DOE–EM/GJTAC2041

Office of Environmental Management – Grand Junction

MOAB UTAH
UMTRA
UMTRA Project

Moab UMTRA Project
2011 Ground Water Program Report

May 2012

U.S. Department of Energy

Office of Environmental Management

Prepared by the Technical Assistance Contractor under contract number DE-AC30-07CC60012
for the U.S. Department of Energy Office of Environmental Management, Grand Junction, Colorado.

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Revision 0

Review and Approval

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Revision History

Revision No.	Date	Reason/Basis for Revision
0	May 2012	Initial issue.

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Figures

Tables

Appendices

Attachments - Available upon request at moabcomments@gjem.doe.gov

Acronyms and Abbreviations

bgs	below ground surface
btoc	below top of casing
CF	configuration
cfs	cubic feet per second
DOE	U.S. Department of Energy
ft	feet or foot
ft btoc	feet below top of casing
gal	gallons
gpm	gallons per minute
IA	interim action
in.	inch
kg	kilograms
lb	pound
µmhos/cm	micromhos per centimeter
mg/L	milligrams per liter
mil	million
msl	mean sea level
OSHA	Occupational Health and Safety Administration
RAC	Remedial Action Contractor
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action

1.0 Introduction

1.1 Purpose and Scope

The purpose of this Ground Water Program Report is to assess the performance of measures the U.S. Department of Energy (DOE) has taken to remediate the ground water at the Moab Uranium Mill Tailings Remedial Action (UMTRA) Project site and to protect endangered fish habitat in the Colorado River adjacent to the site during 2011.

This report describes the Ground Water Program activities for the Moab Project during 2011 and evaluates how the ground water system at the Moab site responds to various pumping regimes and fluctuating river flow.

1.2 Site History and Background

The Moab Project site is a former uranium ore-processing facility located approximately 3 miles northwest of the city of Moab in Grand County, Utah (Figure 1). The Moab mill operated from 1956 to 1984. When the processing operations ceased, an estimated 16 million (mil) tons of uranium mill tailings accumulated in an unlined impoundment. A portion of the impoundment is in the 100-year floodplain of the Colorado River. In 2001, ownership of the site was transferred to DOE. Since April 2009, tailings have been relocated by rail to a disposal cell 30 miles north near Crescent Junction, Utah.

Site-related contaminants, including ammonia and uranium, have leached from the tailings pile into the shallow ground water. Some of the more mobile constituents have migrated downgradient and are discharging to the Colorado River adjacent to the site.

In 2005, DOE issued the *Record of Decision for the Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah*, that includes the cleanup alternative to continue, and expand as necessary, its ongoing active remediation of contaminated ground water at the Moab site. As an interim action (IA), DOE began limited ground water remediation that involves extraction of contaminated ground water from on-site remediation wells and evaporation of the extracted water in a lined pond. Diverted river water is also injected into remediation wells to protect fish habitat in riparian areas along the Colorado River. The IA system is discussed in further detail in Section 2.0.

2.0 Ground Water Program Description

The Ground Water Program at the Moab site is designed to limit ecological risk from contaminated ground water discharging to potential endangered fish species habitat areas along the Colorado River. This protection is accomplished through removal of contaminant mass with ground water extraction wells before it reaches the river. In addition, freshwater is injected between the river and the tailings pile to create a hydraulic barrier that reduces discharge of contaminated water to suitable habitat areas. Ground water and surface monitoring is performed with injection and extraction operations through water levels and analytical samples.

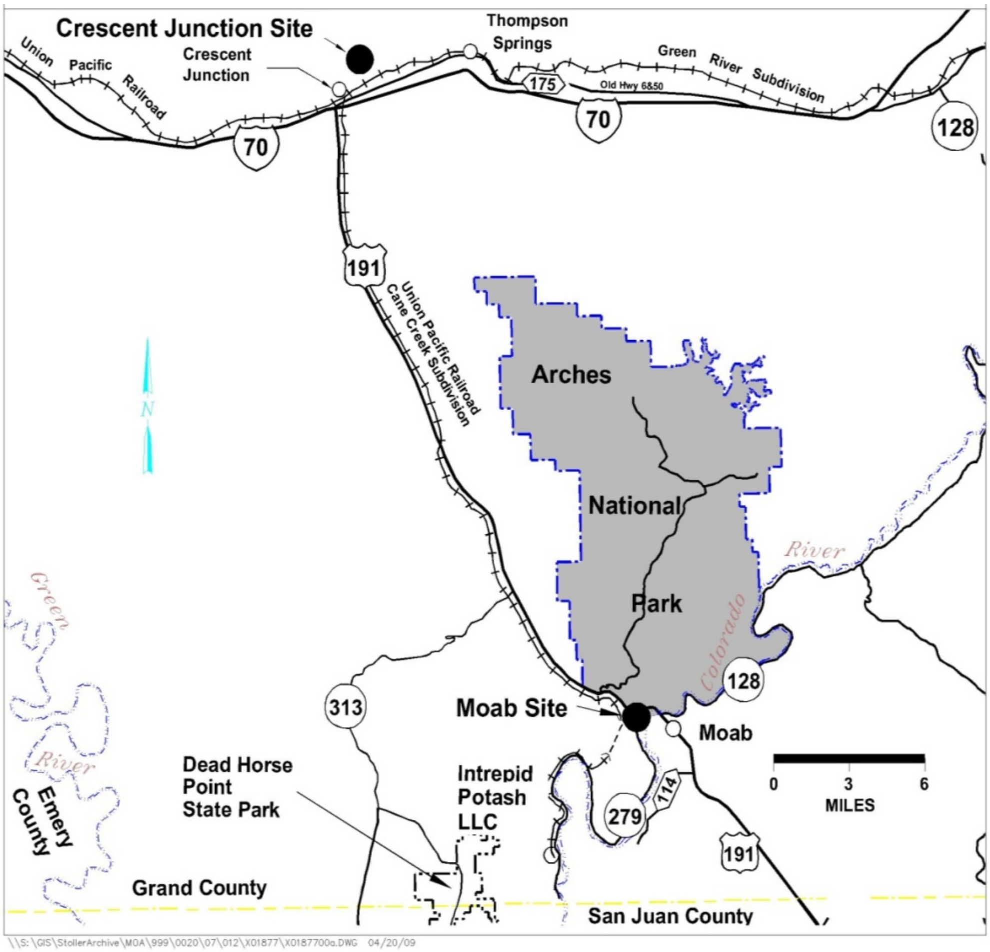


Figure 1. Location of the Moab Project Site

2.1 IA Ground Water System

DOE installed and began operating the first of several configurations (CFs) of extraction/injection wells that compose the IA ground water system in 2003 (Figure 2). The well field consists of five configurations of wells, an infiltration trench, and a baseline area.

The objectives of the IA system are to reduce the discharge of ammonia-contaminated ground water to backwater channels that may be suitable habitat for threatened and endangered aquatic species and to provide performance data for use in selecting and designing a final ground water remedy.

Contaminated ground water from the shallow plume above the brine zone is extracted through a series of wells and pumped to an evaporation pond on top of the tailings pile. The IA system also includes injection of diverted river water into the saturated soil through the wells and an infiltration trench installed near the western bank of the river. Monitoring wells are also part of the IA system for evaluation purposes.

Figure 2. Location of IA Wells

2.2 Hydrology and Contaminant Distribution

The primary hydrogeologic unit present at the Moab site consists of unconsolidated alluvium, and salt beds of the Paradox Formation lie under the alluvium. The alluvium at the Moab site is mostly comprised of either the Moab Wash alluvium or basin-fill alluvium. The Moab Wash alluvium is composed of fine-grained sand, gravelly sand, and detrital material that travels down the Moab Wash and interfingers near the northwestern boundary of the site into the basin-fill alluvium deposited by the Colorado River.

The basin-fill alluvium is composed of two distinct types of material. The upper unit consists mostly of fine sand, silt, and clay, and ranges in thickness from 15 feet (ft) near the saturated zone in some areas. This shallow unit is made of overbank deposits from the Colorado River. The lower part of the basin-fill alluvium consists mostly of a gravelly sand and sandy gravel, with minor amounts of silt and clay. This deeper, coarse alluvium pinches out to the northwest along the subsurface bedrock contact and thickens to the southeast toward the river to more than 450 ft near the deepest part of the basin. The upper silty-sand unit typically has a hydraulic conductivity that ranges from 100 to 200 ft/day.

Water table contour maps indicate the ground water in this area discharges into the Colorado River. Figure 3 was generated using data collected in Febuary 2011 and exhibits how ground water underlying the site discharges directly into the Colorado River under river base flow conditions.

Most ground water beneath the site contains total dissolved solids (TDS) concentrations greater than 10,000 milligrams per liter (mg/L) (brackish water and brine). A brine interface occurs naturally beneath the Moab site that is delineated at a TDS concentration of 35,000 mg/L (50,000 micromhos per centimeter [µmhos/cm]). The interface moves laterally and vertically during the course of each year in response to stresses, such as changes in river stage.

The tailings pile fluids contain TDS exceeding 35,000 mg/L, allowing this fluid to have sufficient density to migrate vertically downward in ground water under previous operating conditions at the site. This former density-driven flow has created a legacy plume of dissolved ammonia that now resides below the brackish water/brine interface. The ammonia beneath the interface represents a potential long-term source of contamination to the upper alluvial ground water system.

Since the cessation of milling operations at the site, the flux of relatively fresh water entering the site upgradient of the tailings pile may have diluted the ammonia levels in the shallow ground water (Figure 4). Oxidation of ammonia to nitrate or nitrogen may also contribute to lower ammonia concentrations observed in the upgradient shallow ground water beneath the tailings pile, where aerobic conditions are more likely. However, there is now flushing of the legacy plume by advective flow of freshwater due to density stratification of the brine zone.

In addition to ammonia, the other primary constituent of concern in ground water is uranium. Figure 5 shows the distribution of dissolved uranium in shallow ground water. Wells to monitor water quality have been installed on the site over a series of 10 different investigations.

