **3.1 Operation of Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units**

In early March 2008, during a routine attempt to restart GWEX1-GWEX3 after a period of cold weather, flow rates from GWEX1 were observed to be lower than normal. Internal water leakage through the steel riser pipe in the well casing was discovered to have resulted from severe corrosion (Figures 3.1 and 3.2). No other damage to the well, pump, or associated control equipment was identified. The damaged riser pipe was replaced with 2-in.-diameter polyvinyl chloride tubing, and the well was returned to service.

Wells GWEX1-GWEX3 and the spray irrigation treatment units operated intermittently, under automated control, during only 4 of the 12 months in the current review period (December 2007-November 2008). The daily operation of the spray treatment units is governed primarily by weather conditions. To ensure effective removal of carbon tetrachloride and to prevent excessive drift of the spray discharge, a minimum air temperature of 40°F and sustained winds of less than 20 mph are required for operation. The extraction wells and treatment units did not operate in December 2007-March 2008, because weather conditions did not meet these criteria. Treated groundwater from the spray irrigation systems was selectively routed to the south subbasin in April-June 2008 and to the north subbasin in August 2008. During much of the summer and fall of 2008, frequent heavy rains resulted in persistent high surface water levels in the wetlands, precluding the addition of treated groundwater. In response to concerns expressed by local property owners regarding flooding of adjacent private croplands and at the request of the NGPC, operation of the spray irrigation units was discontinued in August 2008 for the remainder of the review period.

### **3.2 Operation of Well GWEX4 and the Conventional Air Stripper**

Well GWEX4 and the associated air stripper were operated during all 12 months of the review period.

In late July and again in early October, unexpected shutdowns of GWEX4 and the air stripper occurred. No definitive cause for the shutdowns could be established; however, local power outages might have occurred in association with storms during these periods. (The well pump and stripping unit do not automatically restart after a utilities failure.) No faults were identified with the well, pumping equipment, or treatment equipment, and in each case the system operated normally after being manually restarted.



FIGURE 3.1 Servicing of extraction well GWEX1, March 2008.



FIGURE 3.2 Corrosion and perforation identified in the steel riser pipe of well GWEX1, March 2008.

## 4 Groundwater Production Results

The volumes of groundwater extracted from the Utica aquifer, treated, and discharged during the current review period are summarized in Table 4.1. Performance during the four years of system operation to date is summarized in Section 7.

### 4.1 Production by Wells GWEX1-GWEX3

Wells GWEX1-GWEX3 are equipped with electronically controlled pump drive units linked to digital flow meters that automatically and continuously adjust the flow from each well to maintain user-specified pumping rates. During this review period, the programmed flow rates for these wells were as follows:

- GWEX1, 50 gpm
- GWEX2, 200 gpm
- GWEX3, 125 gpm

The selected rates were achieved, within  $\pm 1$  gpm, throughout the review period (Table 4.2).

GWEX1-GWEX3 were pumped for approximately 1,141 hr during the review period, and they discharged approximately 25.6 million gallons (79 acre-feet) of treated water to the North Lake Basin wetlands. This represents a dramatic decrease (by approximately 65 million gallons, or 72%) relative to the previous reporting period. Operation of the spray irrigation treatment systems was severely limited during the current review period, because of (1) persistent cold weather in December 2007 and early spring 2008 and (2) unusually high rainfall levels in the summer and fall of 2008, which resulted in natural flooding of the wetlands basins and surrounding croplands. The treated groundwater was discharged primarily to the southern wetlands subbasin, at the request of the NGPC.

## **4.2 Production by Well GWEX4**

Measured groundwater pumping rates (determined from an inline flow meter) at GWEX4 remained fairly stable, generally ranging from approximately 56 gpm to 68 gpm, throughout the review period. An initial low rate of 46 gpm occurred briefly, immediately after operation of the well was resumed following the shutdown period in late July-early August 2008 (Section 3.2). A minor adjustment to the electronic pump control unit in September returned GWEX4 to a targeted flow rate of 60-62 gpm. The volume of groundwater pumped in any one complete month (Table 4.1) ranged from about 1.4 million gallons to 2.9 million gallons. Approximately 29.6 million gallons (90.7 acre-feet) of groundwater was treated and discharged during the review period, at a net average pumping rate of 62.3 gpm.

TABLE 4.1 GWEX operation and groundwater production data in December 2007–November 2008.

Month	Wells GWEX1-GWEX3				Volume Discharged to Wetlands <sup>c</sup> (gal)		GWEX4	
	Groundwater Produced <sup>a</sup> (gal)			Operating Time <sup>b</sup> (hr)	North	South	Groundwater Produced (gal)	Operating Time (days)
	GWEX1	GWEX2	GWEX3					
Dec 07	. <sup>d</sup>	-	-	-	-	-	2,775,910	31
Jan 08	-	-	-	-	-	-	2,786,796	31
Feb 08	-	-	-	-	-	-	2,617,548	29
Mar 08	-	-	-	-	-	-	2,824,244	31
Apr 08	1,088,900	4,327,800	2,716,800	361.5	-	8,133,500	2,854,452	30
May 08	1,588,300	6,330,000	3,968,200	528.3	-	11,886,500	2,922,605	31
Jun 08	423,600	1,689,800	1,058,600	141.0	-	3,172,000	2,914,761	30
Jul 08	-	-	-	-	-	-	1,425,869	15
Aug 08	332,300	1,321,700	829,200	110.4	2,483,200	-	1,460,265	20
Sep 08	-	-	-	-	-	-	2,587,160	30
Oct 08	-	-	-	-	-	-	1,810,492	21
Nov 08	-	-	-	-	-	-	2,573,372	30
Column Totals	3,433,100	13,669,300	8,572,800	1,141	2,483,200	23,192,000	29,553,474	329

<sup>a</sup> Combined total production from wells GWEX1-GWEX4: 55,228,674 gal.

<sup>b</sup> Wells GWEX1-GWEX3 operate simultaneously.

<sup>c</sup> Total production to wetlands: 25,675,200 gal.

<sup>d</sup> Unit not in operation.

TABLE 4.2 Comparison of  
actual well production rates  
and target rates.

---

Well	Pumping Rate (gpm)	
	Target	Actual (Net Average)
GWEX1	50	50.1
GWEX2	200	199.7
GWEX3	125	125.2
GWEX4	60-65	62.4

---

## 5 Groundwater Treatment Results

Treated groundwater at Utica is discharged under NPDES permit No. NE0137456, issued by the NDEQ on October 1, 2004.

To comply with the NPDES permit, samples of treated groundwater are collected monthly

- At the outlet of the air stripping unit at GWEX4 and
- From the spray discharge at each of the irrigation treatment units (during months of operation).

The samples are analyzed to determine the residual concentrations of carbon tetrachloride in the treated groundwater and the pH of the effluent. The results of these analyses are reported to the NDEQ quarterly.

The discharges of treated groundwater at Utica are considered by the NDEQ to contribute to the surface waters of the state. On this basis, NDEQ has specified the following compliance limits for the outfall from each treatment unit:

- A target maximum residual carbon tetrachloride concentration of 44.2 µg/L
- An acceptable pH range of 6.5 to 9.0

In conjunction with the compliance sampling, Argonne collects monthly samples of the untreated groundwater from each extraction well. The samples are analyzed for volatile organic compounds (VOCs) to enable estimation of the following:

- Carbon tetrachloride removal efficiencies for the treatment units
- Quantities of carbon tetrachloride removed from the contaminated aquifer

The results of the sampling and analyses during the review period are summarized in Tables 5.1 and 5.2.

## 5.1 Results for Wells GWEX1-GWEX3, with Treatment by Spray Irrigation

The concentrations of carbon tetrachloride found in the untreated groundwater from extraction wells GWEX2 and GWEX3 were highest upon initial startup of the wells in April 2008, then declined during relatively continuous pumping in May and June (Table 5.1). The carbon tetrachloride concentrations at both wells appeared to rebound slightly when pumping was resumed in August. Carbon tetrachloride concentrations at GWEX2 ranged from 42 µg/L to 73 µg/L, while at GWEX3 the levels ranged from 36 µg/L to 130 µg/L.

Observed carbon tetrachloride levels at upgradient extraction well GWEX1 increased slowly during the April-June 2008 pumping period and showed little further change when pumping resumed in August. The observed concentrations at GWEX1 showed no apparent correlation to the concentrations observed at GWEX2 and GWEX3. Carbon tetrachloride concentrations at GWEX1 ranged from 28 µg/L in April to 40-50 µg/L in May, June, and August 2008.

The groundwater produced from wells GWEX1-GWEX3 is combined into a single stream for conveyance to the wetlands via a common pipeline. This combined flow is also sampled monthly as an indicator of the weighted average concentration of carbon tetrachloride in the untreated groundwater supplied to the spray irrigation treatment units. The measured concentrations in the combined flow varied from 43 µg/L to 89 µg/L during the current monitoring period. The temporal variations in concentration observed in the combined flow stream generally mirrored those observed at wells GWEX2 and GWEX3, which together contribute approximately 87% of the total discharge from the extraction well system.

Treated groundwater sprayed from the irrigation units is collected for analysis at the following four locations at the treatment site during each sampling event:

- Beneath the center point of the “west” irrigation span
- Beneath the center point of the “center” irrigation span
- Beneath the center point of the “east” irrigation span

- At a fourth location visually chosen to reflect the estimated site of maximum spray outfall (“max” value; position varying from month to month; based on prevailing wind and spray conditions at the time of sampling)

The results summarized in Table 5.1 show that the concentrations of all spray samples collected during the review period were below the maximum contaminant level of 5.0 µg/L promulgated by the U.S. Environmental Protection Agency for carbon tetrachloride in drinking water. The *maximum* carbon tetrachloride level identified for a single sample of spray discharged from the irrigation treatment units was 4.0 µg/L. The *average* concentration of carbon tetrachloride in the treated groundwater discharged to the wetlands was 1.13 µg/L. The concentrations of carbon tetrachloride in all spray samples were below the maximum target concentration (44.2 µg/L) allowed under the NPDES permit, by roughly an order of magnitude.

The results of the groundwater and spray sample analyses suggest the following *minimum carbon tetrachloride removal efficiency values* for the spray irrigation treatment process:

- More than 92% (based on data for individual samples)
- Approximately 98% (based on the average concentration delivered to the wetlands during the review period)

The results of pH measurements recorded for samples of the treated spray discharge are presented in Table 5.2. In all cases, the observed pH levels (7.88 to 8.51) were within the acceptable range (6.5 to 9.0) specified under the NPDES permit.

## **5.2 Results for Well GWEX4, with Treatment by Air Stripping**

Carbon tetrachloride concentrations in the untreated groundwater produced by GWEX4 (Table 5.1) were relatively stable (13 µg/L to 24 µg/L) in December 2007-November 2008. Carbon tetrachloride was not detected in the effluent from the air stripping unit throughout the review period, indicating a carbon tetrachloride removal efficiency of > 99% for this process. Measured pH levels in all samples of the air stripper effluent (7.48 to 8.40; Table 5.2) were within the acceptable range (6.5 to 9.0) specified under the NPDES permit.

### **5.3 Estimated Removal of Carbon Tetrachloride from the Utica Aquifer**

The groundwater production and carbon tetrachloride concentration data presented in Tables 4.1 and 5.1, respectively, can be used to estimate the total quantity of carbon tetrachloride extracted by wells GWEX1-GWEX4 from December 1, 2007, to November 30, 2008. The results of these calculations, summarized in Table 5.3, indicate that approximately 8 kg (1.3 gal) of carbon tetrachloride was removed from the Utica aquifer during the present review period. In the previous period (December 2006-November 2007), approximately 25 kg (4.1 gal) of carbon tetrachloride was removed.

The significantly lower quantity of carbon tetrachloride recovered in December 2007-November 2008 than in the previous period is a direct consequence of the very limited operation of GWEX1-GWEX3 and the spray treatment units that was possible during most of the current review period (Section 3.1). The data presented in Table 5.1 indicate that the carbon tetrachloride concentrations in the untreated groundwater at GWEX1-GWEX3 were little changed from the previous review period, while the untreated concentrations at GWEX1 decreased slightly from those of the previous review period. No decrease in the volumetric throughput (when the system was operating) or contaminant removal efficiency of the groundwater treatment systems was observed during the current period.

### **5.4 Sampling of Monitoring Wells and Apparent Carbon Tetrachloride Concentration Trends in the Utica Groundwater**

Table 5.4 summarizes construction data for the monitoring wells, as well as the results of groundwater sampling and analyses for VOCs during the current review period. Complete monitoring data for wells MW1-MW4, since sampling at these points began in September 2005, are depicted in Figure 5.1. Figures 5.2-5.5 summarize the carbon tetrachloride concentrations measured at GWEX1-GWEX4, respectively, since the routine operation and sampling of these wells began in November 2004.

Except for MW1, carbon tetrachloride concentrations at all of the monitoring wells (Figure 5.1) have been relatively stable and have shown no persistent rising or falling trends. Carbon tetrachloride concentrations at GWEX2-GWEX4 (Figures 5.3-5.5) appear to be declining slowly, although short-term variability is apparent along the generally decreasing trend for each well. In contrast, carbon tetrachloride concentrations at GWEX1 (Figure 5.2) do not show the same type of generally decreasing trend.

Wells MW1 and GWEX1 are located, respectively, on and near the former CCC/USDA facility property (Figure 2.1). The observed carbon tetrachloride concentrations at GWEX1 have been highly variable (Figure 5.2), but they appear to reflect a trend of gradual increase, through 2007, from the initial measurements in 2004. Well GWEX1 was sampled for VOCs only four times during the current review period, because of limited spray treatment system operation (Section 3.1); however, the recent data suggest a decrease in the concentrations at this well relative to the preceding two (December 2005-November 2006 and December 2006-November 2007) monitoring periods. Carbon tetrachloride levels at well MW1 (Figure 5.1) have consistently been greater than those at the downgradient monitoring wells (MW2-MW4, SB48, SB71, SB72; Figure 2.1), increasing to a maximum of 542 µg/L in June-October 2007. Since October 2007, the observed carbon tetrachloride concentrations at MW1 have consistently decreased.

Together, the MW1 and GWEX1 data might reflect an apparently transient, localized contribution of carbon tetrachloride to the upgradient shallow groundwater, from residual contamination in the soils beneath the former CCC/USDA facility. Further monitoring will be required to evaluate this hypothesis; however, the stable/decreasing contaminant levels observed at all of the downgradient sampling locations suggest that GWEX1 is presently operating effectively as an upgradient capture well.