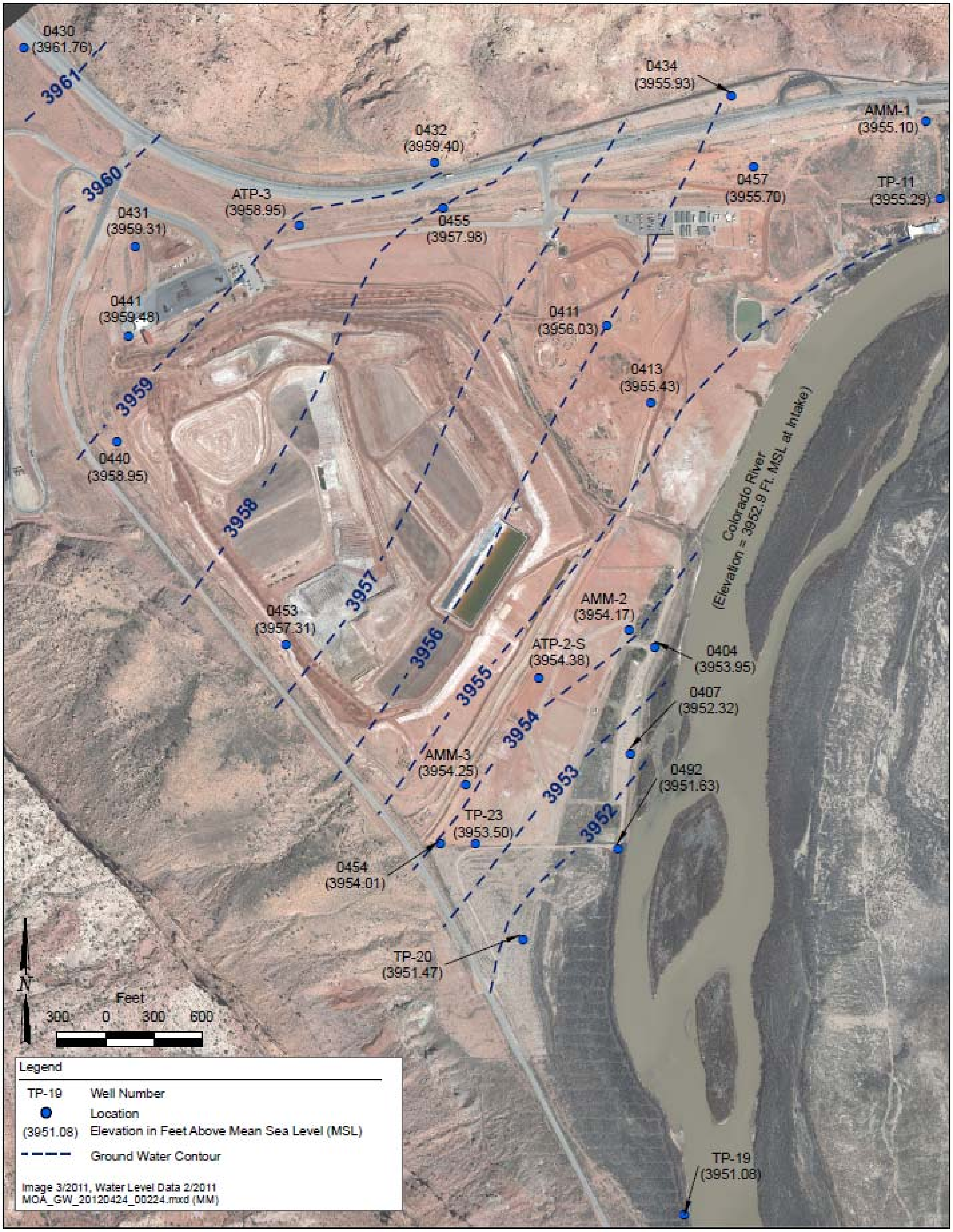


Figure 3. February 2011 Ground Water Surface Elevation Contours

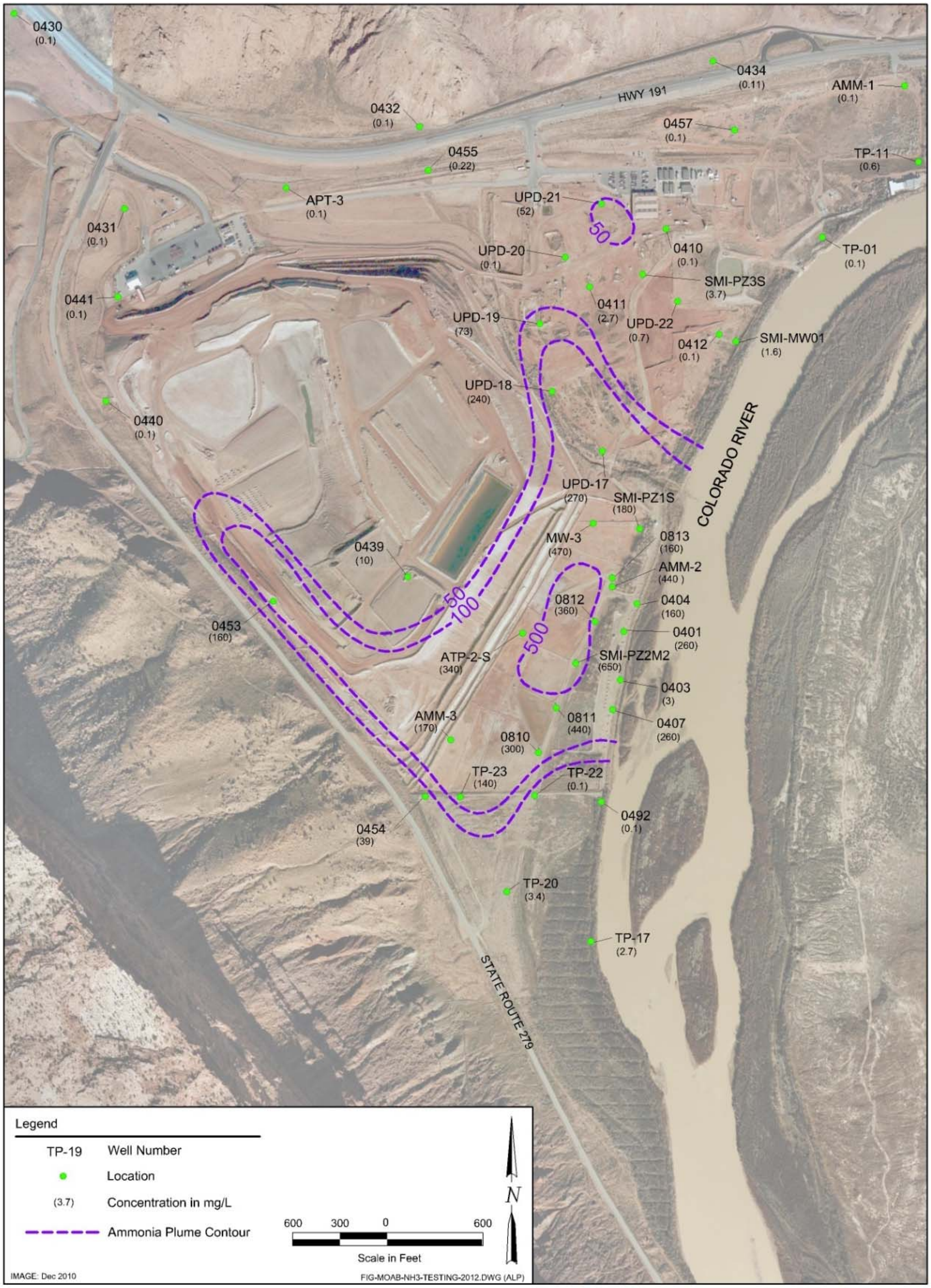


Figure 4. 2011 Location of Ammonia Plume in Shallow Ground Water

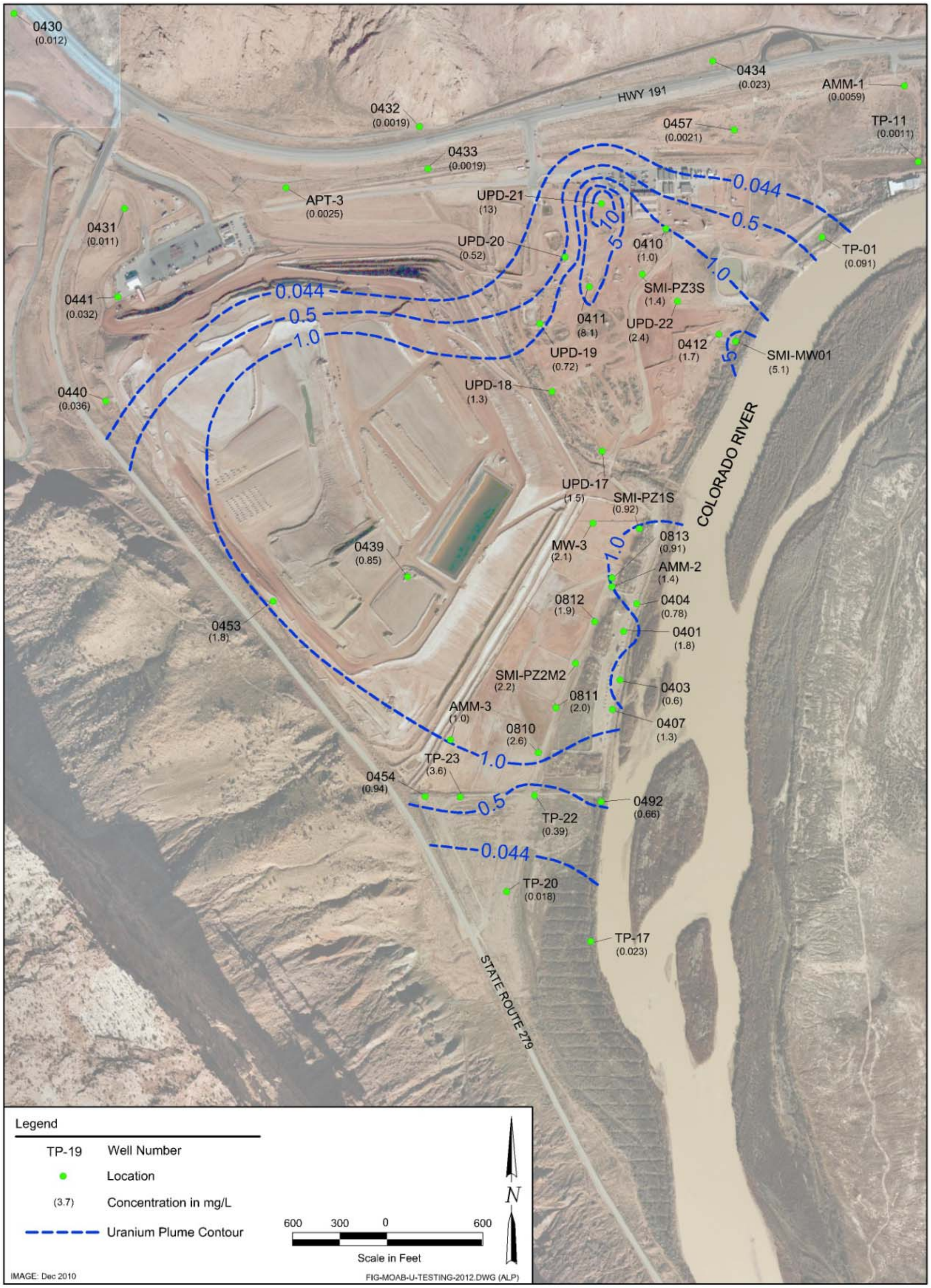


Figure 5. 2011 Location of Uranium Plume in Shallow Ground Water

2.3 Surface Water/Ground Water Interaction

Previous investigations have shown that the surface water flow in the Colorado River can strongly affect ground water elevations and contaminant concentrations in the well field. As the Colorado River reaches peak spring runoff flows of about 10,000 cubic feetm per second (cfs), it changes from gaining to losing conditions, and a lens of freshwater expands in the soils along the river. Figure 6 shows how the losing river conditions impacted the ground water elevation in June 2011. By August, the river elevation began to decrease with respect to the ground water elevation. Figure 7 also shows how the ground water discharges to the Colorado River both at the site and at the Matheson Wetlands. In October 2011, the river returned to gaining conditions, and the ground water discharged back into the river (Figure 8).

The freshwater lens is more prominent on the southern end of the well field, where a backwater channel flows adjacent to the riverbank year-round. In 2011, the peak river flow was 49,000 cfs, which was significantly higher than the average peak of 23,500 cfs, and gaining conditions greatly impacted the IA operations.

3.0 Methods

Well field performance is assessed by measuring extraction/injection rates of remediation wells, measuring water levels, and sampling remediation and monitoring wells. In 2011, the IA well field operations included both extraction and injection.

3.1 Remediation Well Extraction

Each extraction well contains a flow meter that displays the instantaneous flow rate in gallons (gal) per minute (gpm), the cumulative total volume extracted (displayed at “Total 1” on the flow meter), and the net volume since the last reset of the internal memory (displayed as “Total 2” on the flow meter). Flow meter readings are manually recorded on a weekly basis during extraction operations and are used in conjunction with water quality data to estimate the contaminant mass removal from each well.

When the remediation wells are sampled, the resulting ammonia and uranium concentrations are used to calculate the contaminant mass removal. The contaminant mass that is removed is discharged to the evaporation pond on top of the tailings pile, sprayed through the evaporators, used for dust suppression by water trucks, or directed toward the drip system (Section 5.0) on the southeastern apron of the tailings pile. The evaporated contaminants are deposited as salt and will be removed for disposal with tailings and transported to the Crescent Junction disposal site.

3.2 Remediation Well Injection

Each injection well contains a flow meter that displays the instantaneous injection rate in gpm and the total volume. Flow-meter readings are recorded manually on a weekly basis during injection operations and are used in conjunction with water level data to estimate the amount of freshwater mounding in each well.

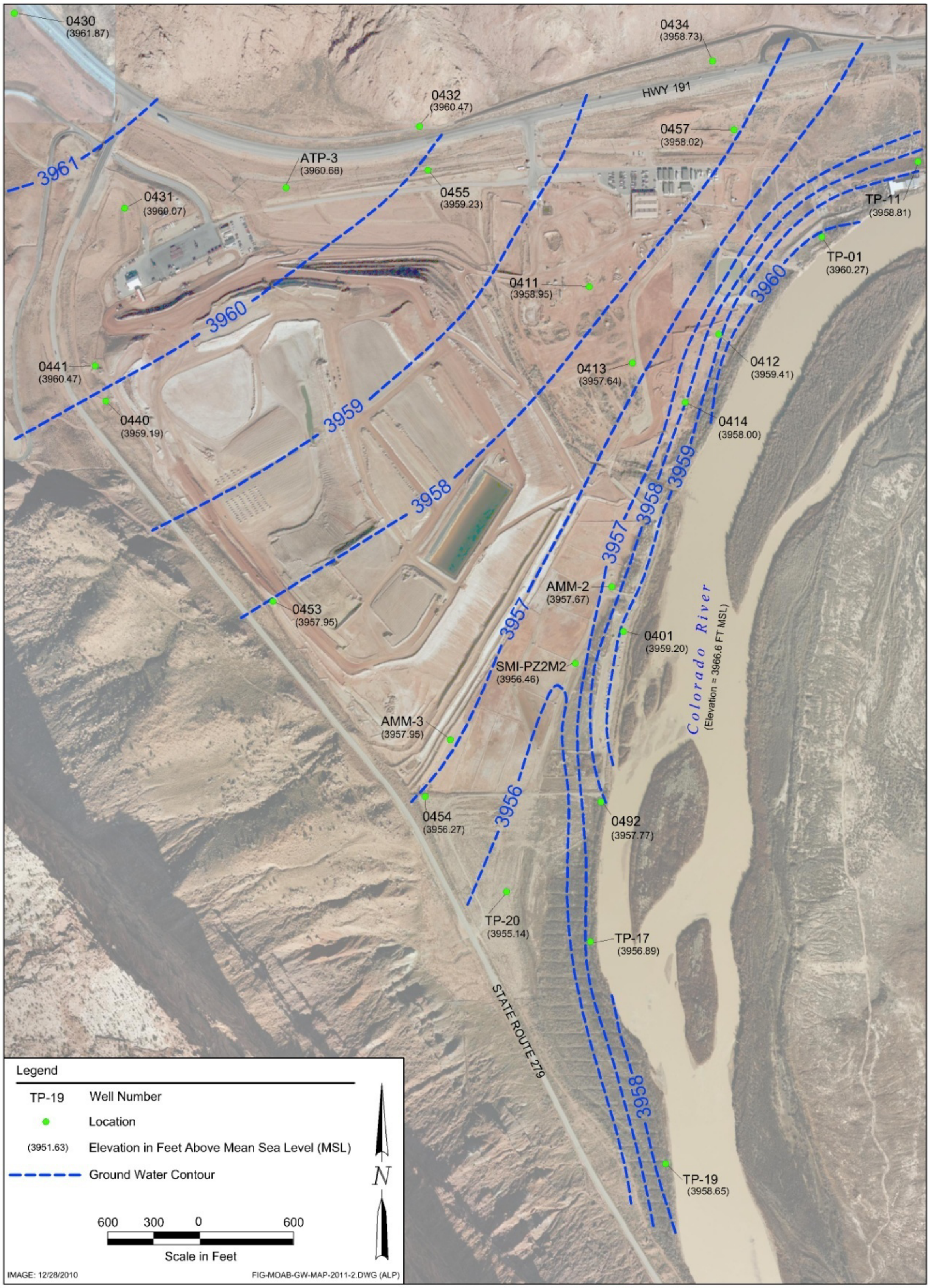


Figure 6. June 2011 Ground Water Elevation Contour Map

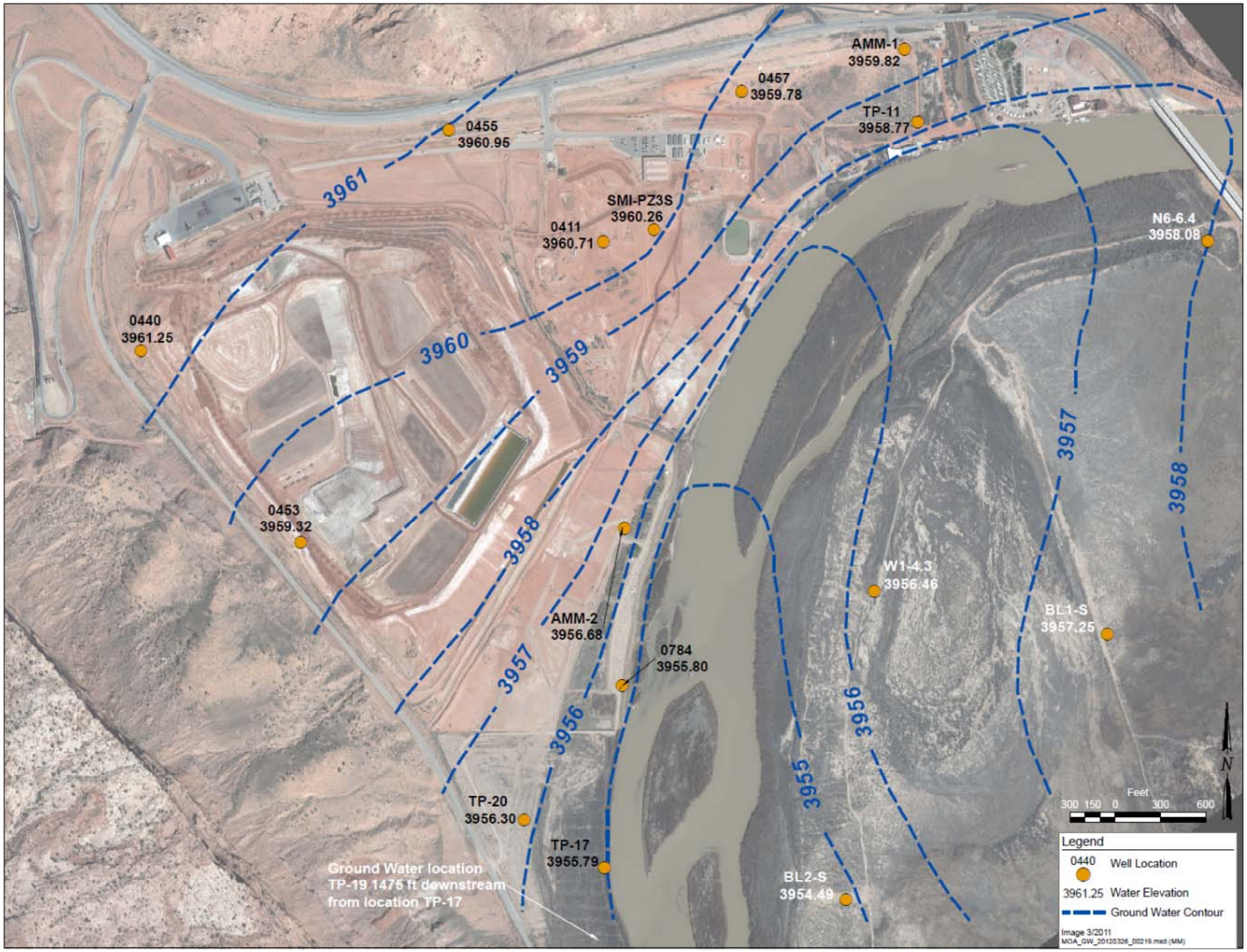


Figure 7. August 2011 Regional Ground Water Elevation Contour Map

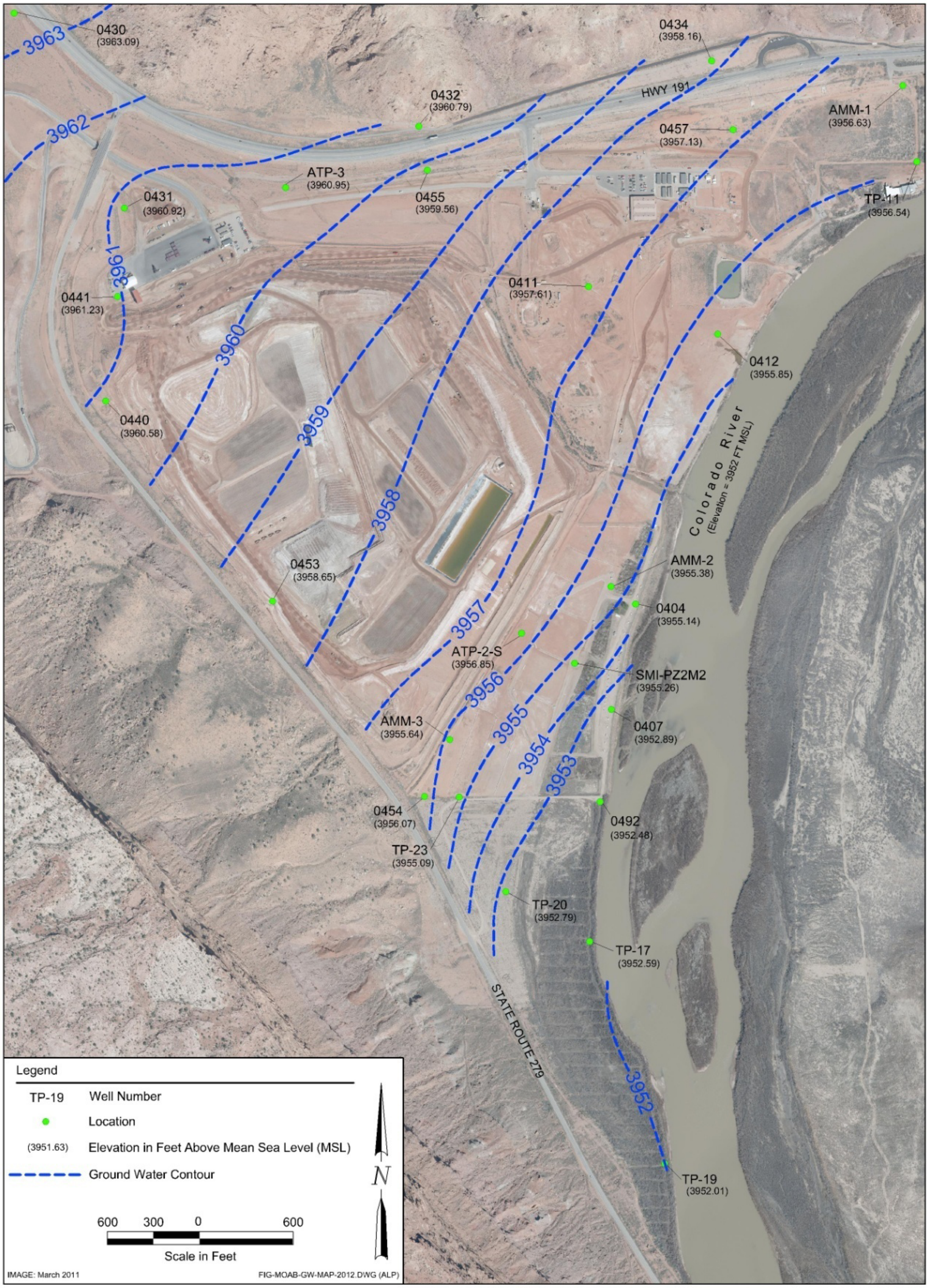


Figure 8. October 2011 Ground Water Elevation Contour Map

3.3 Water Levels

Ground water levels are recorded in the IA well field on a weekly basis during pumping operations to monitor ground water drawdown and freshwater mounding. A water-level indicator is used to measure the depth to ground water (below top of casing [btoc]). Data-logging equipment with pressure transducers are installed at various locations to measure water levels on a more frequent basis.

3.4 Water Quality

Selected well and surface water locations are sampled at various times, depending on the purpose of the sampling event. Before sampling, field parameters including temperature, pH, oxidation reduction potential, conductivity, dissolved oxygen, and turbidity are measured and recorded. Observation wells are sampled with dedicated down-hole tubing and a peristaltic pump, while remediation wells are sampled with dedicated submersible pumps. Water samples are collected at various depths and locations to monitor the primary contaminants of concern, ammonia (as N), uranium, and TDS. All water sampling was performed in accordance with the *Moab UMTRA Project Surface Water/Ground Water Sampling and Analysis Plan* (DOE-EM/GJTAC1830). Samples are shipped overnight to the ALS Environmental in Fort Collins, Colorado.

An ammonia probe is used on site to obtain ammonia concentrations. The probe is used at surface water locations, observation wells during injection, and at extraction wells during operation. Periodically, the ammonia probe data are verified with a laboratory sample analysis. Ammonia data presented in this report that were recorded with the ammonia probe are stated as such. All other ammonia analyses were provided by ALS Environmental.