## 5.5 Evaluation of Groundwater Inorganic Geochemistry

In accord with the approved *Monitoring Plan* for Utica (Argonne 2004), samples of the untreated groundwater from individual extraction wells GWEX1-GWEX4 and the (treated) effluent from the air stripper at GWEX4 were collected in October 2008 and submitted for inorganic geochemical analyses. Because the spray irrigation treatment units could not be operated at this time, no sample was collected for inorganic analyses from the combined flows of GWEX1-GWEX3. The results of the analyses are in Table 5.5, together with equivalent data obtained for these sampling locations in the two previous review periods. The October 2008 results indicate no substantial changes in the geochemistry of the groundwater produced by the extraction wells, treated, and discharged to the surface near Utica and to the North Lake Basin wetlands during the current review period.

TABLE 5.1 Analytical results for carbon tetrachloride in untreated groundwater samples and treated effluent samples in December 2007–November 2008.

Month	Carbon Tetrachloride Concentration (µg/L)												GWEX4 Untreated	Stripper Effluent
	GWEX1-GWEX3 Untreated				North Spray Unit Effluent				South Spray Unit Effluent					
	GWEX1	GWEX2	GWEX3	Mixed <sup>a</sup>	West <sup>b</sup>	Center <sup>b</sup>	East <sup>b</sup>	Max <sup>c</sup>	West <sup>b</sup>	Center <sup>b</sup>	East <sup>b</sup>	Max <sup>c</sup>		
Dec 07	– <sup>d</sup>	–	–	–	–	–	–	–	–	–	–	–	24	ND <sup>e</sup>
Jan 08	–	–	–	–	–	–	–	–	–	–	–	–	19	ND
Feb 08	–	–	–	–	–	–	–	–	–	–	–	–	16	ND
Mar 08	–	–	–	–	–	–	–	–	–	–	–	–	18	ND
Apr 08	28-28 <sup>f</sup>	73	130	89	–	–	–	–	0.2 J <sup>g</sup>	1.4-1.9	2.1	0.7 J-1.0	20-22	ND
May 08	40	50-51	45	50	–	–	–	–	0.7 J	0.7 J	0.4 J	0.4 J	18	ND
Jun 08	50	42	36	43	–	–	–	–	0.5 J	0.3 J	0.3 J	ND	15	ND
Jul 08	–	–	–	–	–	–	–	–	–	–	–	–	13	ND
Aug 08	45-48	62	72	51	3.8	4.0	ND	0.6 J	–	–	–	–	22	ND
Sep 08	–	–	–	–	–	–	–	–	–	–	–	–	18	ND
Oct 08	–	–	–	–	–	–	–	–	–	–	–	–	13	ND
Nov 08	–	–	–	–	–	–	–	–	–	–	–	–	15	ND

<sup>a</sup> Analytical results for samples from the combined flows of GWEX1–GWEX3.

<sup>b</sup> Samples of spray collected below the center point of the respective irrigation span.

<sup>c</sup> Samples of spray collected at the estimated location of maximum spray outfall.

<sup>d</sup> Unit not in operation.

<sup>e</sup> ND, not detected at a method detection limit of 0.1 µg/L.

<sup>f</sup> Ranges of values represent both primary samples and quality control replicates and duplicates.

<sup>g</sup> Qualifier J indicates an estimated concentration below the quantitation limit of 1.0 µg/L for the purge-and-trap method.

TABLE 5.2 Values for pH in untreated groundwater samples and treated effluent samples in December 2007-November 2008.

Month	pH							
	GWEX1-GWEX3 Untreated				North Spray Unit <sup>b</sup>	South Spray Unit <sup>b</sup>	GWEX4 Untreated	Stripper Effluent
	GWEX1	GWEX2	GWEX3	Mixed <sup>a</sup>				
Dec 07	— <sup>c</sup>	—	—	—	—	—	6.93-6.94	8.34-8.35
Jan 08	—	—	—	—	—	—	6.55-6.62	8.05-8.06
Feb 08	—	—	—	—	—	—	7.29-7.31	8.32-8.34
Mar 08	—	—	—	—	—	—	7.18-7.21	8.33-8.40
Apr 08	6.67-6.69	6.60-6.62	6.56-6.57	6.62-6.64	—	7.88-7.94	6.40-6.44	7.87-7.90
May 08	7.29-7.36	7.16-7.21	7.15-7.16	7.14-7.17	—	8.26-8.30	7.02-7.09	8.08-8.25
Jun 08	7.37-7.48	7.20-7.22	7.03-7.04	7.06-7.09	—	8.34-8.51	6.96-6.99	8.08-8.27
Jul 08	—	—	—	—	—	—	7.06-7.49	7.48-7.80
Aug 08	6.79-6.87	6.91-7.04	6.77-6.81	6.82-6.83	8.14-8.41	—	7.01-7.24	7.77-7.99
Sep 08	—	—	—	—	—	—	7.05-7.09	7.99-8.01
Oct 08	—	—	—	—	—	—	6.99-7.09	7.72-7.97
Nov 08	—	—	—	—	—	—	6.81-6.89	7.71-7.83

<sup>a</sup> Ranges of values for multiple measurements of the combined flows of GWEX1-GWEX3.

<sup>b</sup> Ranges of values for spray samples collected at multiple locations at the discharge site.

<sup>c</sup> Unit not in operation.

TABLE 5.3 Estimation of carbon tetrachloride removed from the Utica aquifer in December 2007-  
November 2008.<sup>a</sup>

Month	GWEX1-GWEX3				GWEX4			
	Groundwater Extracted		Carbon Tetrachloride		Groundwater Extracted		Carbon Tetrachloride	
	(gal)	(L)	Concentration <sup>b</sup> (µg/L)	Calculated Amount Removed (kg)	(gal)	(L)	Concentration (µg/L)	Calculated Amount Removed (kg)
Dec 07	— <sup>c</sup>	—	—	—	2775910	10509595	24	0.3
Jan 08	—	—	—	—	2786796	10550810	19	0.2
Feb 08	—	—	—	—	2617548	9910037	16	0.2
Mar 08	—	—	—	—	2824244	10692588	18	0.2
Apr 08	8133500	30793431	89	2.7	2854452	10806955	21 <sup>d</sup>	0.2
May 08	11886500	45002289	50	2.3	2922605	11064982.5	18	0.2
Jun 08	3172000	12009192	43	0.5	2914761	11035285	15	0.2
Jul 08	—	—	—	—	1425869	5398340	13	0.1
Aug 08	2483200	9401395.2	51	0.5	1460265	5528563	22	0.1
Sep 08	—	—	—	—	2587160	9794988	18	0.2
Oct 08	—	—	—	—	1810492	6854523	13	0.1
Nov 08	—	—	—	—	2573372	9742786	15	0.1
TOTAL				6.0				2.0

<sup>a</sup> Total carbon tetrachloride removed from the aquifer: 8.0 kg.

<sup>b</sup> Concentration in untreated samples of the combined flow from wells GWEX1-GWEX3.

<sup>c</sup> Unit not in operation.

<sup>d</sup> Average of the range of values shown in Table 5.1.

TABLE 5.4 Well construction data and analytical results for carbon tetrachloride in groundwater samples from the permanent monitoring wells.

Well	Depth (ft BGL)		Carbon Tetrachloride ( $\mu\text{g/L}$ )			
	Total	Screened Interval	Feb 08	May 08	Aug 08	Nov 08
SB48	98.5	83.5-93.5	0.1 J <sup>a</sup>	ND <sup>b</sup>	ND	ND
SB71	94.2	84-94	0.6 J	ND	ND	ND
SB72	122.3	82.6-112.6	1.0	0.8 J	0.8 J	1.5
MW1	105	85-100	218	155	148	100
MW2	115	90-110	9.6	11	6.6	12
MW3	125	100-120	84	35	64	51
MW4	125	100-120	3.6	3.4	4.7	3.7-4.0 <sup>c</sup>

<sup>a</sup> Qualifier J indicates an estimated concentration below the quantitation limit of 1.0  $\mu\text{g/L}$  for the purge-and-trap method.

<sup>b</sup> ND, not detected at a method detection limit of 0.1  $\mu\text{g/L}$ .

<sup>c</sup> Ranges of values represent both primary samples and quality control replicates and duplicates.

TABLE 5.5 Comparison of inorganic geochemical results for untreated groundwater samples and treated effluent samples.

Analyte	Concentration (mg/L)																	
	GWEX1			GWEX2			GWEX3			GWEX1-GWEX3			GWEX4 Untreated			GWEX4 Effluent		
	Oct 2006	Oct 2007	Oct 2008	Oct 2006	Oct 2007	Oct 2008	Oct 2006	Oct 2007	Oct 2008	Oct 2006	Oct 2007	Oct 2008	Oct 2006	Oct 2007	Oct 2008	Oct 2006	Oct 2007	Oct 2008
Total Alkalinity	266	— <sup>a</sup>	—	275	—	—	255	—	—	262	—	—	287	—	—	287	—	—
Aluminum	< 0.2 <sup>b</sup>	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	—	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Calcium	84.9	80.4	83.9	87.5	88.5	95.4	89.4	100	99.7	96.9	90.7	—	109	105	110	106	108	110
Chloride	13.2	11 H <sup>c</sup>	13	24.0	20 H	16	24.0	21 H	28	21.9	19 H	—	28.9	24 H	31	29.3	27 H	32
Iron	<0.1	<0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	—	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Magnesium	13.0	13.3	13.2	13.6	15	15.6	13.9	16.9	16.1	15.1	15.3	—	17.0	17.7	17.7	16.5	18	17.8
Manganese	< 0.015 <sup>b</sup>	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	—	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015
Phosphate	0.305	0.180 H	0.40	0.307	0.250 H	0.39	0.299	0.250 H	0.46	0.311	0.210 H	—	0.293	0.250 H	0.42	0.298	0.250 H	0.40
Phosphorus	0.273	0.298	0.307	0.279	0.311	0.291	0.318	0.312	0.258	0.287	0.308	—	0.255	0.283	0.294	0.275	0.292	0.295
Potassium	6.27	5.19	5.38	6.33	5.87	5.83	6.43	6.36	6.48	6.85	5.97	—	7.10	6.29	6.70	6.86	6.4	6.50
Silicon	17.0	13.1	16.9	16.5	16.9	17.2	16.5	17.9	17.9	17.0	18.1	—	17.3	15.9	18.2	16.8	16.0	18.2
Sodium	31.9	31.8	34	34.4	38.2	41.6	35.1	43.7	37.8	38.4 <sup>d</sup>	39.1	—	41.6	44.4	44.6	41	45.1	44.8
Sulfate	23.1	21 H	26	39.1	31 H	38	46.3	40 H	52	39.3	33 H	—	64.9	50 H	55	63.6	54 H	56
Zinc	< 0.02 <sup>b</sup>	0.07 B <sup>e</sup>	0.0395	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	—	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Nitrate (as N)	10.3	9.1 H	18	15.0	12 H	13	19.5	17 H	18	15.5	13 H	—	20.5	16 H	20	20.7	17 H	21
Nitrate-Nitrite N	9.24	—	—	14.7	—	—	17.6	—	—	15.5	—	—	20.8	—	—	20.5	—	—

<sup>a</sup> No analysis.

<sup>b</sup> Analyte not identified at analytical method detection limit indicated.

<sup>c</sup> Qualifier H indicates that the holding time before analysis was exceeded.

<sup>d</sup> Reported incorrectly as 41.6 in the report for operation in December 2006-November 2007 (Argonne 2008).

<sup>e</sup> Qualifier B indicates that the analyte was detected in an associated blank sample.

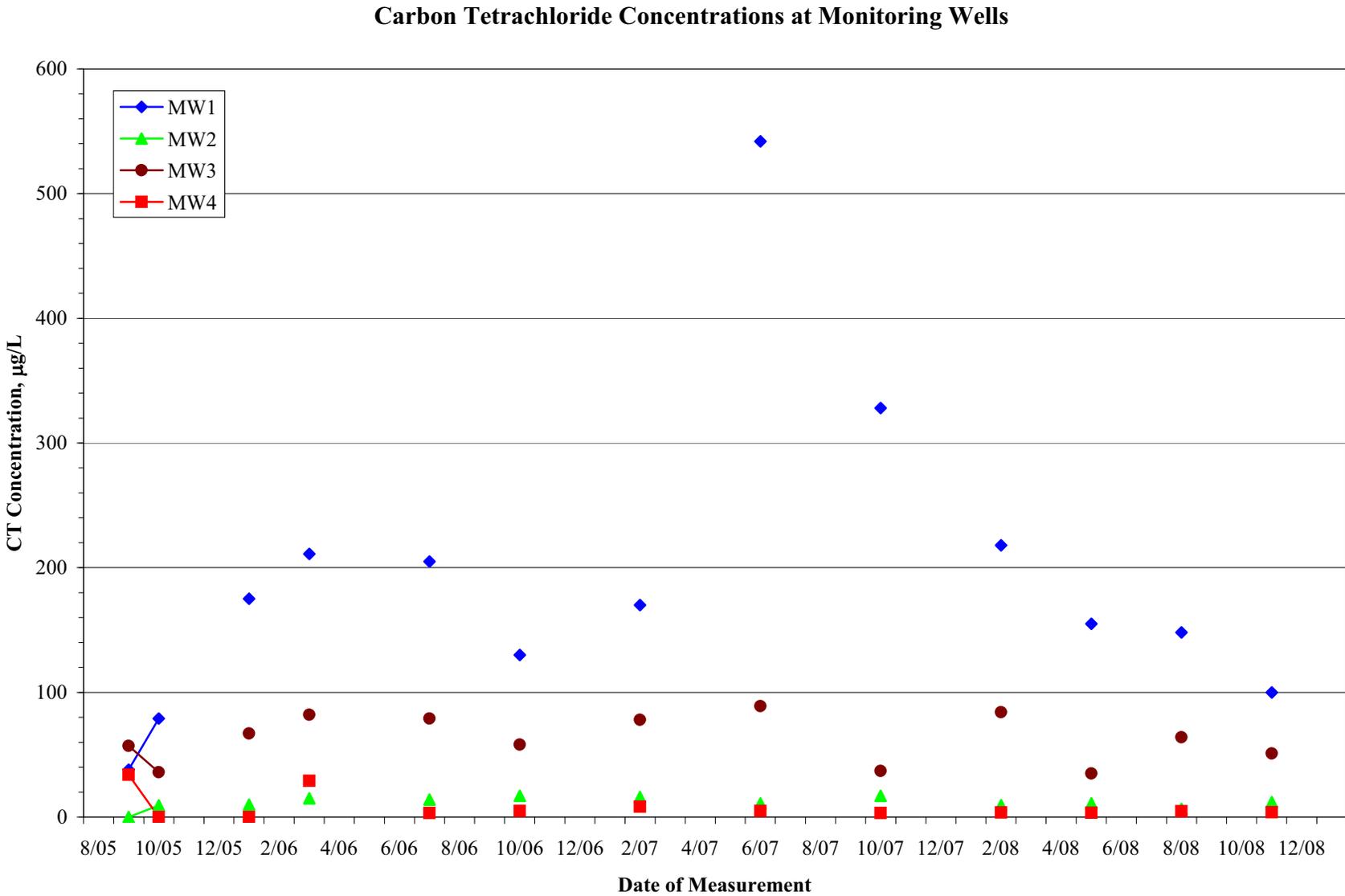


FIGURE 5.1 Carbon tetrachloride concentrations at monitoring wells MW1-MW4, November 2004 to November 2008.