4.0 Ground Water Extraction Operations and Performance

4.1 IA Operations

This section provides information regarding the IA well field extraction performance during the 2011 pumping season when CF5 was actively extracting ground water. Also included in this section is a discussion regarding the total ground water extraction rate, hydraulic control, mass removal, and water quality for 2011. Appendix A contains tables of well construction information, chronology, pumping volumes, mass removal, drawdown data, and specific capacity calculations for the extraction operations.

In 2011, extraction operations were greatly impacted by the above average run-off and by available storage in the evaporation pond. The extraction schedule was altered to focus on remediation wells from CF5 to increase ammonia and uranium removal.

Ground water extraction from CF5 began in mid-April, and the extracted ground water was directed through the enhanced evaporator units. By April 26, all of the CF5 wells were operable, but the system was shut down due to the high river flow in late May.

The CF5 portion of the well field remained submerged under flood water from late May until late July. The system was tested on August 24 to ensure it was working properly after the flood event. Extraction operations resumed on September 8 at locations PW02, 0811, 0812, and 0813. On October 7, extraction began at well 0810, and the ground water discharged to the drip system, while PW02 was directed to the evaporation pond. The evaporators were winterized in November, and the system was shut down on December 15 for the remainder of the year. Well construction information and a chronology of events for CF5 can be found in Appendix A (Tables A-1 and A-2). The total volume removed from CF5 was 9.7 mil gal, which is slightly less than the volume removed in 2010. This is a result of the well field shutdown due to flooding.

The associated volume of ground water extracted by each well in CF5 is shown in Appendix A, Table A-3. If a flow meter malfunctioned, the volumes were estimated based on the most recent flow rate recorded. Figure 9 provides a graphic summary of the cumulative volume of ground water extracted from CF5 in 2011. The plateau from May to September is due to the well field shutdown during flooding.

4.1.1 CF5 Pumping Rate and Ground Water Extracted Volume

CF5 extraction wells 0810 through 0816 and PW02 were used to extract ground water in 2011. The well screens are placed at varying depths (Appendix A, Table A-1) due to varying depths to the brine interface in the CF5 area. All of the CF5 extraction wells were tested on March 31 to assess the functionality of the system. On May 31, the extraction system was shut down due to the high river flow. The system was tested once again on August 24 and restarted on September 8 (wells PW02, 0811, 0812, and 0813). At this time, the extraction water was sent directly to the drip system (refer to Section 5.0 for more information on the drip system).

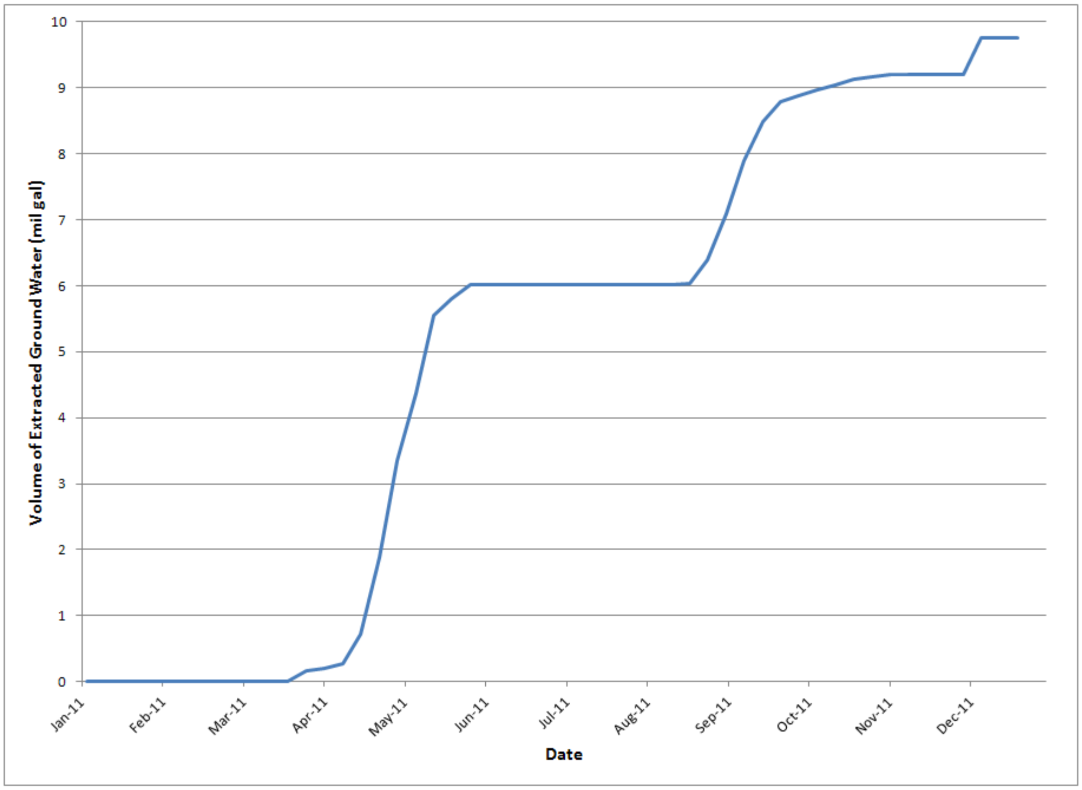


Figure 9. Cumulative Volume of Extracted Ground Water During 2011

The evaporation units were winterized in mid-November; subsequently, only well PW02 was operated discharging directly to the evaporation pond. Well PW02 was shut down on December 15 for the remainder of the year.

Monthly extraction volumes between March and December 2011 for each of the eight wells comprising the CF5 system are listed in Appendix A, Table A-3. CF5 wells individually extracted between 373,891 and 4,790,770 gal. A total of approximately 9.7 mil gal of ground water was extracted from the CF5 wells during the 2011 pumping season.

4.2 IA Extraction Performance

4.2.1 Ground Water Levels and Hydraulic Control

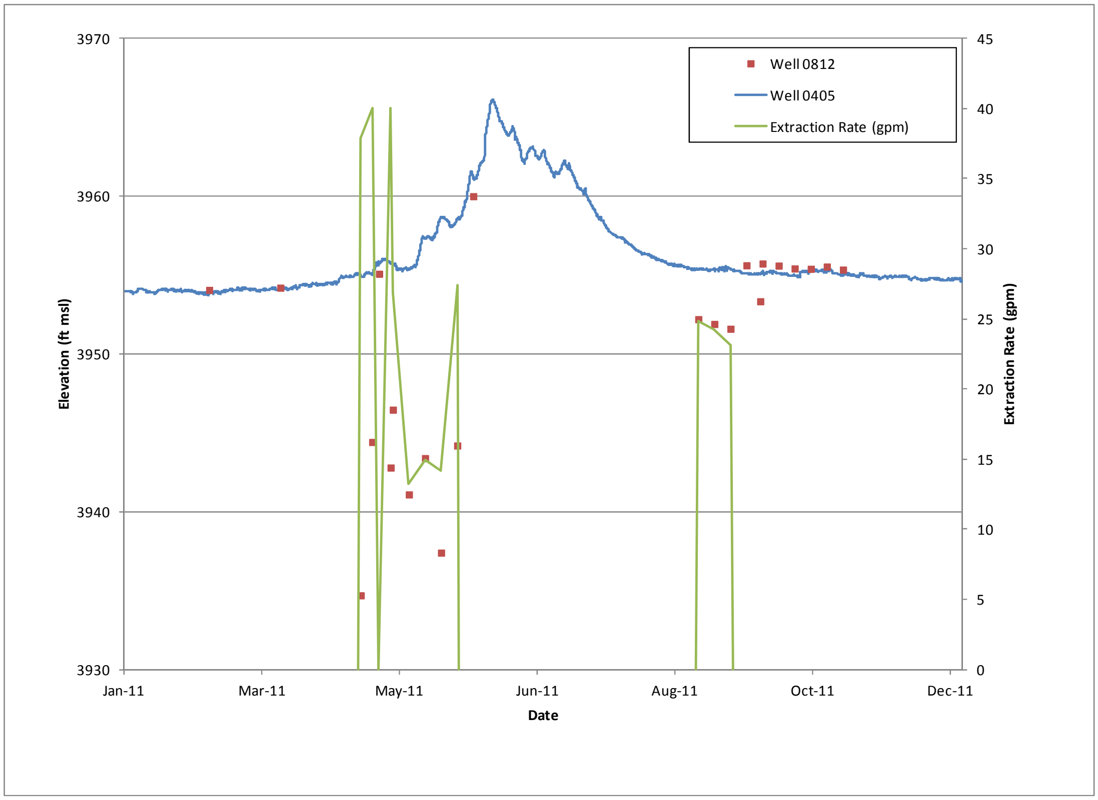
Hydrographs were prepared to compare ground water elevations from observation well 0405 located in the northern end of the well field and ground water elevations of the CF5 extraction wells during the pumping season. Applicable extraction rates for each well were plotted against the ground water elevations to determine drawdown during operations. Well 0405 water elevation data were adjusted so that both wells were assigned the same non-pumping water level. The difference between the two wells gives a qualitative estimate of drawdown in response to pumping. Drawdown calculations were not completed for CF5 wells 0813, 0814, 0815, and 0816, because they did not run for an extended period of time, and the short-term drawdown would not be representative of long-term pumping. Figure 10 shows the drawdown during extraction on wells 0812 and PW02. Appendix A, Figures A-1 and A-2 contain the drawdown plots for wells 0810 and 0811.

Table 1 lists the highest drawdown for the extraction wells. The first drawdown value listed for each well was measured in the spring. The shaded row is the drawdown after well development in August. Note that the amount of drawdown observed was significantly less after well development, even when the extraction rate is increased. Figure 11 shows the drawdown during extraction operations at locations 0810, 0811, and PW02 in October. Well 0813 had the lowest drawdown and the highest extraction rate.

4.2.2 Extraction Well Specific Capacity

Specific capacity is the measure of a well’s performance relative to formation hydraulic characteristics. Individual extraction well drawdown data were used to compute the specific capacity during the 2011 pumping season. While this is not a rigorous method of calculating specific capacity because it does not account for well interference, it provides a qualitative evaluation of the relative performance of each extraction well (Table 2).

The specific capacity data in Table 2 represent the extraction wells that were most utilized in 2011. The first line of data for each well is specific capacity data before each well was developed in the summer, while the second line presents the specific capacity after well development. The specific capacity increased after development in wells 0810, 0811, and 0812. There was not a drastic change in specific capacity after development in extraction well PW02.



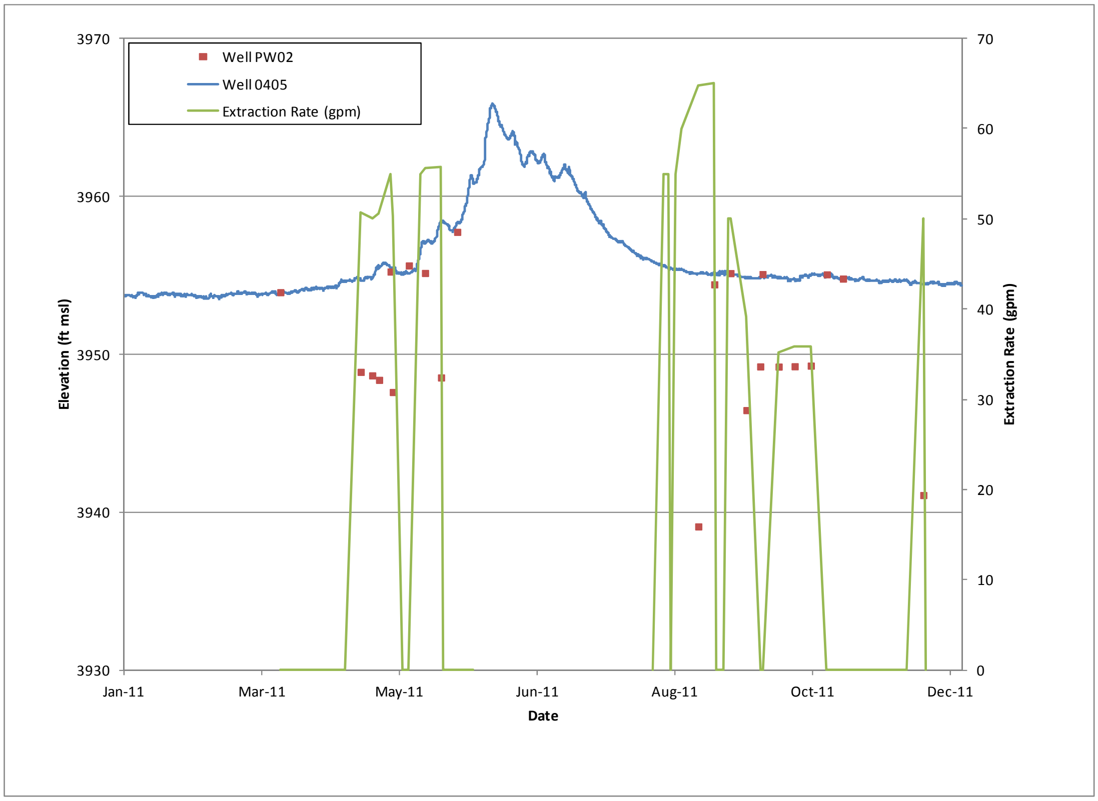


Figure 10. Water Level Data from CF5 Extraction Wells 0812 and PW02

Table 1. Drawdown Measured in CF5 Wells in 2011

Location	Date	Drawdown (ft)	Extraction Rate (gpm)
0810	5/19/11	24.01	4
	9/22/11	2.72	40
0811	4/28/11	21.77	13
	9/15/11	3.31	16.8
0812	5/19/11	21.22	14.2
	9/22/11	3.72	23.1
PW02	4/28/11	7.87	50.4
	10/27/11	5.69	36

Table 2. Computed Specific Capacities at CF5 Extraction Wells During 2011

Well	Drawdown (ft)	Pumping Rate (gpm)	Specific Capacity (gpm/ft)
0810	24.05	24.0	1.0
	2.72	40.0	14.7
0811	21.77	13.3	0.6
	3.31	16.8	5.1
0812	21.22	14.2	0.1
	3.72	23.1	6.2
PW02	7.87	50.4	6.4
	5.69	35.8	6.3

The specific capacity of well 0810 increased after well development from 1 to 14.7 gpm/ft (at a pumping rate of 40 gpm). In 2010, the specific capacity of this well was 9.4 gpm/ft at 47.4 gpm. Wells 0811, 0812, and PW02 had similar specific capacity values in 2010 and 2011 after well development.

4.3 Contaminant Mass Removal

The ammonia and uranium mass removed by CF5 extraction wells in 2011 is presented in Tables A-4 and A-5 of Appendix A. These values are based on ground water extraction volumes recorded by flow meters located along the well head discharge pump lines. The mass of ammonia and uranium removed from ground water by the extraction wells was calculated by multiplying the monthly extraction volumes by corresponding concentration of ammonia and uranium in each well.

The concentrations used in these calculations were drawn from analytical data presented in Appendix D. To estimate the contaminant mass removed when analytical data were not available for the specific month, concentrations were derived from previous and subsequent months to provide an approximate concentration.

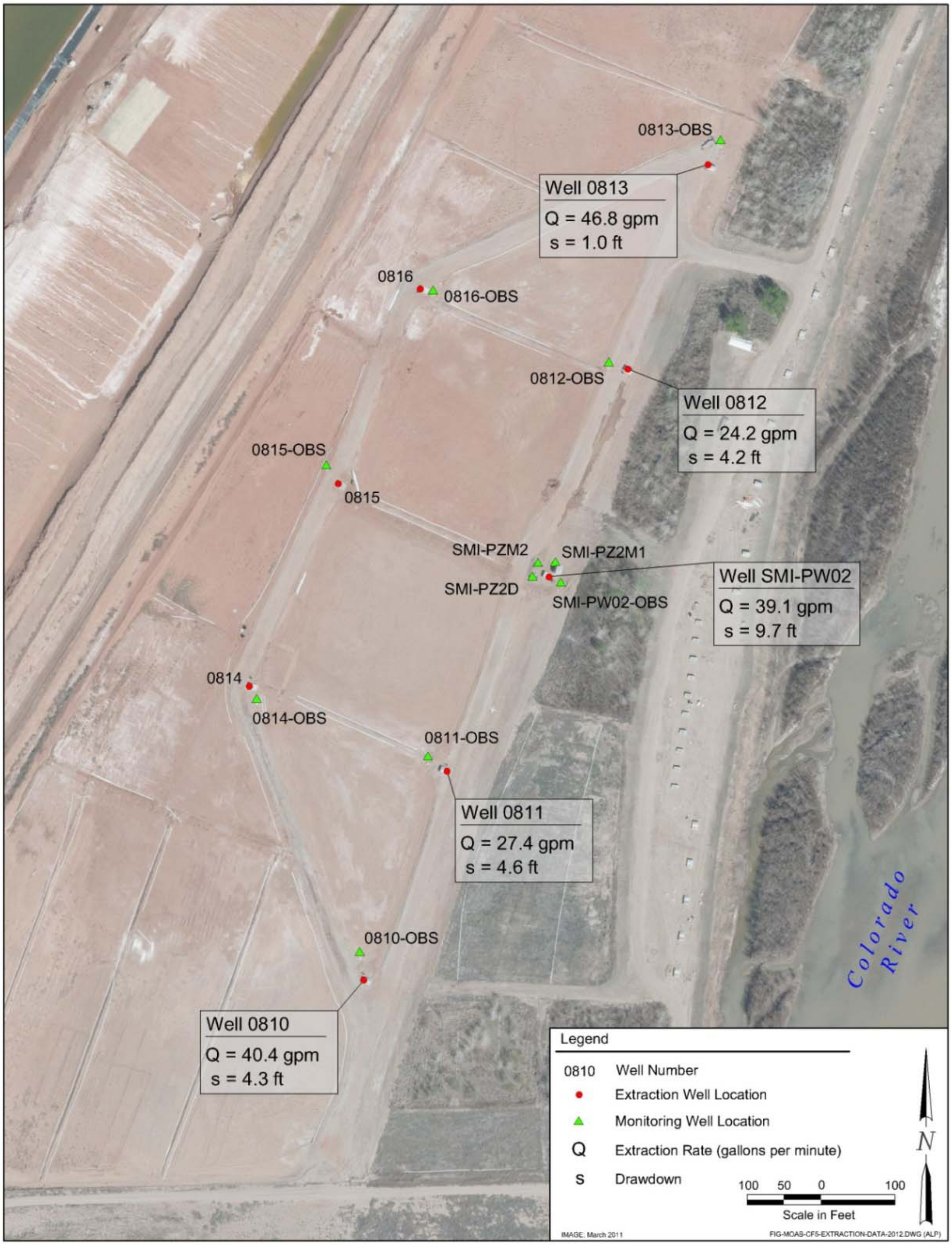


Figure 11. October 2011 CF5 Drawdown During Extraction Operations

During the 2011 pumping season, a total of approximately 37,710 pounds (lbs) (17,105 kg) of ammonia and 233.7 lbs (106 kg) of uranium were extracted from the ground water. Table A-4 in Appendix A shows that extraction wells 0810 and PW02 removed the most ammonia mass, 4,264 lbs (1,934 kg) and 22,500 lbs (10,206 kg), respectively.