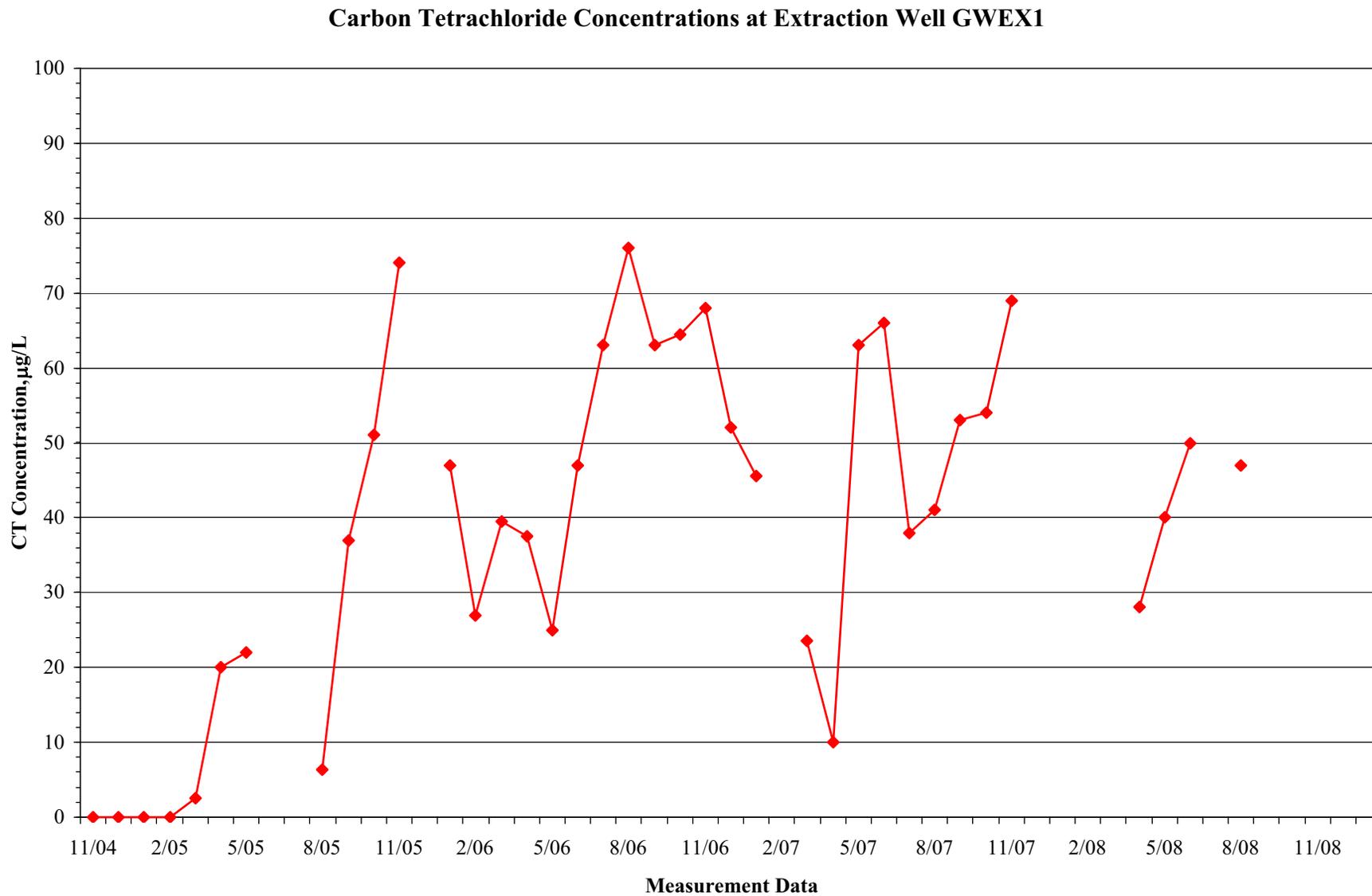


FIGURE 5.2 Carbon tetrachloride concentrations at extraction well GWEX1, November 2004 to November 2008.

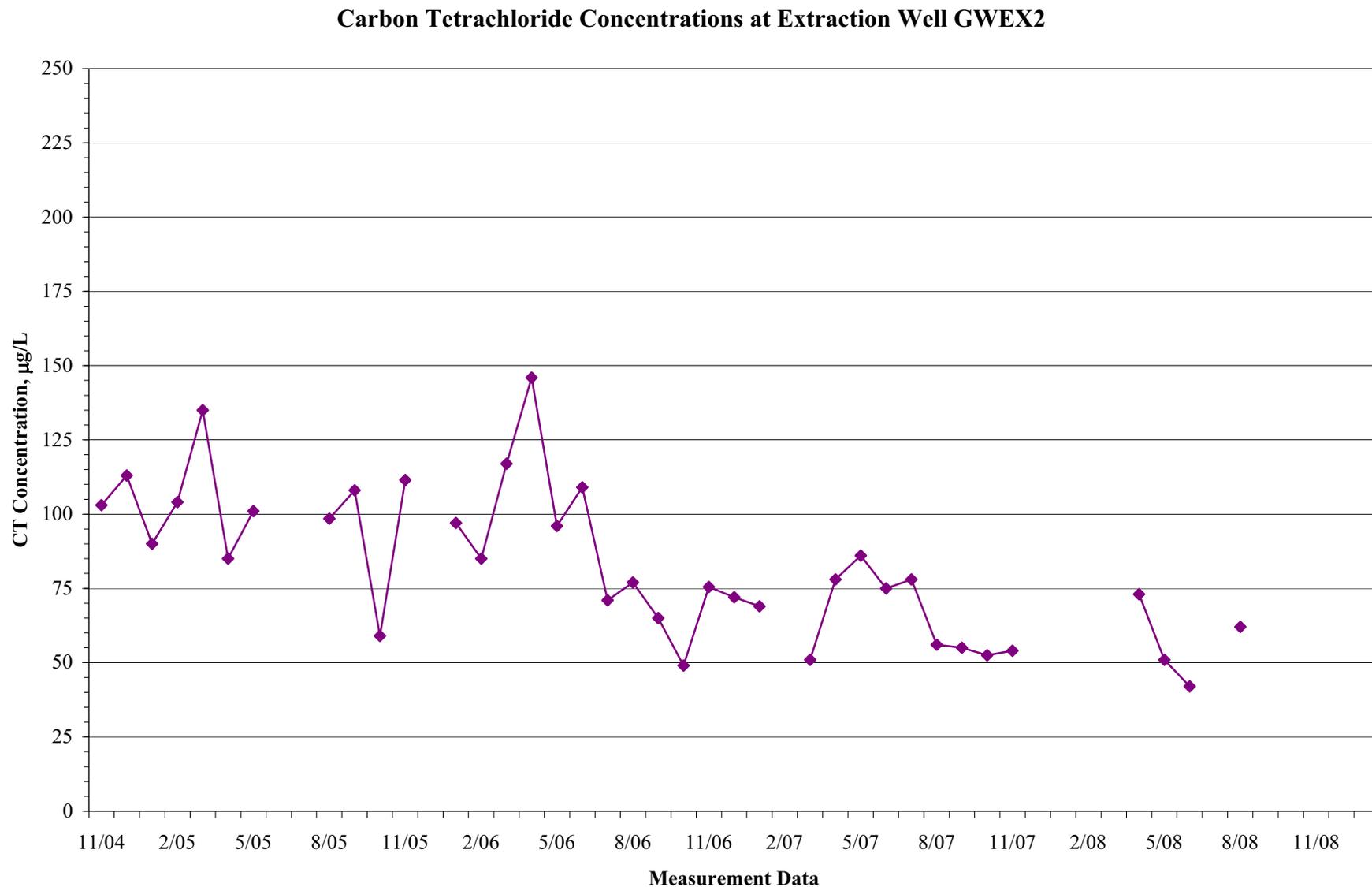


FIGURE 5.3 Carbon tetrachloride concentrations at extraction well GWEX2, November 2004 to November 2008.

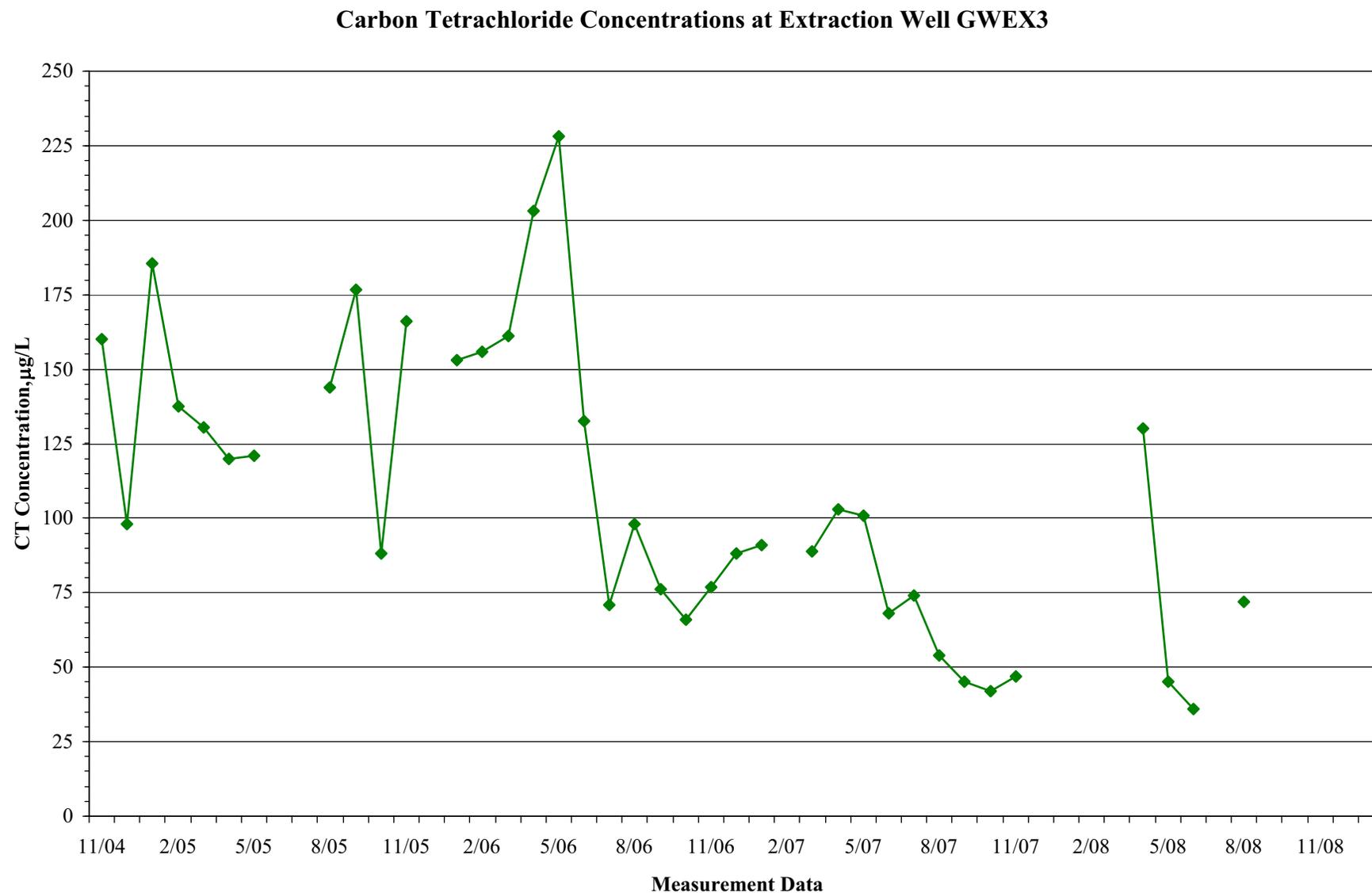


FIGURE 5.4 Carbon tetrachloride concentrations at extraction well GWEX3, November 2004 to November 2008.