Estimated mass withdrawals of uranium at CF5 extraction wells are presented in Appendix A, Table A-5, which shows that the greatest mass of uranium was extracted from wells 0810 and PW02 at 41.9 lbs (19 kg) and 125.7 lbs (57 kg), respectively. These are the two CF5 wells that extracted the most volume of ground water in 2011.

4.4 Ground Water Chemistry

Ground water samples were collected from the well field in April and October 2011, during various river stages and pumping regimes. The following section describes the ground water chemistry from CF5 in the IA well field. The sample schedule for 2011 was streamlined to focus on locations with active pumping operations. Limited sampling was conducted in 2011 due to accessibility during the high river flow. All analytical data from 2011 can be found in Appendix D. Ground water samples are collected from the IA well field and shipped to ALS Environmental for analysis. In 2011, most of the ground water samples were analyzed for uranium and ammonia (as N).

In addition, field parameters, such as temperature, pH, conductivity, and oxidation reduction potential, were recorded. All analyses performed by ALS Environmental were validated and documented in a data validation package.

4.4.1 CF5

The first sampling event occurred in late April when ammonia and uranium samples were collected from all of the CF5 wells to obtain concentrations for mass removal calculations. Ammonia concentrations varied from 210 mg/L (well 0814) to 520 mg/L (wells 0812 and PW02) (Table 3). Uranium concentrations varied from 1.5 mg/L (well 0813) to 3.7 mg/L (well 0815). The specific conductance (Table 3) varied from 12,710 µmhos/cm (well 0813) to 46,430 µmhos/cm (well PW02). This indicates that brine interface (approximately 50,000 µmhos/cm) was located near the PW02 screened interval (20 to 60 ft below ground surface [bgs]).

Samples were also collected from locations 0810, 0811, 0812, 0813, and PW02 in early October. At this time, the highest ammonia concentration was 520 mg/L in extraction well PW02. The highest uranium (4.5 mg/L) and specific conductance (30,856 µmhos/cm) concentrations were also measured in well PW02. The lowest concentration of ammonia, uranium, and specific conductance was measured in well 0813 (Table 3).

The concentrations measured in 2011 are comparable to those measured in 2010. The October values are slightly lower than average, indicating that the floodwater may have infiltrated the soil and diluted the contaminant concentrations for an extended period of time. Figure 11 presents the pumping rates and resulting drawdowns measured during the October 2011 sampling event.

Table 3. CF5 Analytical Data from 2011

Location	**Date**	**Ammonia (mg/L)**	**Uranium (mg/L)**	**Specific Conductance (µmhos/com)**
0810	4/27/11	370	3.3	33,420
	10/4/11	300	2.6	29,873
0811	4/27/11	490	2.9	26,271
	10/4/11	440	2	21,942
0812	4/27/11	520	2.2	25,653
	10/5/11	360	1.9	18,582
0813	4/27/11	300	1.5	12,710
	10/5/11	160	0.91	9,284
0814	4/27/11	210	3.1	27,891
0815	4/27/11	300	3.7	30,715
0816	4/27/11	230	2.2	16,950
PW02	4/27/11	520	2.8	46,430
	10/5/11	520	4.5	30,856

5.0 Evaporation Pond Operations

The evaporation pond, located on the southeastern portion of the tailings pile, stores the ground water that was extracted from the CF5 wells. Water stored in the pond is removed by evaporation, water trucks for dust suppression on top of the tailings pile, through the use of evaporation units that are located on the edge of the pond, or discharged through a drip system.

The drip system was added to the southeastern side of the tailings pile in April 2011 to assist in water evaporation. The 100-ft-long system consists of 26 lateral lines and contains 49 emitters. Each emitter has the ability to discharge 0.6 gal per hour. The drip system is attached to the 6-inch (in.) extraction line. Beneath the system is erosion matting to limit erosion on the side of the pile.

A chronology of the evaporation pond operations can be found in Table B-1 in Appendix B and is summarized here. Table B-2 contains the evaporation pond level and volume for 2011, and Table B-3 contains the evaporator operations. Appendix D contains the analytical data.

The Remedial Action Contractor (RAC) began to use water from the evaporation pond for dust suppression in late January when the pond level was 8.5 ft. By mid-April, the pond level had dropped to 5.3 ft, and extraction was tested on CF5. In late April, continuous extraction began from seven of the eight CF5 wells, with a maximum flow rate of 247 gpm. The purpose for the high extraction rate was to increase the pond level before shutting down the well field due to the expected high river flow.

Extraction was shut down on May 31, due to the high river flow, and remained off until PW02 was restarted on August 24. The well field was shut down again in late August through early September due to well development activities and plumbing upgrades. Extraction resumed on CF5 wells 0810, 0811, 0812, and 0813 on September 8, when the pond was at 6.4 ft. Beginning in early October, extraction was minimized to focus on extracting only from wells 0810 and PW02 to limit the volume delivered to the pond. The evaporators and the drip system were winterized for the season on November 11, and seven of the extraction wells were winterized by November 18.

5.1 Evaporation Pond Water Balance

Water inflows and outflows, along with the pond level, are illustrated in Figure 12. Withdrawal began in March, when extraction operations began in CF5. As Figure 12 illustrates, the outflow remained fairly consistent from March until December in 2011. Table B-2 in Appendix B contains evaporation pond levels and the volume of water in the pond during 2011.

Inflow to the evaporation pond began in March, when extraction began at CF5. An increase in flow was observed in late April and May when the extraction rate was increased to provide sufficient water for dust suppression while the well field was expected to be shut down due to high river flows. The volume of water through the evaporators was available in September 2011, when flow meters were added. When the wells were winterized and shut down in December, the volume of water in the pond started to decline rapidly.

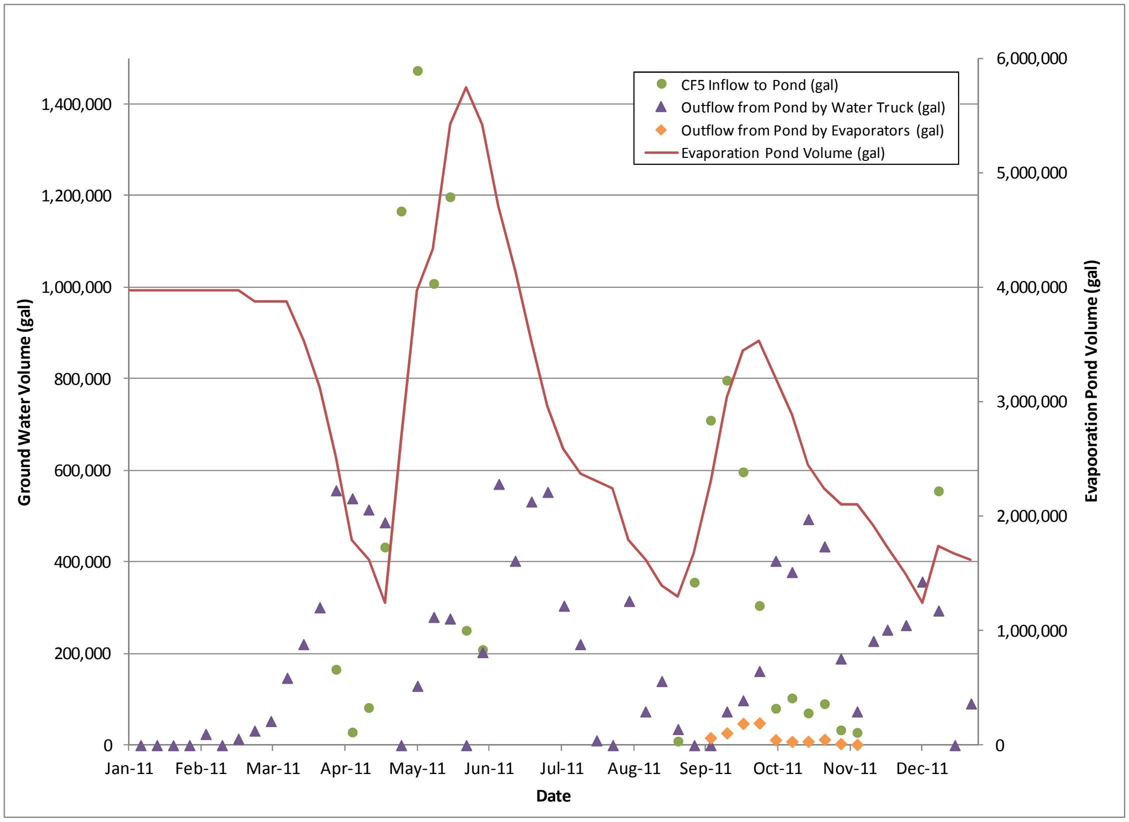


Figure 12. Rates of Water Delivery and Outflow to and from theEvaporation Pond and Pond Volume During 2011

5.2 Evaporation Pond Water Quality

The evaporation pond was sampled twice, in May and November 2011. In May, four samples were collected to determine if the pond was stratified, since the dense excavation seep water was added to the pond in 2010.

Two samples were collected off of the northern end of the pond at depths of 1 and 12 ft below the water surface. Two additional samples were collected at the same depths off the southern end of the pond. Sample results did not suggest that the water was stratified vertically or horizontally (Table 4).

In November, an evaporation pond sample was collected at the southern end of the evaporation pond, close to the surface of the pond (Table 4). The pond depth was approximately 3 ft lower than when the sample was collected in May. As shown in Table 4, the ammonia, TDS, and uranium concentrations all increased significantly. This may be as a result of the lower pond level or due to the fact that late-year extraction focused on wells with the highest ammonia and uranium concentrations to maximize mass removal.

Table 4. Evaporation Pond Analytical Data from 2011

Location	Date	Pond Level (ft)	Analyte Concentration (mg/L)		
			Ammonia	TDS	Uranium
0548-N-1	5/2/11	8.5	590	30,000	2.5
0548-N-12	5/2/11	8.5	650	27,000	2.4
0548-S-1	5/2/11	8.5	580	27,000	2.5
0548-S-12	5/2/11	8.5	570	30,000	2.5
0548	11/21/11	5.5	980	43,000	4.3

6.0 Injection Operation and Performance

The main objective of freshwater injection is to form a hydrologic barrier between the tailings pile and the backwater channel that flows adjacent to the well field and to dilute contaminants before ground water discharges into the backwater channel. Freshwater injection into the CF4 wells occurred from March to May and from August to December 2011.

The injection system runs off of Colorado River water that is diverted at the freshwater intake pump, which is then pumped through a sand and bag filter and injected into the remediation wells. Construction information for the CF4 wells can be found in Table C-1 of Appendix C.

CF4 is located in the southern portion of the IA well field, adjacent to a prominent backwater channel that remains open to the main river channel until the river flow drops below 3,000 cfs. The brine/freshwater interface is higher in elevation in this portion of the well field, and sample results have indicated that the ground water discharges to the adjacent backwater channel. During base-flow conditions, the volume of water flowing into the channel is not sufficient to dilute the ammonia concentration that is introduced from the ground water.

Approximately 11,000,000 gal of freshwater were injected into CF4 during 2011.To date, this represents the highest volume injected into the IA well field in a single year.

6.1 Injection Performance

A chronology of the injection events in 2011 can be found in Table C-2 of Appendix C. In February, before starting injection operations, water levels were collected from the remediation and observation wells, and ammonia probe samples were analyzed from the observation wells (Figure 13). Ammonia probe sample results from CF4 can be found in Appendix D. The purpose of the sample collection was to obtain baseline chemical data before injection operations. Injection into all 10 CF4 remediation wells began in March at a rate of 70 to 80 gpm. At this time, the river flow varied from 3,300 to 5,010 cfs. For most of the month, the remediation wells ran only during work hours. Ammonia probe samples were collected in mid-March to assess the injection operations. The results confirmed that the specific conductance and ammonia concentrations were declining in response.

From late March until early May, the injection system ran for 24 hours a day. Through April and May, the injection rate varied from 51 to 77 gpm. Ammonia probe samples were collected and specific conductance was measured in early April. Analytical laboratory samples were collected from the observation wells from April 27 to 28.

When the river flow increased to 16,400 cfs on May 9, the system was shut down so that the freshwater lens could migrate into the well field and dilute contaminants. The river flow remained above average over the summer months, and specific conductance and ammonia probe readings, collected in mid-July, indicated that the extent of the freshwater lens was sufficient to dilute the ammonia concentrations and suppress the brine interface.

As a result of the above average peak river flow, the injection system remained off until early August when the river flow dropped to 6,000 cfs. On August 3, a new bag filtration system was added to the injection system. The original filter removes particles up to 20 microns, and the new bag filter removes particles from 1 to 5 microns.

The injection system ran between 69 and 91 gpm throughout most of August during daytime operations. The CF4 remediation wells were re-developed by a subcontractor in mid-August to improve the efficiency of the injection operations. The productivity of some of the wells (mainly 0774, 0776, and 0778) had decreased since the flood event. By re-developing the wells, the injection water migrated more into the formation as opposed to mounding in the well casing. Ammonia probe samples were collected and specific conductance was recorded in late August.

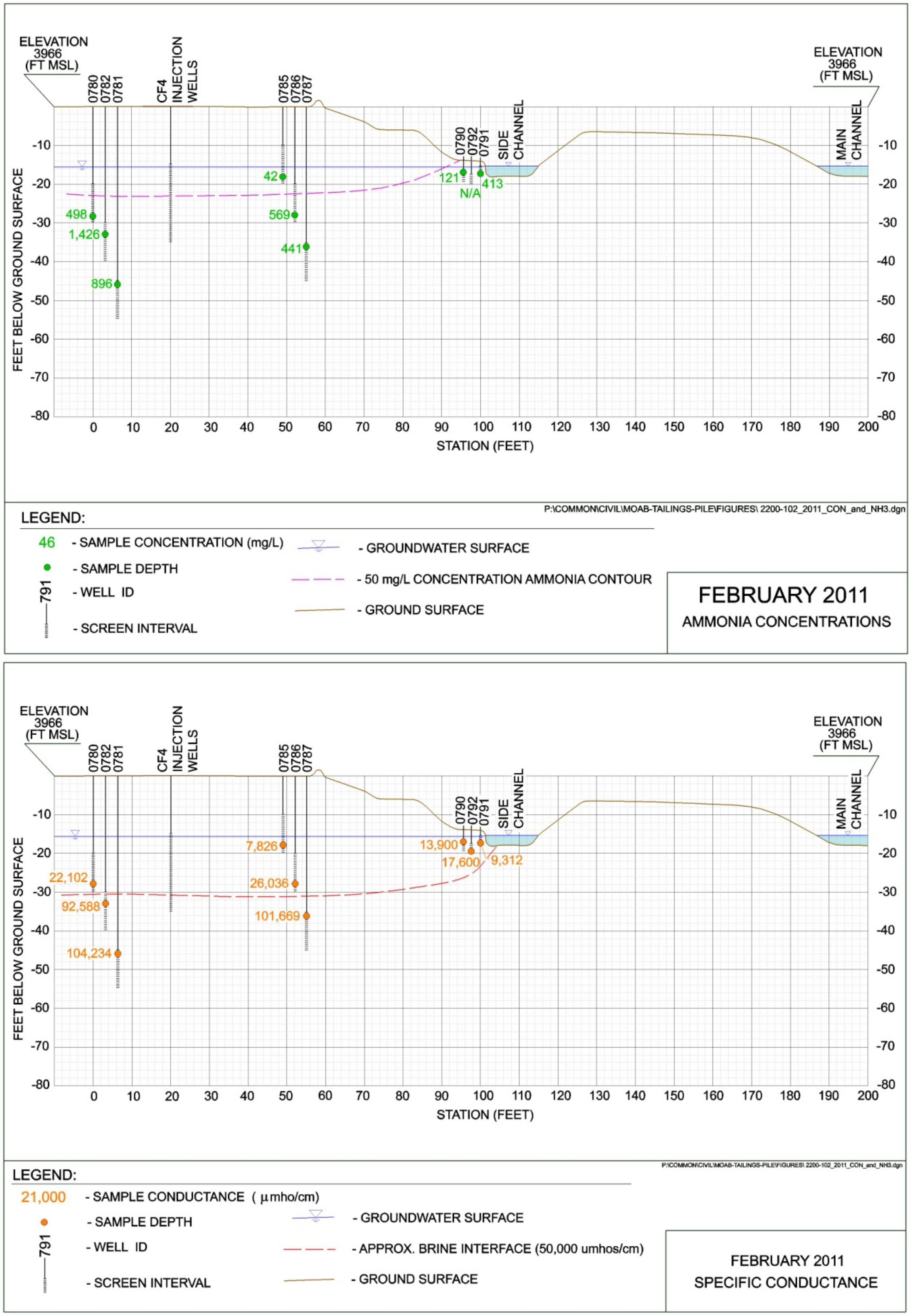


Figure 13. Cross-section Through CF4 Before Injection, February 2011

Injection resumed August 29 and continued through the fall at 36 to 93 gpm. The river flow at this time ranged from 3,500 to 5,000 cfs. During the late summer and fall, the injection system was periodically shut down due to high turbidity in the river. After storm events, the river becomes saturated with silt and clay particles that occasionally pass through the sand filter media and may introduce sediments into the injection wells. Analytical laboratory and ammonia probe samples were collected from the observation wells and well points from October 3 to 5. Figure 14 shows an ammonia and specific conductance cross-section of CF4 during injection operations.

The injection system was winterized on December 7, when the river flow was 3,870 cfs. The ammonia and specific conductance concentration of the ground water was measured to document the rebound of the brine interface after operations ceased. Analytical laboratory and ammonia probe samples were collected from the CF4 observation wells and well points on December 7 to 9 (Figure 15). Ammonia probe samples were collected and specific conductance was recorded again on December 21 to determine how the ground water system responds after the injection operations ceased.

6.2 Summary of Chemical Data from Observations Wells

Ammonia probe samples were collected before starting injection, during operations, and after injection was shut down and winterized. All analytical data can be found in Appendix D.

In February, the ammonia concentration varied from 42.7 mg/L (18 ft bgs) to 1,426 mg/L (33 ft bgs) (Figures 16 and 17). The brine interface was located between 28 and 33 ft bgs, and the ground water elevation in the observation wells varied from 13.2 to 14.75 ft bgs.

During this time, the river flow was 3,440 cfs. Figure 13 shows a cross-section of the ammonia and specific conductance concentrations in February 2011.

After the injection system started in mid-March, ammonia concentrations decreased; however, there was an increase at locations 0787 (36 ft bgs) and at 0781 (46 ft bgs) (Figures 16 and 17). It is likely that the deeper wells had an increase in ammonia due to the suppression of the brine interface. During this time, the brine interface was below 46 ft bgs. The highest specific conductance concentration measured in March was 15,264 µmhos/cm.

By late April, the river flow had increased to 10,500 cfs, and the injection system had been running for a couple of months. Ammonia concentrations had decreased significantly. For example, downgradient location 0786 (28 ft bgs) had a decrease from 569 mg/L of ammonia in February to 3.44 mg/L in April (Figure 17). The upgradient observation wells also had a dramatic decrease in ammonia at all sample depths. The brine interface was below 46 ft bgs (Figure 16). The low ammonia and specific conductance measured in April are probably the result of injection operations and increased river flow (10,500 cfs).

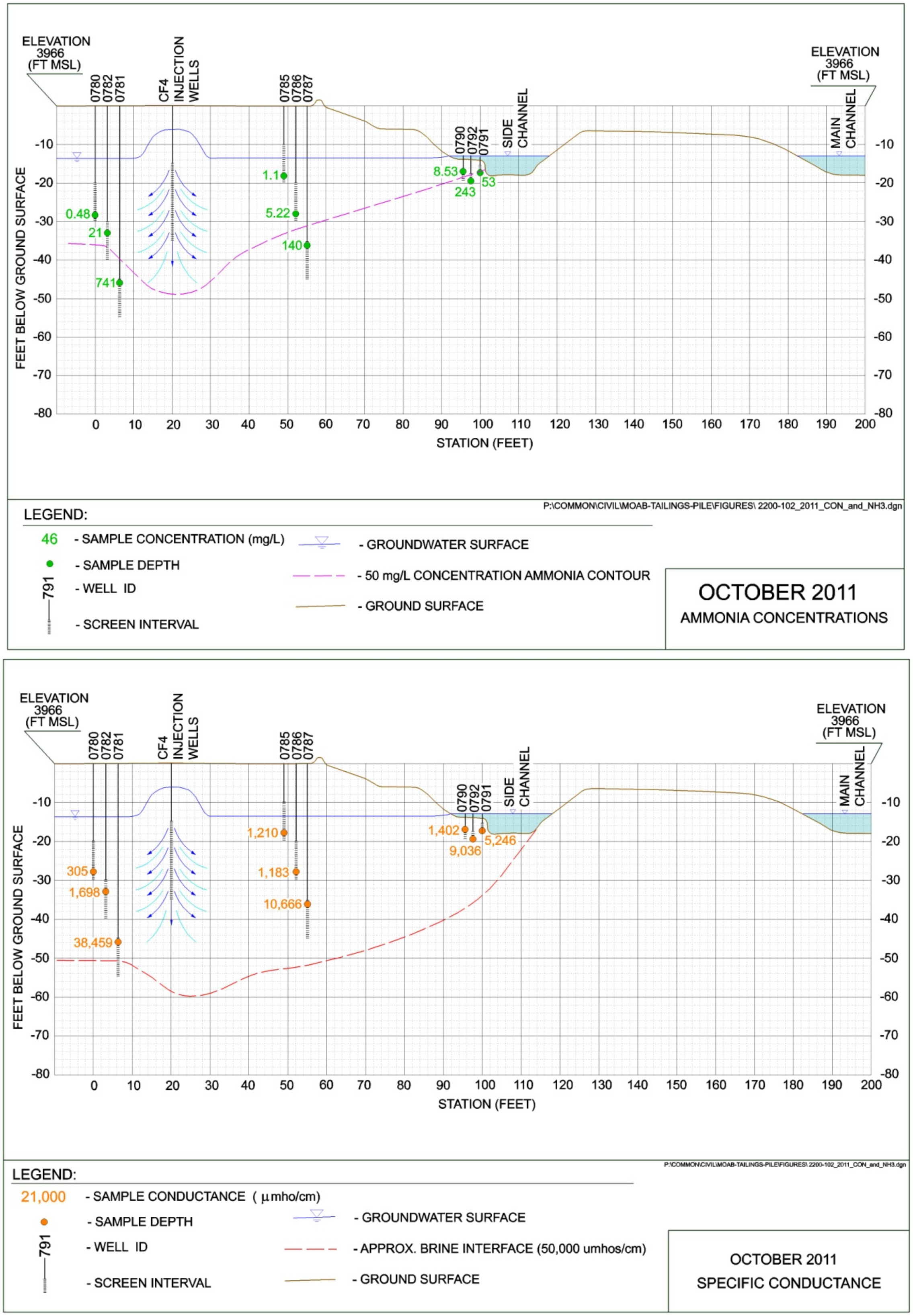


Figure 14. Cross-section Through CF4 During Injection, October 2011

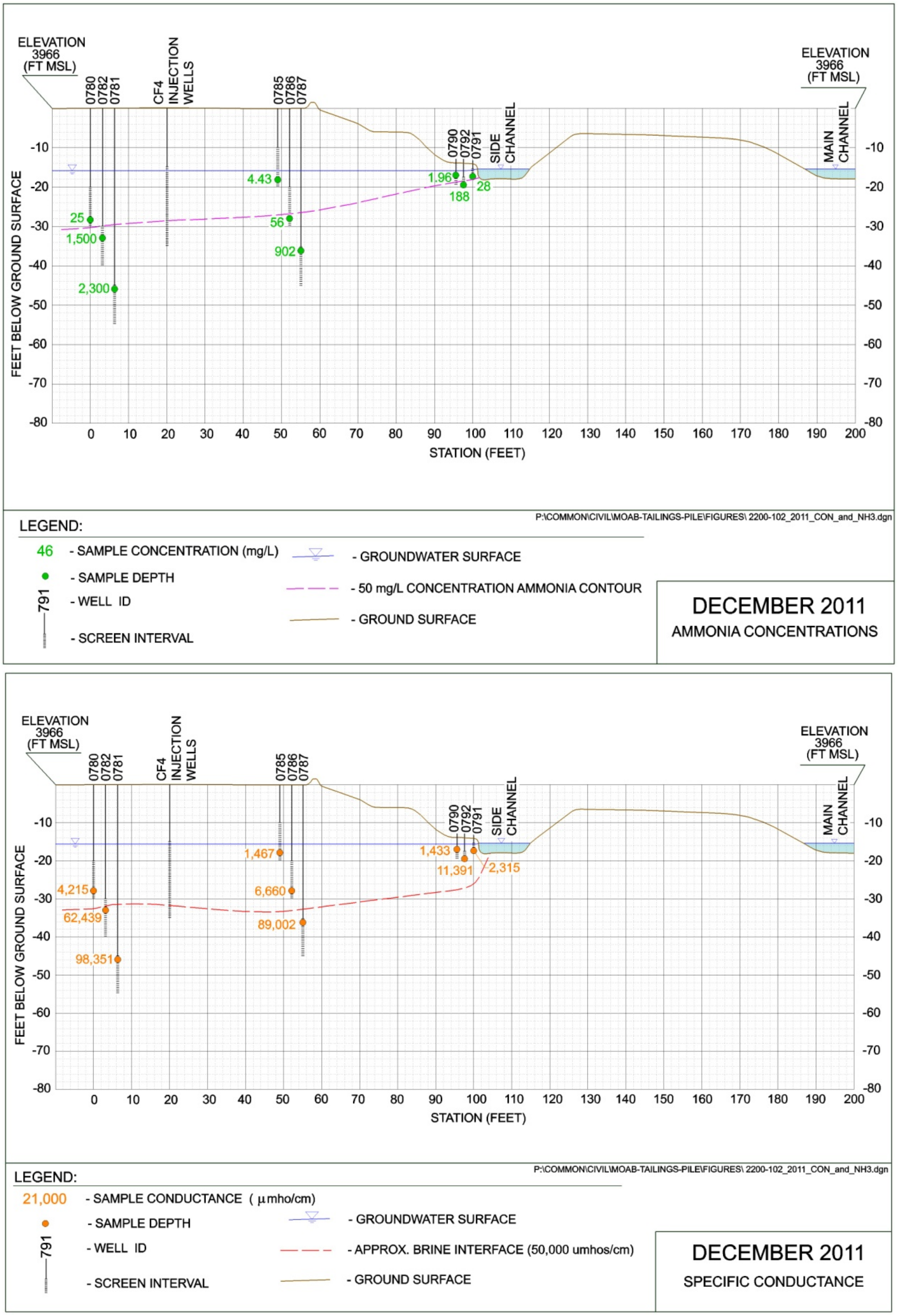


Figure 15. Cross-section Through CF4 After Injection Operations Ceased, December 2011

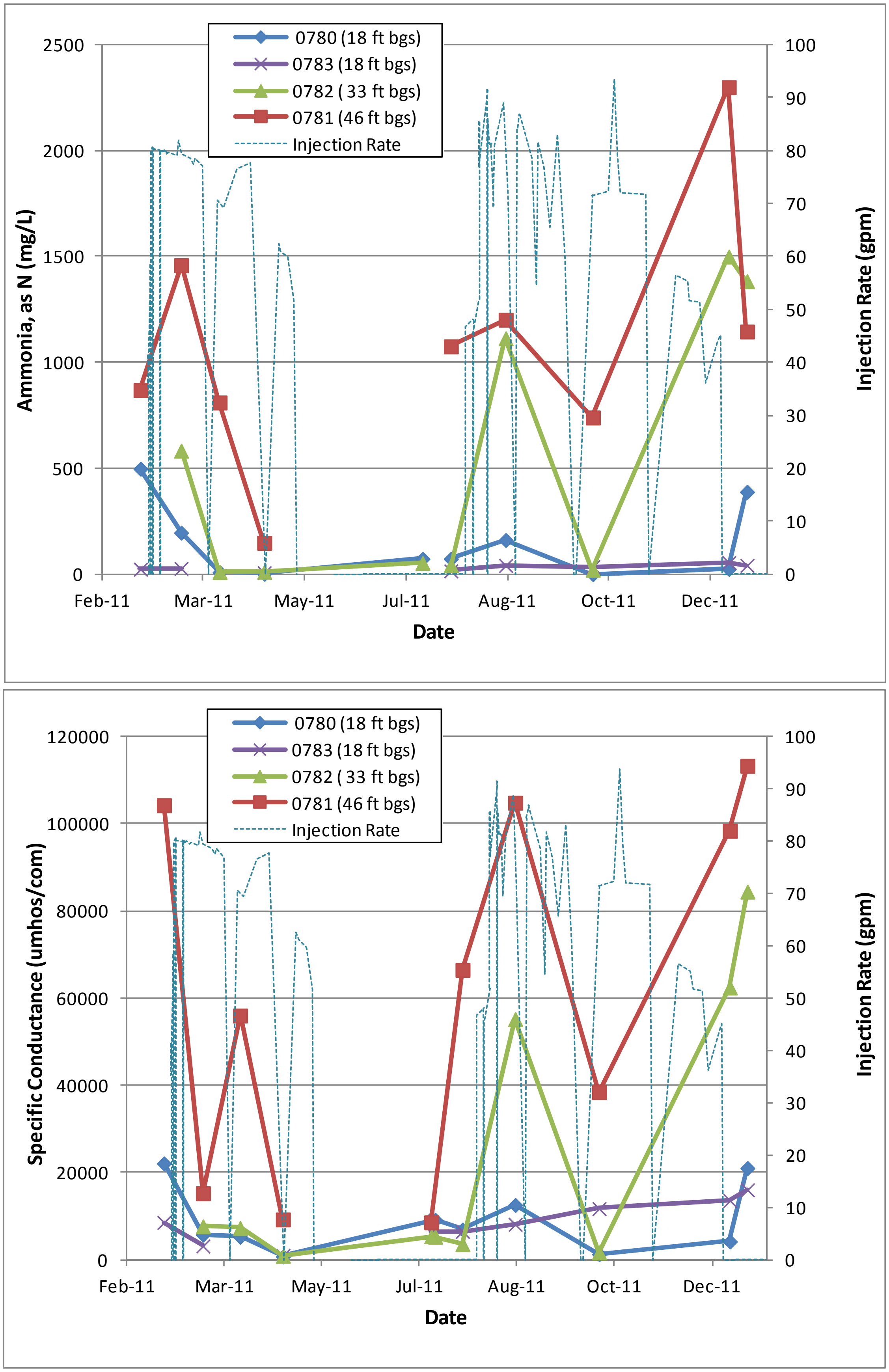
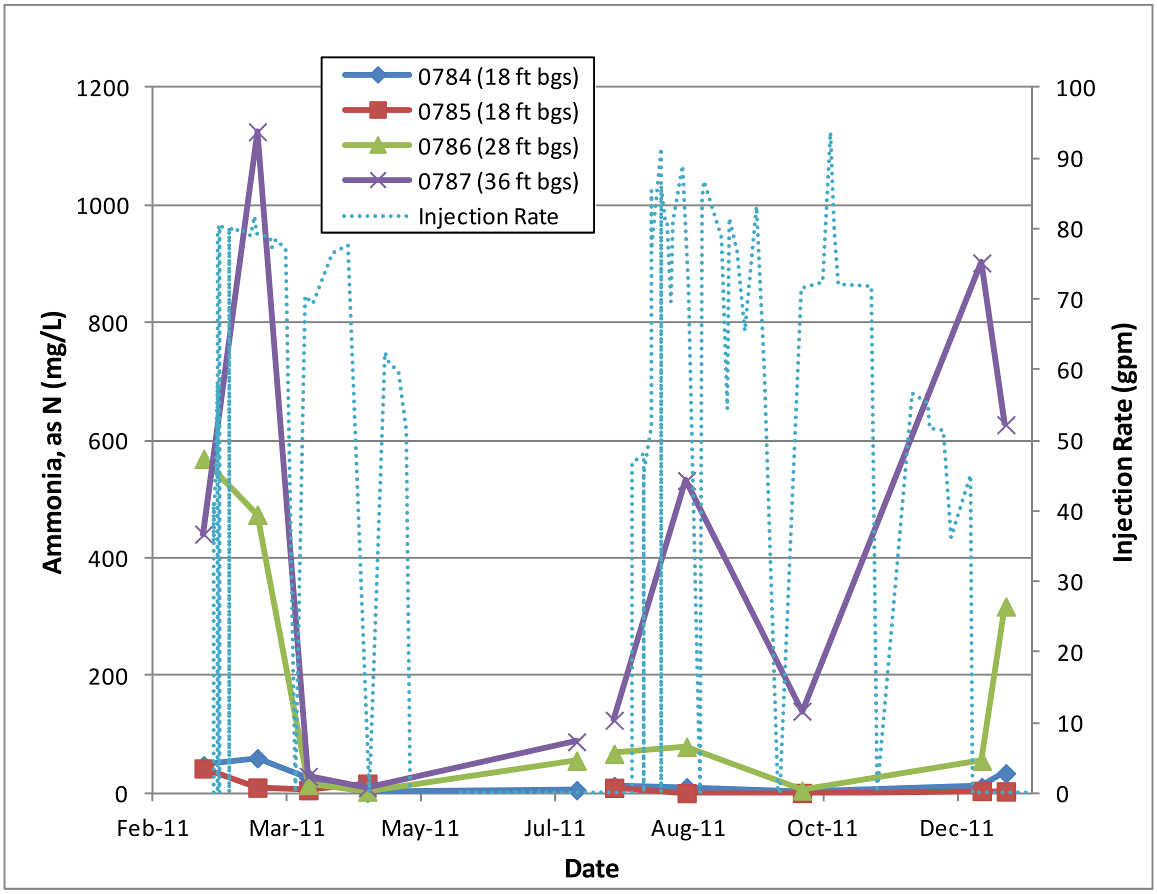


Figure 16. Ammonia and Specific Conductance in Upgradient Wells vs. Injection Rate 2011



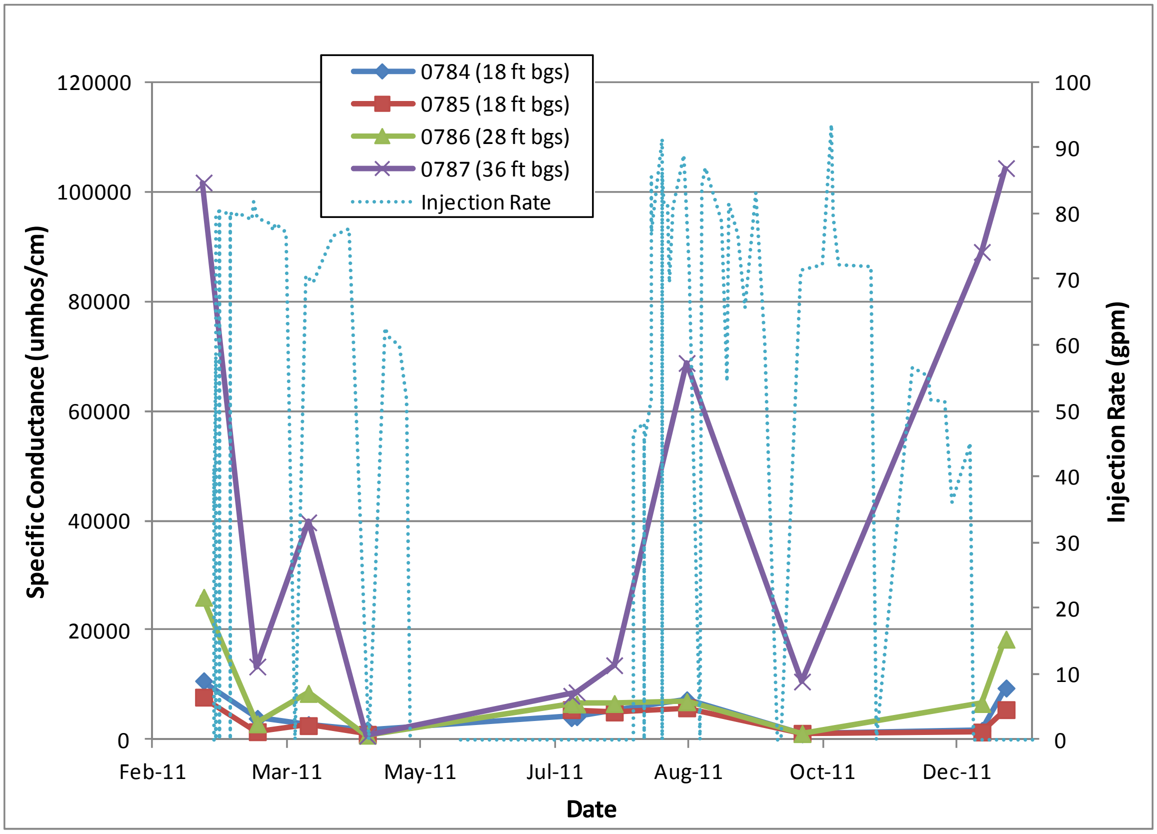


Figure 17. Ammonia and Specific Conductance in Downgradient Wells vs. Injection Rate 2011

The CF4 observation wells were not accessible during the peak river flow from late May until June. Ammonia probe readings were collected once again in July, when the river flow was 11,700 cfs, before the start of injection operations. At this time, the ammonia concentrations varied from 9.77 mg/L (well 0785 at 18 ft bgs) to 1076 mg/L (well 0781 at 46 ft bgs), and the brine interface was located between 33 and 46 ft bgs (Figures 16 and 17). Ammonia concentrations tended to increase at 33 to 46 ft, likely in response to the rebound of the brine interface.