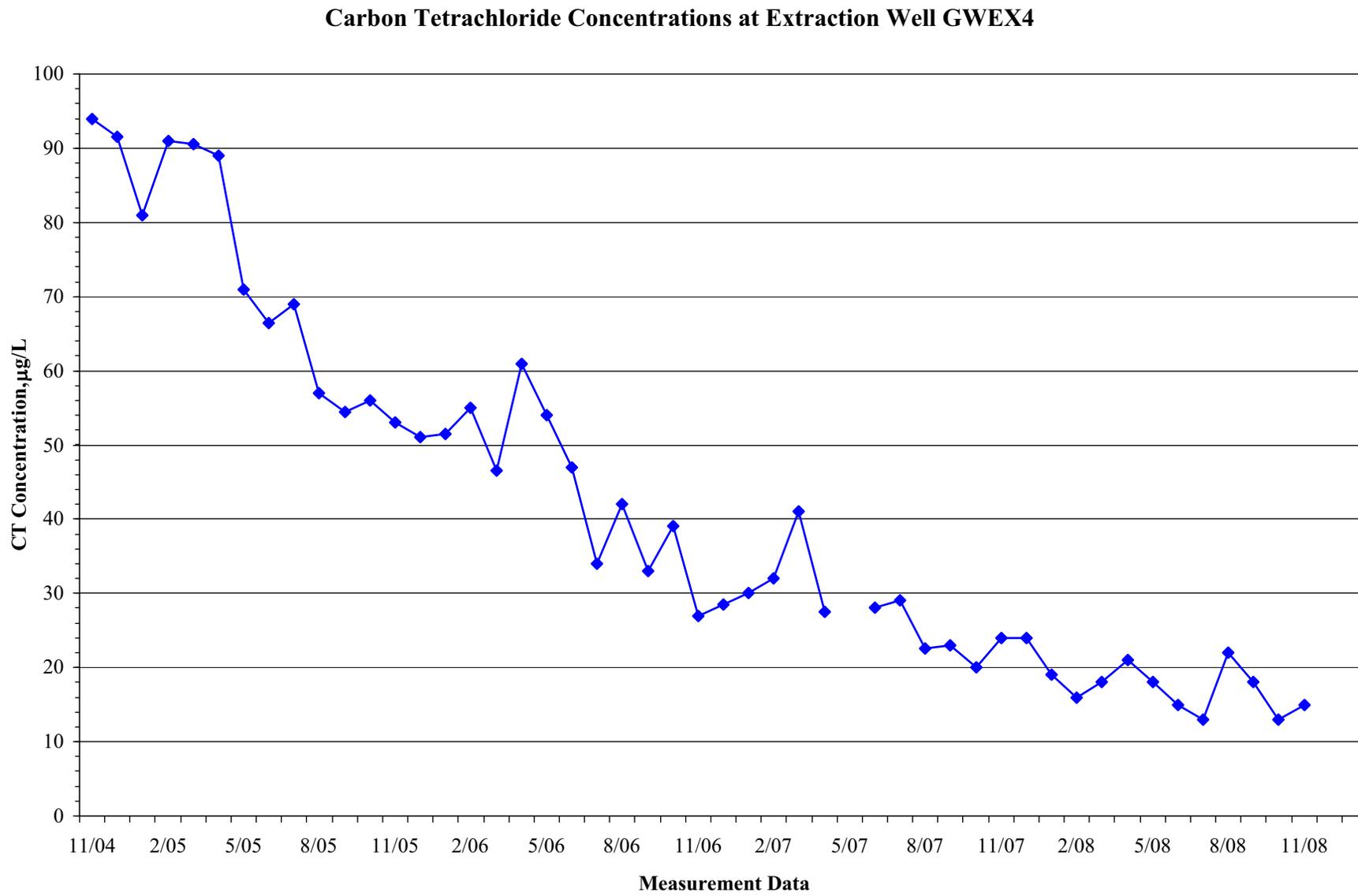


FIGURE 5.5 Carbon tetrachloride concentrations at extraction well GWEX4, November 2004 to November 2008.

## 6 Operation, Maintenance, and System Modifications

### 6.1 Wells GWEX1-GWEX3 and the Spray Irrigation Treatment Units

Maintenance required for extraction wells GWEX1-GWEX3 during the review period was limited to replacement of the original steel riser pipe carrying groundwater from the downhole pump to the surface (pitless) adaptor in well GWEX1, to correct an internal leak caused by corrosion and perforation of the riser pipe (Figures 3.1 and 3.2). No other maintenance was required for the extraction wells during this review period.

Maintenance and repairs for the spray irrigation units and the groundwater delivery system included the following:

- Periodic field inspection of the units and all operating parameters
- Seasonal mowing along the gravel access roads and pads at the north and south spray treatment sites
- Replacement of the pressure sensor (located on one of the irrigation spans) that monitors the spray treatment system discharge pressure at the north spray treatment site

Frequent heavy rainfalls during the current review period resulted in persistent high surface water levels throughout the Utica wetlands, as well as local flooding of several adjacent private farm properties. Because of this flooding, operation of GWEX1-GWEX3 and the spray irrigation treatment units was not possible during much of the summer and fall of 2008. To assist in quantifying the relationship of water levels in the wetlands to the potential for flooding of the surrounding private croplands, the NGPC proposed (1) a topographic survey of selected critical surface “spill point” locations at the boundaries of the NGPC property and (2) the installation of two permanent staff gauges so that the wetlands water levels could be determined readily (Figure 6.1). With the approval of the CCC/USDA, representatives of the NGPC and Argonne met to discuss this proposal, and Argonne obtained preliminary cost estimates for the requested effort; however, no further action was taken during the review period because of logistic (access) concerns expressed by the NGPC during the fall of 2008.

## 6.2 Well GWEX4 and the Air Stripping Unit

Well GWEX4 and the shallow-tray air stripper required no maintenance or repairs during the review period. The well and air stripper were restarted manually after unexpected shutdowns in late July and again in early October 2008, possibly due to storm-related electrical power outages (Section 3.2). In each instance, the well and air stripper functioned normally after being restarted.

Treated groundwater from GWEX4 is discharged to an open ditch directly west of the well and treatment building (Figure 2.1), in keeping with the approved NPDES permit. The ditch serves as part of Utica's storm drainage system, which carries surface flow southward from the town. The ditch borders a county road, as well as adjacent private farm properties. In June 2008, Argonne was approached by representatives of the Utica city council, requesting that the GWEX4 discharge be rerouted, underground, to an exit point farther south of the town to address concerns expressed by the city regarding the present GWEX4 drainage arrangement and the conditions along the ditch. With the approval of the CCC/USDA, Argonne representatives met with the city government to discuss their concerns, and Argonne has investigated possible engineering and cost issues associated with the city's request. As of this reporting, however, no other actions have been taken by Argonne on behalf of the CCC/USDA.

## 6.3 Operating and Maintenance Costs

Operating and maintenance costs for the current review period are summarized in Table 6.1, with previous costs for comparison. The costs for the current period include one-time expenses associated with identification and repair of the corroded riser pipe in well GWEX1.

The total operating and maintenance costs for the Utica project during the current review period (\$168,081) increased by approximately 25% relative to the equivalent costs for December 2006-November 2007 (\$134,056) but were significantly lower than the costs for the preceding two periods of operation (\$282,586 in October 2004-November 2005 and \$270,916 in December 2005-November 2006). The observed costs for the current review period primarily reflect an increase in "routine" operating expenses (up \$29,286 relative to the previous period). The current routine costs include increased support and monitoring efforts associated with the physical location and documentation of the remediation system pipelines and electrical (well control and power) lines at the site, to comply with requests from the Nebraska Diggers Hotline service.

These actions were necessary to ensure that the subsurface CCC/USDA installations at Utica are protected from damage by unrelated construction or digging activities that occur periodically at this site.

TABLE 6.1 Summary of operating and maintenance costs for the Utica restoration project.

Item	Cost (\$)			
	Oct 2004- Nov 2005	Dec 2005- Nov 2006	Dec 2006- Nov 2007	Dec 2007- Nov 2008
<i>Routine Costs</i>				
General				
Management	18,127	17,699	5,544	4,891
Logistics Support	64,145	74,713	10,475	24,959
Remediation				
Monitoring	170,880	110,546	97,164	118,036
Technical Oversight	17,727	5,228	13,537	8,119
SUBTOTAL	270,879	208,186	126,720	156,006
<i>Non-routine Costs</i>				
Monitoring Network				
Establishment	11,707			
Radio Control				
System		5,140		
Irrigation Span				
Repairs		57,591		
Valve Actuator				
Replacement			5,071	
Repair of North				
Spray Pad Control				
Panel			2,265	
GWEX1 Repairs				12,075
SUBTOTAL	11,707	62,731	7,336	12,075
TOTAL	282,586	270,916	134,056	168,081



FIGURE 6.1 Location proposed by the Nebraska Game and Parks Commission for the surveying of topographic elevations and the installation of permanent water level gauging staffs at the North Lake Basin Wildlife Management Area.

## 7 Summary

Historical performance data and costs for the Utica system are summarized in Table 7.1.

A combined total of approximately 55 million gallons of contaminated groundwater was extracted and treated during the operation of the aquifer restoration systems at Utica from December 1, 2007, to November 30, 2008. Approximately 46% of the total volume treated (25.6 million gallons; 79 acre-feet) was used to supplement the natural water entering the North Lake Basin Wildlife Management Area. Discharge of treated groundwater to the wetlands was not possible during much of the current review period, because of inclement weather conditions and persistent natural flooding of the wetlands basins and the surrounding private croplands.