Injection ran throughout the fall, and ammonia probe samples were collected in October and December. In general, the ammonia concentrations decreased at all depths in October, ranging from 1.1 mg/L (well 0785 at 18 ft bgs) to 740 mg/L (well 0781 at 46 ft bgs) (Figures 16 and 17). The brine interface was located at approximately 46 ft bgs.

Figure 14 shows a cross-section through CF4 during injection operations in October. Note how the specific conductance and ammonia concentrations have decreased.

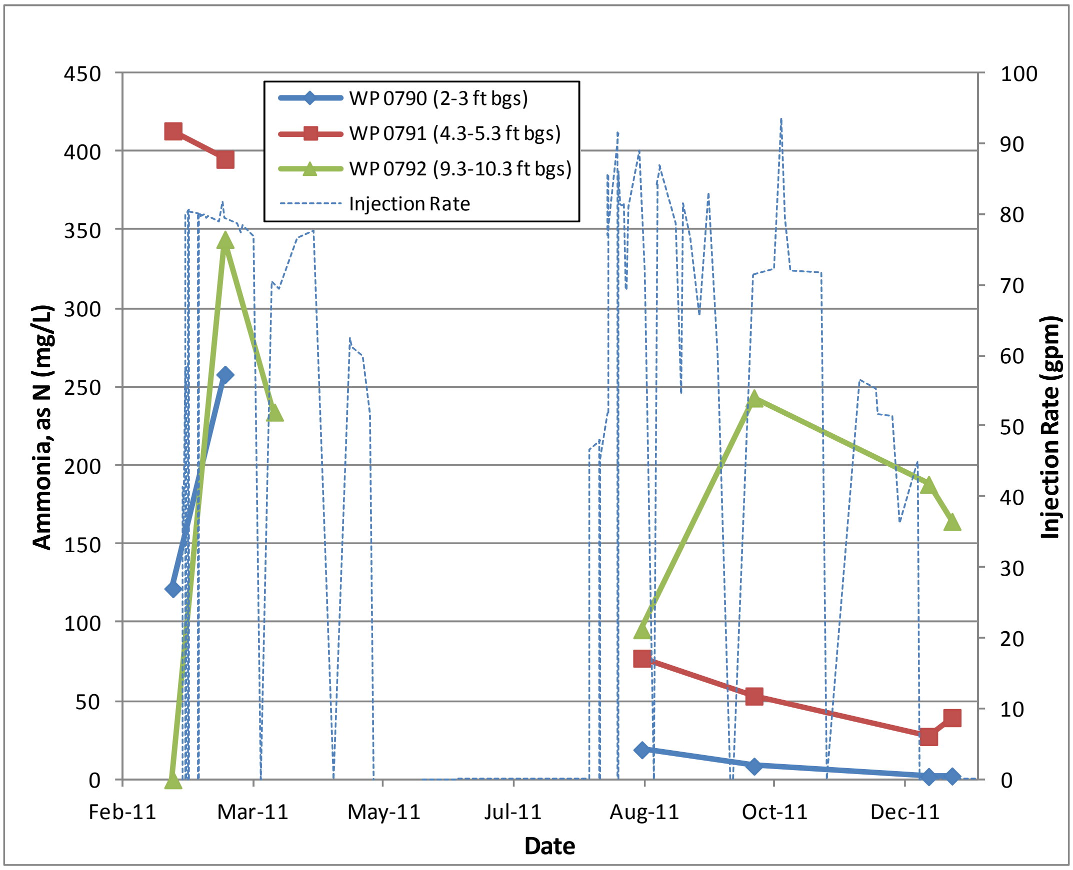
In December, the ammonia concentrations began to increase at all of the observation wells. The injection rate was lower in the injection wells, and the river flow had decreased to 4,000 cfs. Figure 15 shows a cross-section of the CF4 ammonia and specific conductance concentrations after the injection operations had ceased. At this time, the brine interface was between 28 and 33 ft bgs (Figures 16 and 17).

6.3 Well Point Chemical Results

CF4 includes six well points; three are located at the base of the river bank (0790, 0791, and 0792), and three are located across the backwater channel (0793, 0794, and 0795). Well points 0793, 0794, and 0795 are typically dry, and during most of the year, there are access issues when river flow is above 4,000 cfs. Therefore, samples were only collected out of well points 0790, 0791, and 0792 in 2011. Before the start of the injection system, well point 0791 (4.5 to 5.3 ft bgs) had the highest ammonia concentration of 413 mg/L (Figure 18). Specific conductance levels indicated that the brine interface was located below the screened interval of the well points.

Well points were inaccessible during the spring runoff, and samples were not collected again until August, when the injection system was operable. At this time, the ammonia concentrations were greatly reduced to between 19.01 and 95.5 mg/L. The specific conductance dropped significantly in all of the well points to between 1,505 and 5,702 µmhos/cm.

Surface water samples were collected in the CF4 backwater channel in July 2011, when the river flow was 26,900 cfs. The ammonia concentration was 0.021 mg/L, the specific conductance was 549 µmhos/cm, and the uranium concentration was 0.0016 mg/L. All of these concentrations are typical for surface water concentrations during high flow.



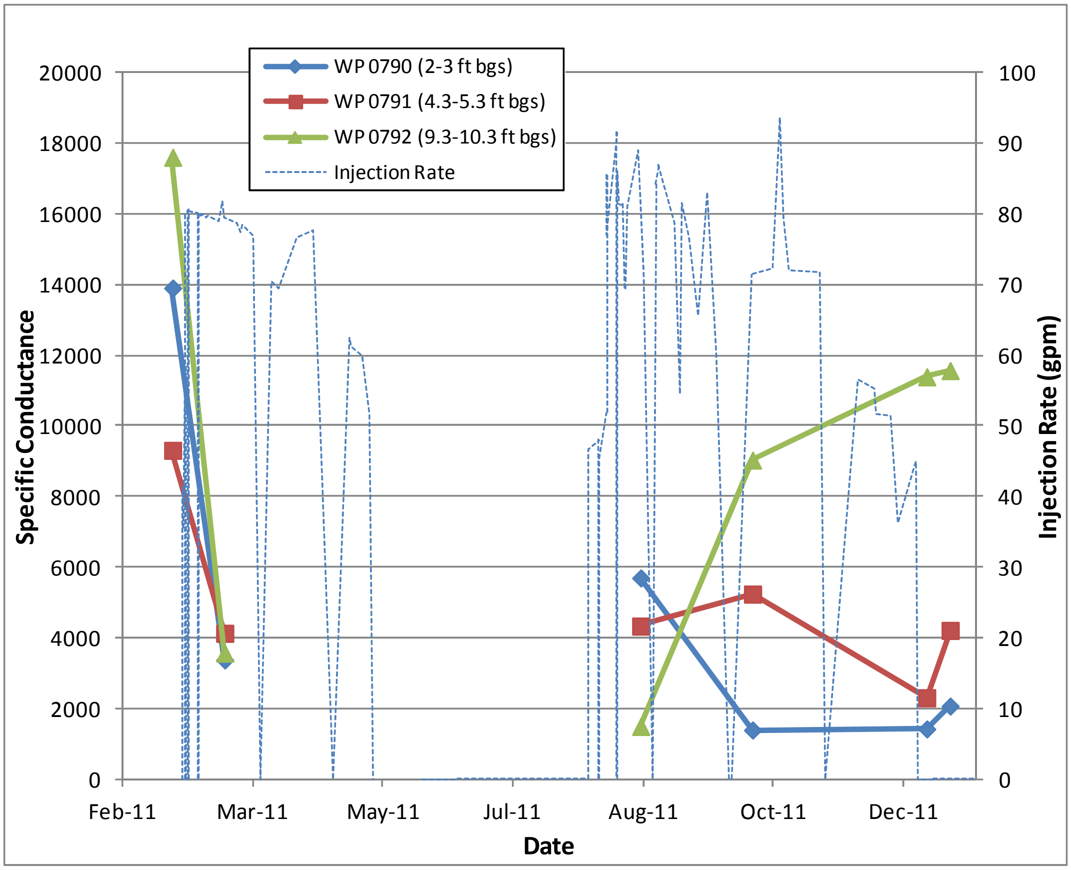


Figure 18. Ammonia and Specific Conductance in Well Points vs. Injection Rate 2011

6.4 Freshwater Mounding

Water levels were collected on a near-daily basis during injection operations and on a weekly basis for the surrounding observation wells. To determine the amount of freshwater mounding in each well, the collected water levels were plotted against the pressure transducer water levels in background well 0405. The water-levels in each well were calibrated to match well 0405 during non-pumping, base-flow conditions.

Tables 5 and 6 summarize the mounding data that is shown in Appendix C, Figures C-1 to C-10 for the injection wells. Figures C-11 to C-18 in Appendix C illustrate the mounding data in CF4 observation wells.

Maximum mounding occurred in each injection well at varying dates in the spring and fall. During the spring run-off, the Colorado River switches from a gaining stream to a losing stream, and water gets stored in the riverbank adjacent to the well field. The backwater channel adjacent to CF4 can impact the water level in nearby injection and observation wells. River flow remained above average from May until December in 2011.

Injection well 0776 had the most mounding, which occurred on April 14, when the injection rate into the well was 1.4 gpm (Table 5). Observation well 0785 had the most mounding on March 9, when the injection rate was 84.3 gpm for all of CF4 (Table 6). Some of the mounding may be the result of the injection well development that occurred in late August, when water was surged into the injection wells.

Table 5. Maximum Mounding Observed in CF4 Injection Wells

Well	Date	Type	Maximum Mounding (ft)	Injection Rate (gpm)
0770	5/9/11	Injection Well	10.04	15.47
0771	11/16/11	Injection Well	10.99	4.33
0772	4/14/11	Injection Well	11.41	5.02
0773	5/9/11	Injection Well	10.20	5.22
0774	5/9/11	Injection Well	10.99	9.72
0775	11/23/11	Injection Well	10.53	13.61
0776	4/14/11	Injection Well	12.60	4.35
0777	9/19/11	Injection Well	7.92	8.3
0778	4/14/11	Injection Well	11.52	6.47
0779	10/6/2011	Injection Well	9.99	2.83

Table 6. Freshwater Mounding Observed in CF4 Observation Wells

Well	Date	Location	Maximum Mounding (ft)	Distance from Injection Source (ft)
0780	8/30/11	Upgradient	2.37	15
0783	5/12/11	Upgradient	1.14	30
0784	4/20/11	Downgradient	2.3	30
0785	3/9/11	Downgradient	3.5	25
0786	4/7/11	Downgradient	1.45	30

The shallow upgradient wells showed up to 2.37 ft of mounding when the cumulative injection rate was 82.52 gpm, while the downgradient shallow wells had a maximum mounding of 3.5 ft (Table 6). This indicates that freshwater injection impacts wells up to 30 ft upgradient and downgradient. The mounding observed in 2011 is much higher than that observed in 2010. This is likely due to the above average river flow in 2011 or because of the higher injection rates.

Figure 19 shows a ground water contour map of CF4 during injection operations in October 2011. The most mounding occurred in the vicinity of remediation well 0776. With a maximum ground water elevation of 3965.71 ft, there was a gradient of at least 9 ft between the river and the remediation wells. Less mounding occurred in the southern area of CF4.

7.0 Surface Water Monitoring

In 2011, the river flow ranged from 3,500 to 48,500 cfs from May until December. Typically, the flow ranges from 3,130 to 23,500 cfs. The river flow was above average during the time of year when the young-of-year pikeminnow may reside in the backwater channel, and a habitat did not form adjacent to the well field in 2011.

Table 7 includes the habitat flow ranges from 2006 to 2011. The only two sections of the backwater channel that currently become a habitat are located adjacent to CF4 and CF1.

Surface water samples were collected in July and December (Table 8). The purpose of the July sampling event was to confirm that no contamination left the site during the flooding, and the December samples were collected as a part of the site-wide sampling event, which takes place during base river flow. All of the sample results indicate that the ammonia concentration was below the acute and chronic criteria, based on temperature and pH.

Background surface water samples collected at the Cisco gaging station in 1999 and 2000 indicate that the uranium concentration in that portion of the river varied from 0.0026 to 0.0066 mg/L (*Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement* [DOE/EIS-0355]). Most of the surface water sample results were below or equivalent to the background concentration. Two locations, CR3 and 0218, had concentrations of 0.014 to 0.016 mg/L (Table 9).

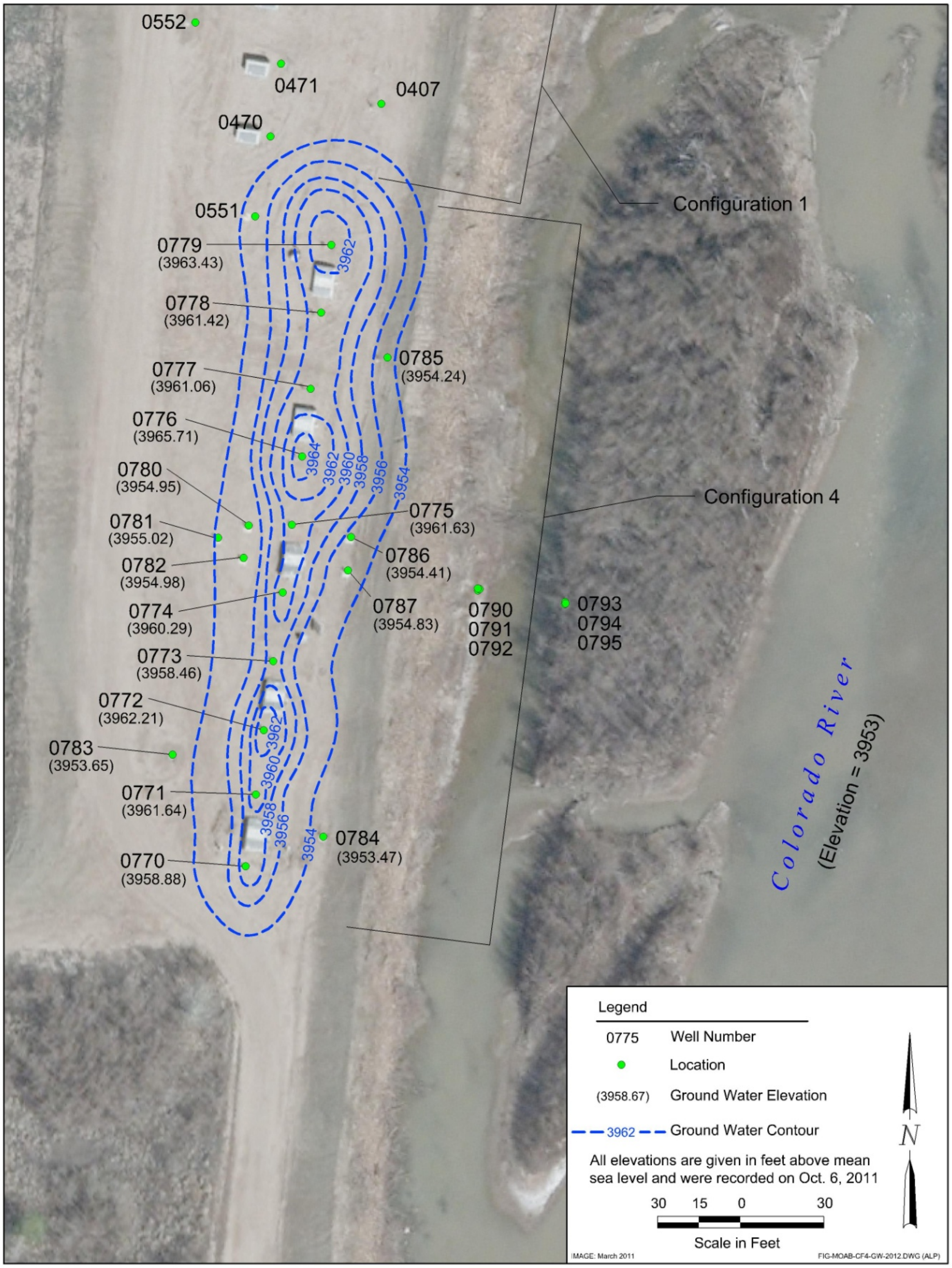


Figure 19. Ground Water Contour Map of CF4 During Injection Operations

Table 7. Habitat Flow Ranges from 2006 to 2011

Well Field Configuration near the River Habitat	2006 Habitat Flow Range (cfs)	2007 Habitat Flow Range (cfs)	2008 Habitat Flow Range (cfs)	2009 Habitat Flow Range (cfs)	2010 Habitat Flow Range (cfs)	2011 Habitat Flow Range (cfs)
1	4,500	5,000-4,000	N/A	4,300-3,700	4,800	~4,000[1]
2	5,400-4,500	6,790-5,500	7,400-6,000	7,800-6,500	8,890-7,000	NA
3	7,500-4,570	6,790-5,700	7,790-7,400	NA	NA	NA
4	NA	<3,400	NA	<3,500	<3,000	<3,000

NA = not applicable (area did not develop into habitat)

[1] The channel adjacent to CF1 did not become a suitable habitat in 2011 because the upriver elevation was lower than the downriver elevation. The flow listed in the table represents the flow at which the channel did not connect to the river on both ends.

Table 8. Surface Water Ammonia Concentrations and Comparisons to State of Utah and Federal Criteria

Loc	Date	Temp (°C)	pH	Ammonia as N (mg/L)	State/Federal AWQC-Acute Total as N[1] (mg/L)	State/Federal AWQC-Chronic Total as N[2] (mg/L)
0274	7/13/11	20.64	7.75	0.021	14.4	2.86
CR1	7/13/11	18.30	7.63	0.1	17.0	3.18
CR5	7/13/11	18.57	7.96	0.1	10.1	2.24
0201	12/7/11	1.8	7.70	0.1	9.65	3.58
0218	12/7/11	2.1	7.59	0.1	11.4	3.98
0228	12/8/11	1.7	8.02	0.17	5.62	2.43
CR1	12/7/11	1.4	8.28	0.1	3.15	1.52
CR3	12/8/11	1.5	7.95	0.1	5.62	2.43
CR5	12/7/11	1.7	7.64	0.1	11.4	3.98

Loc = Location, Temp = Temperature, AWQC = Ambient Water Quality Criteria.

[1] State of Utah, Standards of Quality for Waters of the State (Effective May 1, 2008), Rule R317-2, Table 2.14.2, 1-Hour Average (Acute) Concentration of Total Ammonia as N (mg/L).

[2] State of Utah, Standards of Quality for Waters of the State (Effective May 1, 2008), Rule R317-2, Table 2.14.2, 30-Day Average (Chronic) Concentration of Total Ammonia as N (mg/L), Fish Early Life Stages Present.

7.1 Comparative Elevation Study of the Backwater Channels

An elevation survey was conducted in the backwater channels adjacent to the well field in March and again in December. Elevations were measured in a series of west/east profiles along the backwater channels of CF2, CF1, and CF4 to determine if 2011 spring runoff impacted the morphology of these areas. Patterns of erosion and deposition can be observed by comparing the elevations from March to December. Figure 20 shows the cross-section profiles through the CF1, CF2, and CF4 backwater channels in March and December.

Table 9. Surface Water Uranium Concentrations

Location	Date	Uranium Concentration (mg/L)
0274	7/13/11	0.0016
CR1	7/13/11	0.0016
CR5	7/13/11	0.0018
0201	12/7/11	0.005
0218	12/7/11	0.014
0228	12/8/11	0.0066
CR1	12/7/11	0.0043
CR3	12/8/11	0.016
CR5	12/7/11	0.006

CF2

From March to December, the CF2 backwater channel had nearly 3 ft of deposition along the banks and base of the backwater channel (Figure 20). During the high runoff, this area contained stagnant water and abundant debris, so it is possible that the debris contributed to the deposition. The only portions of the cross-section that did not change in elevation were the upper western riverbank (downgradient of the well field) and along the top of the sand bar, just east of the channel. As of December, the elevation of the bottom of the channel was 3,955.89 ft above mean sea level (msl), compared to 3,953.13 ft msl in March.

CF1

Elevation data indicate that the bottom of the channel has eroded since March (Figure 20). The eastern bank of the backwater channel and the sand bar adjacent to the river have approximately 1.5 ft of deposition. This channel had water flowing through to the river until the river flow reached approximately 3,500 cfs. The flow would likely be enough to cause 1 ft of erosion from March to December.

CF4

The profile data suggest that some slight erosion took place in the channel bottom (approximately 1 ft). More than 2 ft of sediment was deposited on the eastern bank of the channel. This channel contains river water year-round, so it is possible that the flow contributed to the 1 ft of erosion. From north to south, the elevation drops significantly from CF2, south towards CF4. In December, the elevation of the CF2 channel was 3,956 ft msl, and there is a drop of approximately 3.3 ft before the channel reaches the center of the CF1 channel. There is an additional drop of 2.0 ft between CF1 and CF4 (Figure 20). The gradient of the base of the backwater channel from north to south is 0.01.

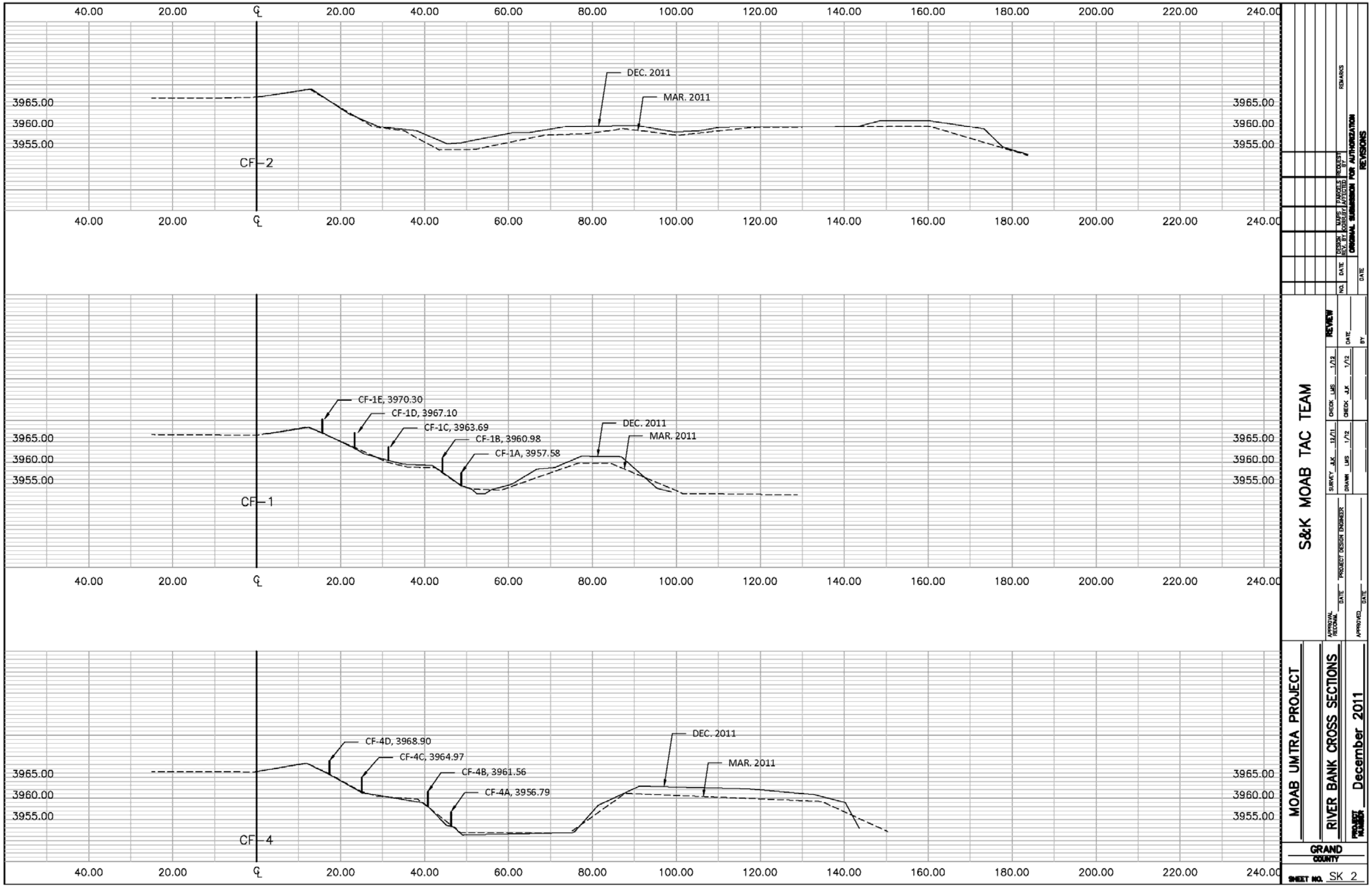


Figure 20. March and December 2011 Survey Comparison Across CF2, CF1, and CF4 Side Channels

8.0 Investigations

8.1 Evaporation Pond Water Level Investigation

In late June, a pressure transducer was added to the evaporation pond that accurately measures the level of the water stored within the pond. Using the data collected by the transducer, it was possible to check the accuracy of the volume of water added to the pond by the extraction system and the volume of water removed by the water trucks. During extended time periods when no water was being added or removed from the pond, it was also possible to measure the evaporation rate.

In early September, flow meters were added to the evaporation units that discharge over the pond. Using the data collected from these meters in conjunction with the transducer data, it was possible to estimate how efficient the evaporator units were at removing water from the system. All results are provided in Appendix B.

8.2 Ground Water Treatment Process Development

In 2011, Golder and Associates was contracted to complete treatability studies on the ground water in support of treatment process development and design of a ground water treatment system. A variety of treatment alternatives for removing ammonia and uranium from site ground water were addressed as part of this investigation, and all bench scale testing was completed with the assistance of the Colorado Mesa University Department of Physical and Environmental Sciences.

Two treatment options are presented in Golder's draft "Ground Water Treatment Process Development" (August 2011) in Attachment 1. The first option incorporates chemical precipitation, utilizing co-precipitation agents (either iron or barium), for removing uranium from the ground water. Under this treatment option, lime would then be added for pH adjustment, and the water would then be pumped through a passive pond-type system with aeration and mixing to promote ammonia removal.

The second option is similar to the first option, but includes a series of three stripping towers for ammonia removal as opposed to using treatment ponds. Details regarding these treatment options, including capital and annual operations and maintenance costs, are included in Attachment 1.

8.3 Air Quality Modeling

Air modeling was completed by the Applied Research Center at Florida International University to estimate the air pollution potential of ground water contaminants at a variety of receptor points when equipment is utilized to enhance evaporation and disperse ground water into the air. A Gaussian air dispersion model was used to air concentrations for a number of ground water contaminants as a function of distance to the point source. The average wind velocity and direction measured at the site weather station, ammonia and metal concentrations measured in ground water, and evaporator operating specifications were used as model inputs. The point source for the modeling was set adjacent to the evaporation pond, where the evaporation units are located.

The final report, “An Air Quality Model of Ground Water Evaporation System for the UMTRA Project, Moab, Utah,” (February 2011), is provided in Attachment 2. By assuming steady-state emissions and a fully developed plume, the modeling methodology provides a conservative estimate of the maximum concentration for a number of receptor points. The evaporator’s large flow rate ratio of air to water (1500:1 by volume) provides significant dilution at the point source, reducing the air contaminant concentrations.

The modeling results indicate that all ammonia concentrations will be below the Occupational Safety and Health Administration (OSHA) 8-hour exposure limit for the various receptors, which include on top of the tailings pile (600 ft from the point source), the vicinity of the Moab site administrative offices (0.5 mile from the point source), the Matheson Wetlands Preserve (1 mile from the point source), the city of Moab (3 miles from the point source), and Arches National Park (0.8 miles from the point source).

The modeling results also indicate that the maximum computed concentrations in air are negligible compared to OSHA’s exposure limits for all contaminants. Taking into account that the evaporation units are controlled by a nearby weather station that automatically shuts off the pumps supplying the units when the pre-set wind speed or direction are exceeded, there are no adverse impacts associated with this evaporation system.

8.4 Northeastern Uranium Plume Investigation

An investigation of the northeastern uranium plume, located north of the IA well field, was completed in 2011. This area of concern lies within the boundary of the former millsite and in the vicinity of the historical unlined trash pits.

Sixteen boreholes were investigated, and soil samples were analyzed for radium-226 and the ground water was analyzed for uranium. The results indicated that there is no correlation between ground water contamination and soil contamination. The soil with the highest radium-226 concentration was located in the shallow sample depths. Uranium concentrations in the shallow ground water were the highest in the vicinity of the former millsite, and an intermediate depth uranium plume was documented in the southeastern portion of the investigation area. There is not a correlation between the soil and ground water contamination, and sample results indicate that there is not a single source of contamination. The summary report, *Moab UMTRA Project Northeastern Uranium Plume Investigation Report* (DOE-EM/GJTAC2020), was submitted in January 2012.

8.5 Ground Water Flow Model Development

A.D. Laase Hydrologic Consulting was contracted to develop a ground water flow model for the Moab site in 2011. Previous modeling for the site was developed using the FEFLOW program (in Section 7.0 of *Site Observation Work Plan for the Moab, Utah, Site* (GJO-2003-424); however, it was difficult to update the model with current site data using this code and run simulations.

The SEAWAT program transient flow model was developed using Ground Water Vistas (V6) as the interface, and consists of 15 layers with 25-ft by 25-ft grid cells. Temporally, the model was divided into 13 stress periods (an initial steady-state period followed by 12 transient stress periods corresponding to the months) to simulate the changing Colorado River flows that impact the ground water system underlying the site. Documentation containing details regarding the model configuration and calibration are contained in Attachment 3.

8.6 Mass Flux Discharge Estimation

Although ground water extraction captures contaminants before discharging to the Colorado River, some mass is not captured. To estimate the mass that may discharge a simple investigation was conducted. This investigation included assessing the area of discharge, the ground water contaminant concentrations and ground water flow rate.

The reach along the river was segregated horizontally into zones based on ground water monitoring points that are located along (or as close as possible in areas with limited points) the river bank. These zones were then divided vertically based on the depth to the brine interface in that vicinity. The top of the brine interface was assumed to be the bottom of the cell, as the ground water flow below the interface is considered to be minimal, and the contaminants tend to concentrate at this depth. In general, a shallow zone extended from the ground water surface to 10 ft below the ground water surface, a middle zone from 10 to 25 ft below the ground water surface, and the deep zone extends from 25 to 40 ft below the ground water surface.

A spreadsheet was prepared to calculate the cross-sectional area of each of these two-dimensional cells, and the ground water discharge was calculated by multiplying this area by the Darcy velocity. A hydraulic conductivity of 30 ft/day (same as the calibrated ground water flow model) and a hydraulic gradient of 0.0013 ft/ft (as measured under river base flow conditions) were applied.

Contaminant concentrations were then applied horizontally to the end of each cell, and an average was calculated for the middle of the cell. Vertically a concentration was calculated based on the chemical data at the specified depth, with emphasis on keeping a vertically stratified flow regime. The most recent data available were used, with older data filled into cells as necessary.

The cell mass flux was calculated by multiplying the concentration by the ground water discharge. This mass flux calculation follows the procedure as presented in the *Mass Flux Toolkit, V 1.0* (Farhat and Newell, 2006). A total mass flux discharge to the river was calculated by adding the values for all included cells.

Based on this calculation, the site discharges and estimated 58.5 lbs/day of ammonia and 0.6 lbs/day of uranium under river base flow conditions.

9.0 Summary and Conclusions

In 2011, the IA operations focused on ground water extraction in the spring and fall and on and fresh water injection in the spring, fall, and winter. The above average snow-melt runoff greatly impacted the operations, such that the well field operations were suspended from late May through August.

The ammonia mass removal rate was higher in 2011 than it has been for the past 5 years. In 2011, the uranium mass removal rate has slightly decreased from the 2010 rate, but is higher than previous years. Figure 21 shows that while less ground water was extracted in 2011, the mass removal rate of ammonia and uranium was maximized.

Figures 22 and 23 display the mass of ammonia and uranium removed since 2007, respectively. As these figures display, the contaminant mass removal correlates with the volume of ground water extracted. The significant decrease in the volume of ground water extracted and corresponding ammonia and uranium mass removal after 2009 is a result of site activities, specifically the removal of the sprinkler system from the top of the tailings pile as the tailings relocation was instigated. With the removal of this system the capacity to evaporate water was significantly reduced, and it was not possible to continue ground water extraction starting in 2010 at a comparable rate.

A drip system was added to the IA system in spring of 2011 to assist in the removal of extraction water. The system was utilized in April and May and again in October in addition to the two evaporator units and the water truck removal. This system may be utilized in the future based on site conditions.

Nearly 11,000,000 gal of freshwater were injected during 2011. This is the highest volume injected since the construction of the IA well field in 2004. The injection system operated from March until May and again from August until December at a rate of up to 93 gpm. The ammonia and specific conductance concentrations indicated that injection helped to suppress the brine interface and dilute contaminants adjacent to the backwater channel.

The contaminant mass flux discharging into the river was estimated for river base flow conditions. This calculation, which was completed initially in 2011, estimates that up to 58.5 lbs of ammonia and 0.6 lbs of uranium discharges into the river per day. This calculation does not consider when the Colorado River is under losing conditions, and the mass flux is significantly less.