Groundwater modeling studies performed by Argonne during the development of the aquifer restoration approach for Utica (Argonne 2000) indicated that, *on average*, the extraction of approximately 97 million gallons of groundwater per year would be required to maintain hydraulic control of the groundwater plume and achieve cleanup of the aquifer in an estimated 10-15 years. The actual groundwater produced during the December 2007-November 2008 review period represents approximately 57% of this average annual goal; this is the lowest production achieved during a review period since operation of the groundwater treatment effort at Utica began in November 2004. The highest annual production to date (approximately 119 million gallons; 123% of the annual target) was achieved in the preceding (December 2006-November 2007) monitoring period. The cumulative volume of groundwater extracted and treated by the Utica systems since the aquifer restoration efforts began now represents 91% of the theoretical cumulative target for the four-year period November 2004-November 2008 (down from 103% for the three-year period November 2004-November 2007).

The original modeling studies (Argonne 2000) suggested that the natural groundwater flow and contaminant migration rates at this site are sufficiently low to accommodate periodic fluctuations in the volume of groundwater extracted annually, as long as the target *average* extraction rate is generally maintained. The low groundwater recovery observed during the current review period therefore does not represent an immediate concern. If environmental conditions at the wetlands basins continue to impact the groundwater pumping and treatment efforts significantly over several consecutive years, however, alternatives might need to be examined to ensure that adequate hydraulic control and recovery of the carbon tetrachloride plume are maintained. As outlined in Section 3.2 of the approved *Monitoring Plan* for Utica (Argonne 2004), groundwater sampling with the Argonne cone penetrometer at selected location,

as performed at the site by Argonne in 1998 and again in 2003 (Argonne 2003), is recommended at 5-year intervals to obtain a more detailed picture of the progress of the restoration effort toward completion. Remediation of the Utica aquifer began in fall 2004; the first five-year performance sampling event is therefore recommended during the later part of the next review period, in fall 2009.

Sampling and analysis of the effluent water from the air stripping and spray irrigation treatment units indicated that in December 2007-November 2008 these systems functioned at a minimum efficiency of 92% (on the basis of data for individual samples from the spray treatment units). Efficiencies of approximately 98% were calculated for the spray treatment units (on the basis of the average concentration delivered to the wetlands during the review period) and > 99% for the outfall from the air stripping unit. Carbon tetrachloride concentrations in all discharges of treated water at the site were below the permitted maximum target (44.2 µg/L) by roughly an order of magnitude.

Calculations based on the volumes and measured carbon tetrachloride concentrations of the groundwater extracted and treated during the current review period indicated that approximately 8 kg (1.3 gal) of carbon tetrachloride was removed from the Utica aquifer in December 2007-November 2008. The significantly lower quantity of carbon tetrachloride recovered in this period, in comparison to the previous review period (25 kg, or 4.1 gal, in December 2006-November 2007) is a direct consequence of the very limited operation of GWEX1-GWEX3 and the spray treatment units that was possible during most of the current review period. No decrease in the volumetric throughput (when operating) or contaminant removal efficiency of the groundwater treatment systems was observed during the current period (Table 7.1).

The costs incurred by Argonne for operating and maintenance of the aquifer restoration effort at Utica in December 2007-November 2008 were approximately \$168,000. These current costs include increased logistics support and monitoring costs associated with efforts to document and periodically locate the subsurface remediation system components at the site, in response to requests from the Nebraska Diggers Hotline service. These actions were necessary to ensure that the CCC/USDA installations at Utica are protected from damage by unrelated construction or digging activities that are occurring with increasing frequency at this site.

TABLE 7.1 Summary of performance of the groundwater restoration systems at Utica.

	Review Period			
	Oct 2004- Nov 2005	Dec 2005- Nov 2006	Dec 2006- Nov 2007	Dec 2007- Nov 2008
Groundwater Produced (gal)	66,364,652	113,949,510	119,274,680	55,228,674
Groundwater Produced (% of annual goal)	68	117	123	57
Groundwater Discharged to Wetlands (gal)	34,611,960	84,365,500	90,954,300	25,675,200
Carbon Tetrachloride in Combined Untreated Groundwater from GWEX1-GWEX3 (µg/L)	100-122	71-139	48-90	43-89
Carbon Tetrachloride in Treated Spray Discharge <sup>a</sup> (range of values, µg/L)	ND <sup>b</sup> -7.2	ND-6.9	ND-3.7	ND-4.0
Carbon Tetrachloride in Treated Spray Discharge <sup>a</sup> (average, µg/L)	1.45	0.91	0.61	1.13
Carbon Tetrachloride in Untreated Groundwater at GWEX4 (µg/L)	53-95	26-70	20-43	13-24
Carbon Tetrachloride in Treated Air Stripper Effluent <sup>a</sup> (µg/L)	ND	ND	ND	ND
Carbon Tetrachloride Removed (kg, gal)	23, 3.8	34, 5.6	25, 4.1	8, 1.3
Minimum Carbon Tetrachloride Removal Efficiency for Spray Treatment (%)				
Based on Individual Samples	> 94	> 93	> 95	> 92
Based on Averages	~ 99	~ 99	~ 98	~ 98
Carbon Tetrachloride Removal Efficiency for Air Stripper (%)	> 99	> 99	> 99	> 99
pH of Treated Spray Discharge <sup>c</sup>	7.01-8.18	7.10-8.32	7.09-8.36	7.88-8.51
pH of Treated Air Stripper Effluent <sup>c</sup>	7.01-8.35	7.50-8.58	7.79-8.33	7.71-8.41
Costs (\$)				
Routine	270,879	208,186	126,720	156,006
Non-routine	11,707	62,731	7,336	12,075
TOTAL	282,586	270,916	134,056	168,081

<sup>a</sup> Compliance level, 44.2 µg/L.

<sup>b</sup> ND, not detected at a method detection limit of 0.1 µg/L.

<sup>c</sup> Compliance level, 6.5-9.0.

## 8 References

Argonne, 2000, *Final Report: Stage I Investigations of the Agricultural/Environmental Enhancement Pilot Program, Utica, Nebraska*, prepared for the Commodity Credit Corporation, U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, January.

Argonne, 2003, *Update on Groundwater Sampling Results for Utica, Nebraska, and Pumping Alternatives for the Utica Aquifer/Wetlands Restoration Pilot Program*, ANL/ER/AGEM/CHRON-484, prepared for the Commodity Credit Corporation, U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, April 9.

Argonne, 2004, *Final Monitoring Plan for the Utica Aquifer-North Lake Basin Restoration Project at Utica, Nebraska*, ANL/ER/TR-04/006, prepared for the Commodity Credit Corporation, U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, November.

Argonne, 2005, *Summary of First-Year Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in October 2004-November 2005*, ANL/EVS/AGEM/TR-05-06, prepared for the Commodity Credit Corporation, U.S. Department of Agriculture, by Argonne National Laboratory, Argonne, Illinois, December.

Argonne, 2006, *Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2005-November 2006*, ANL/EVS/AGEM/TR-06-11, prepared for the Commodity Credit Corporation, U.S. Department of Agriculture, Washington, D.C., by Argonne National Laboratory, Argonne, Illinois, December.

Argonne, 2008, *Summary of Operations and Performance of the Utica Aquifer and North Lake Basin Wetlands Restoration Project in December 2006-November 2007*, ANL/EVS/AGEM/TR-08-05, prepared for the Commodity Credit Corporation, U.S. Department of Agriculture, Washington, D.C., by Argonne National Laboratory, Argonne, Illinois, February.



**Environmental Science Division**

Argonne National Laboratory

9700 South Cass Avenue, Bldg. 203

Argonne, IL 60439-4843

[www.anl.gov](http://www.anl.gov)



U.S. DEPARTMENT OF  
**ENERGY**

A U.S. Department of Energy laboratory  
managed by UChicago Argonne, LLC