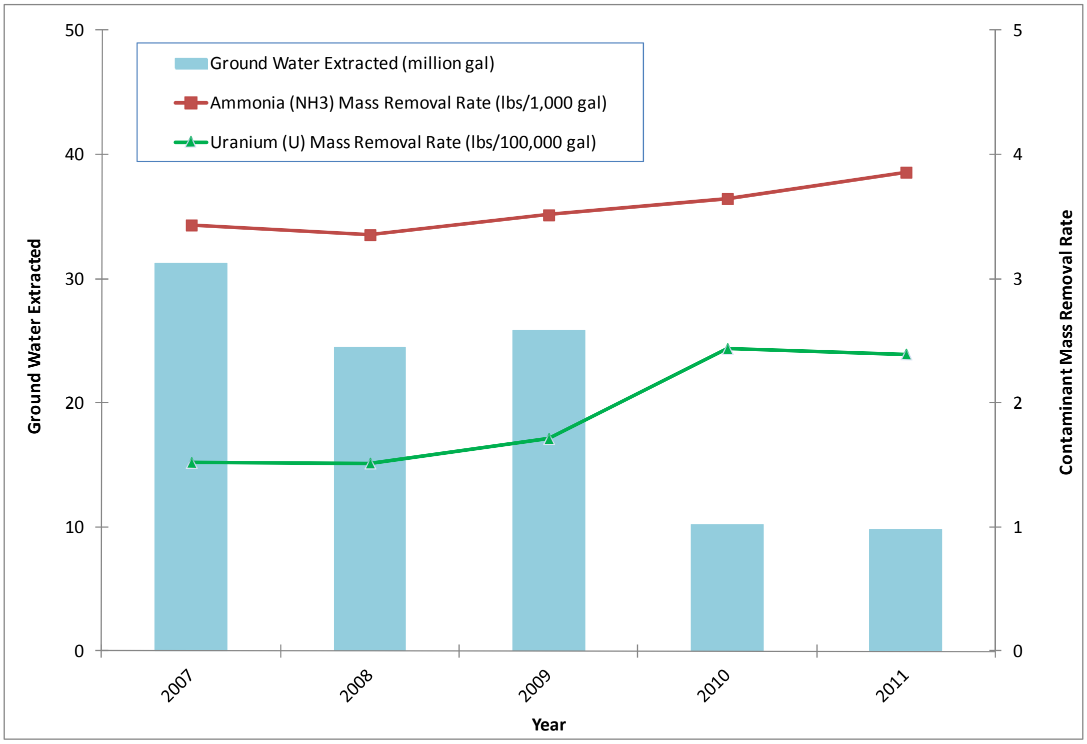


Figure 21. Ground Water Extraction vs. Mass Removal for 2007 Through 2011

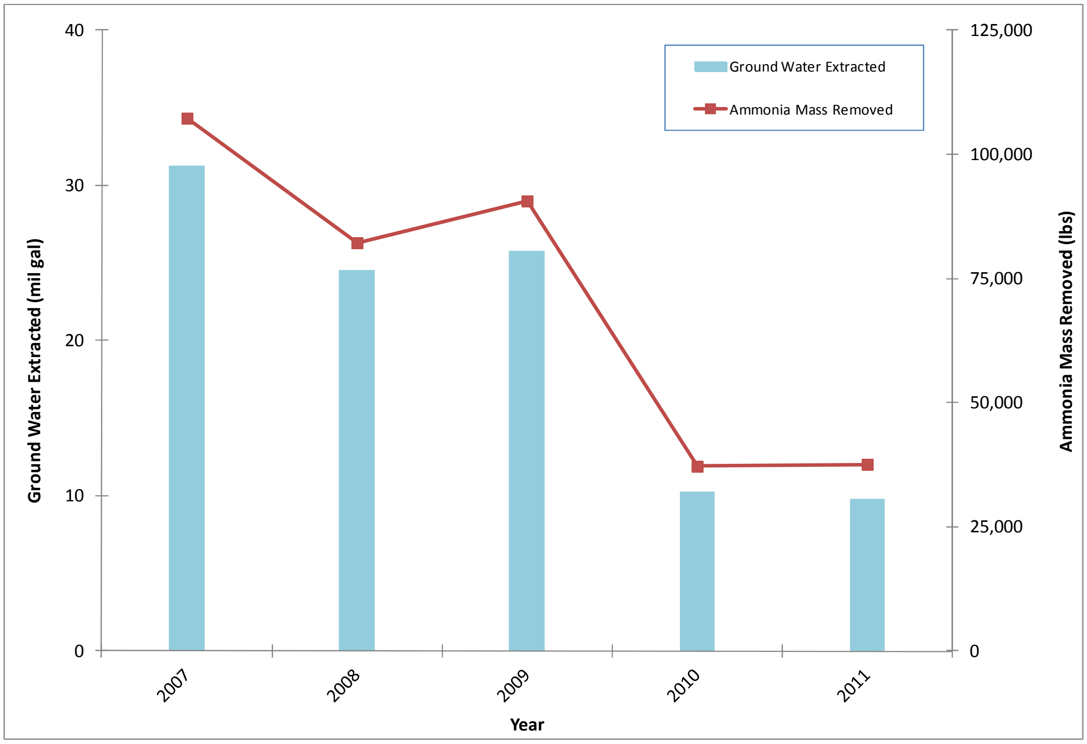


Figure 22. Volume of Ground Water Extracted and Ammonia Mass Removal, 2007 Through 2011

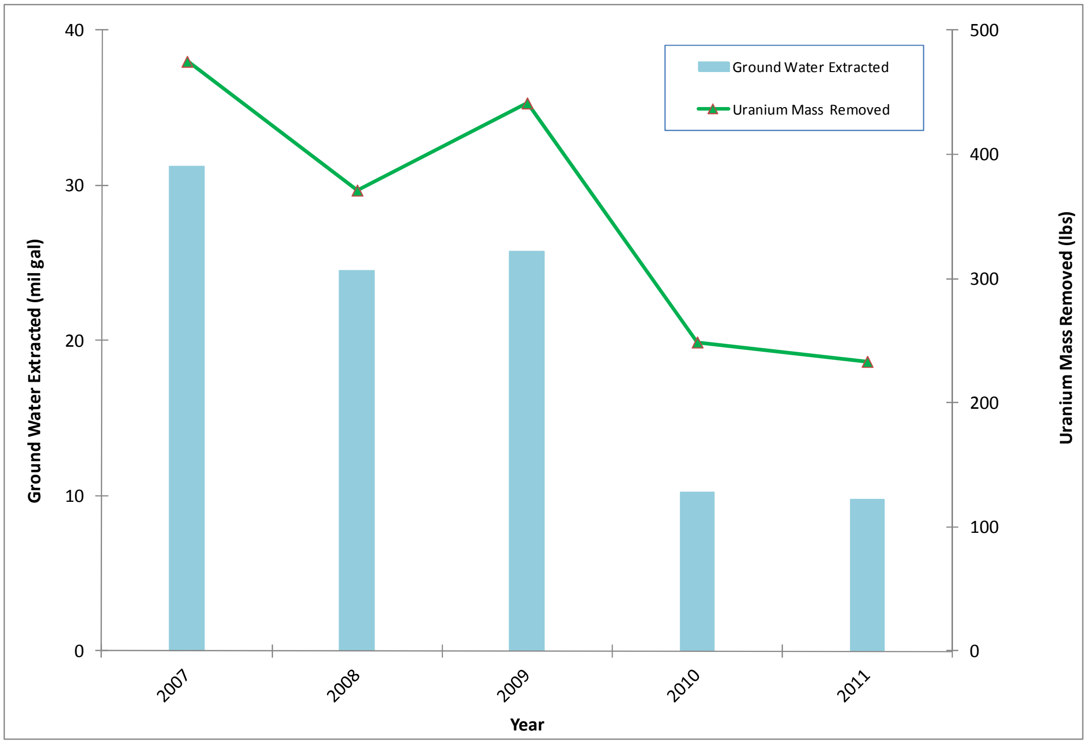


Figure 23. Volume of Ground Water Extracted and Uranium Mass Removal, 2007 Through 2011

None of the adjacent backwater channels became a suitable habitat in 2011 due to the high river flow. All of the surface water samples had ammonia and uranium concentrations within background values. An elevation survey of the backwater channel before and after the peak runoff indicated that the deposition occurred in the vicinity of CF1 and CF2; however, slight erosion was noted in the backwater channel adjacent to CF4.

The installation of a pressure transducer in the evaporation pond to collect the pond level on a hourly basis enabled the measurement of evaporation from the pond, which ranged from 0.4 gpm (measured in late December 2011) to 22.7 gpm (measured in late June 2011). Using these data in combination with the evaporator inflow rate, the evaporator unit efficiency was estimated to range in September 2011 from approximately 5 to 12 percent.

An investigation regarding ground water treatment as an alternative to evaporation was completed that identified two viable options for removal of ammonia and uranium from site ground water. Air quality modeling was performed to determine if there were any health risks associated with the use of evaporator units. Based on the modeling results, all air contaminant concentrations associated with the discharge of site ground water from the evaporators are below OSHA exposure limits at a variety of receptor locations.

A three-phased investigation of the uranium plume located to the northeast of the tailings pile identified a number of small source areas as opposed to a single source. In addition, a numerical ground water flow model for the site was developed and calibrated, and will be used to simulate changes to the ground water flow system based on various treatment options.

10.0 References

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Appendix A.
Tables and Data for 2011 Ground Water Extraction

Table A-1. Summary of Well Construction in CF5

Well	Well Type/ Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0810	Extraction	8	3,966.56	10.4 – 40.4	40.4
0811	Extraction	8	3,966.59	8.6 – 38.6	38.6
0812	Extraction	8	3,966.62	14.2 – 44.2	44.2
0813	Extraction	8	3,966.67	14.4 – 44.4	44.4
0814	Extraction	8	3,967.02	12.4 – 42.4	42.4
0815	Extraction	8	3,967.13	21.7 – 51.7	51.7
0816	Extraction	8	3,967.38	20.9 – 50.9	50.9
SMI-PW02	Extraction	4	3,965.60	20 – 60	60.3
0810-OBS	Observation/Shallow	1.5	3,966.90	4.4 – 14.4	14.4
0811-OBS	Observation/Shallow	1.5	3,967.20	4.4 – 14.4	14.4
0812-OBS	Observation/Shallow	1.5	3,966.94	3.5 – 13.5	13.5
0813-OBS	Observation/Shallow	1.5	3,967.01	4.4 – 14.4	14.4
0814-OBS	Observation/Shallow	1.5	3,967.03	3.4 – 13.4	13.4
0815-OBS	Observation/Shallow	1.5	3,967.00	3.4 – 13.4	13.4
0816-OBS	Observation/Shallow	1.5	3,967.19	3.3 – 13.3	13.3

Table A-2. Chronology for CF5 in 2011

Date	River Flow (daily mean cfs)	Activity
1/30/11	1,270	RAC began pulling water from the evaporation pond.
3/24/11	4,860	Sampled wells 0810 and 0812 for Golder bench test.
3/31/11	4,400	Tested extraction system; ran ~20 minutes.
4/12/11 – 4/13/11	6,440 – 6,790	Performed 1-hour pump tests on all CF5 extraction wells. Started extraction.
4/20/11		Started running evaporators.
4/26/11	10,500	Wells 811 (22 gpm), 812(19 gpm), 813 (48 gpm), 815 (36 gpm), and PW02 (50 gpm) running overnight (total 175 gpm in morning). Started 810 after repairing leak (27 gpm) at 13:35. Well 814 turned on (49 gpm) at 16:00. Also started 816 at 16:10 (38 gpm, could not pump lower rate). At 38 gpm from 816, near capacity of landshark tank. Turned off at 16:27; all 7 other wells left running overnight. Total pumping rate 247 gpm at end of the day.
4/27/11	10,400	Sampled CF5 wells 0810-0816 and PW02 (RIN 1104057).
5/31/11	35,800	Well field shut down due to high river flow.
8/24/11	4,750	Tested extraction at PW02 starting at 0845; ran for 2 hours.
9/8/11	5,200	PW02 ran all day. Wells 0811, 0812, and 0813 were started at 7:30 and ran until 16:40. LS2 was started at 8:30 and ran until 16:40 pumping 36,385 gal.
10/4/11 – 10/5/11	4,710 – 4,930	Sampled wells 0810, 0811, 0812, 0813, and PW02.
10/7/11	5,640	Started 810 @ 10:00 for drip system and PW02 for LS. Went inside Contamination Area; found both control panels for LS units knocked down due to yesterday's winds. Able to get LS1 running; LS2 did not work. Switched valves and ran LS1 at ~32 gpm starting at 10:30. Adjusted PW02 to ~35 gpm. At 15:00 had to shut down LS1 due to work on 814/815 electrical system; also shut down 810 and PW02 at 15:15.
11/11/11	4,010	Landshark was winterized for the season.
11/15/11	4,120	Winterized wells 0812, 0811, PW02, and 0810.
11/18/11	3,800	Winterized wells 0813, 0814, 0815, 0816. The lateral lines were also drained.
12/15/11	4,260	PW02 was shut off at 10:00 and the lines were drained and winterized.

Table A-3. Extraction Volumes

Month	Ground Water Volume Extracted (gal)							
	Well 0810	**Well 0811**	**Well 0812**	**Well 0813**	**Well 0814**	**Well 0815**	**Well 0816**	**Well PW02**
Mar-11	150,629	0	1,922	1,811	1,230	3,004	3,188	2,841
Apr-11	121,684	130,645	106,191	202,767	118,044	194,448	8,137	817,414
May-11	868,153	87,824	435,718	396,138	558,187	175,981	430,363	1,025,890
June-11	0	0	31,564	0	42,895	0	85,900	0
July-11	0	0	0	0	0	0	0	0
Aug-11	0	0	0	0	0	0	0	8,917
Sept-11	210,270	155,211	149,040	122,449	0	0	0	2,127,088
Oct-11	13,917	211	398	0	0	0	0	204,617
Nov-11	12,632	0	0	0	0	0	0	48,609
Dec-11	0	0	0	0	0	0	0	555,394
2011 Total Volume	**1,377,285**	**373,891**	**724,833**	**723,165**	**720,356**	**373,433**	**527,588**	**4,790,770**

Q = average rate; vol = volume

Table A-4. Estimated Ammonia Mass Withdrawals at CF5 Extraction Wells During 2011

Ammonia Mass Removal								
Month	**Well 0810**		**Well 0811**		**Well 0812**		**Well 0813**	
	Conc. (mg/L)	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**
Mar-11	350	200	520	2.1	550	4.0	330	2.3
Apr-11	350	161	520	257	550	243	330	253
May-11	350	1086	520	173	550	907	330	495
June-11	350	6.4	520	0	550	66	330	0
Sept-11	350	309	520	306	550	310	330	153
Oct-11	300	158	440	0	360	0	160	0
Nov-11	300	14	440	0	360	0	160	0
Dec-11	300	0	440	0	360	0	160	0
Total	**NA**	**1,934**	**NA**	**738**	**NA**	**1,530**	**NA**	**903**

Month	**Well 0814**		**Well 0815**		**Well 0816**		**Well PW02**	
	Conc. (mg/L)	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**
Mar-11	320	1.5	350	4.0	210	2.5	570	6.1
Apr-11	320	141	350	258	210	6.5	570	1764
May-11	320	676	350	233	210	342	570	2213
June-11	320	52	350	0	210	68	570	0
Aug-11	ND	0	ND	0	ND	0	570	787
Sept-11	ND	0	ND	0	ND	0	570	3822
Oct-11	ND	0	ND	0	ND	0	520	403
Nov-11	ND	0	ND	0	ND	0	520	96
Dec-11	ND	0	ND	0	ND	0	520	1093
Total	**NA**	**870**	**NA**	**495**	**NA**	**419**	**NA**	**10,184**

kg = kilograms, NA = not applicable

Table A-5. Estimated Uranium Mass Withdrawals at CF5 Extraction Wells During 2011

Uranium Mass Removal								
Month	**Well 0810**		**Well 0811**		**Well 0812**		**Well 0813**	
	Conc. (mg/L)	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**
Mar-11	3.5	2.0	2.7	0	2.3	0	0.94	0
Apr-11	3.5	1.6	2.7	1.3	2.3	1.0	0.94	0.7
May-11	3.5	10.9	2.7	0.9	2.3	3.8	0.94	1.4
June-11	3.5	0.6	2.7	0	2.3	0.3	0.94	0
Sept-11	3.5	2.8	2.7	1.6	2.3	1.3	0.94	0.4
Oct-11	2.6	1.1	2.0	0	1.9	0	0.91	0
Nov-11	2.6	0.1	2.0	0	1.9	0	0.91	0
Dec-11	2.6	0	2.0	0	1.9	0	0.91	0
Total	**NA**	**19.1**	**NA**	**3.8**	**NA**	**6.4**	**NA**	**2.6**
Month	**Well 0814**		**Well 0815**		**Well 0816**		**Well PW02**	
	Conc. (mg/L)	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**	**Conc. (mg/L)**	**Removed (kg)**
Mar-11	2.7	0	3.4	0	2.3	0	3.0	0.8
Apr-11	2.7	1.2	3.4	2.5	2.3	0.1	3.0	9.3
May-11	2.7	5.7	3.4	2.3	2.3	3.7	3.0	11.7
June-11	2.7	0.4	3.4	0	2.3	0.7	3.0	0
Aug-11	ND	0	ND	0	ND	0	3.0	4.1
Sept-11	ND	0	ND	0	ND	0	3.0	20.1
Oct-11	ND	0	ND	0	ND	0	3.9	3.0
Nov-11	ND	0	ND	0	ND	0	3.9	0.7
Dec-11	ND	0	ND	0	ND	0	3.9	8.2
Total	**NA**	**7.3**	**NA**	**4.8**	**NA**	**4.5**	**NA**	**57.9**

kg = kilograms, NA = not applicable, ND = no data

Table A-6. Computed Specific Capacities at CF5 Extraction Wells During 2011

Well	Static DTW (ft btoc)	Measured DTW (ft btoc)	Drawdown (ft)	Pumping Rate (gpm)	Specific Capacity (gpm/ft)
0810	7.59	11.90	4.31	22.13	5.13
		14.50	6.91	32.11	4.65
		17.04	9.45	39.67	9.45
		20.29	12.7	48.46	3.82
0811	8.23	10.56	2.33	13.19	5.66
		13.05	4.82	30.81	6.39
		15.00	6.77	41.26	6.09
		17.12	8.89	51.54	5.80
0812	6.69	12.98	6.29	24.78	3.94
		15.22	8.53	29.97	3.51
		19.78	13.09	41.56	3.17
		23.55	16.86	49.78	2.95
0813	8.45	8.59	0.14	15.30	109
		8.77	0.32	28.79	89.97
		8.97	0.52	41.77	80.33
		9.09	0.64	50.36	78.69
0814	5.83	7.05	1.22	15.20	12.46
		8.85	3.02	33.30	11.03
		9.99	4.16	42.24	10.15
		11.22	5.39	51.66	9.58
0815	7.94	12.10	4.16	25.8	6.20
		13.93	5.99	33.92	5.66
		15.85	7.91	41.18	5.21
		19.64	11.7	53.30	4.56
0816	6.61	8.36	1.75	13.13	7.50
		8.60	1.99	27.11	13.62
		9.11	2.5	43.29	17.32
		9.61	3.0	50.51	16.84
PW02	12.17	14.77	2.6	28.88	11.11
		15.95	3.78	40.08	10.60
		17.10	4.93	50.84	10.31

ft btoc = feet below top of casing

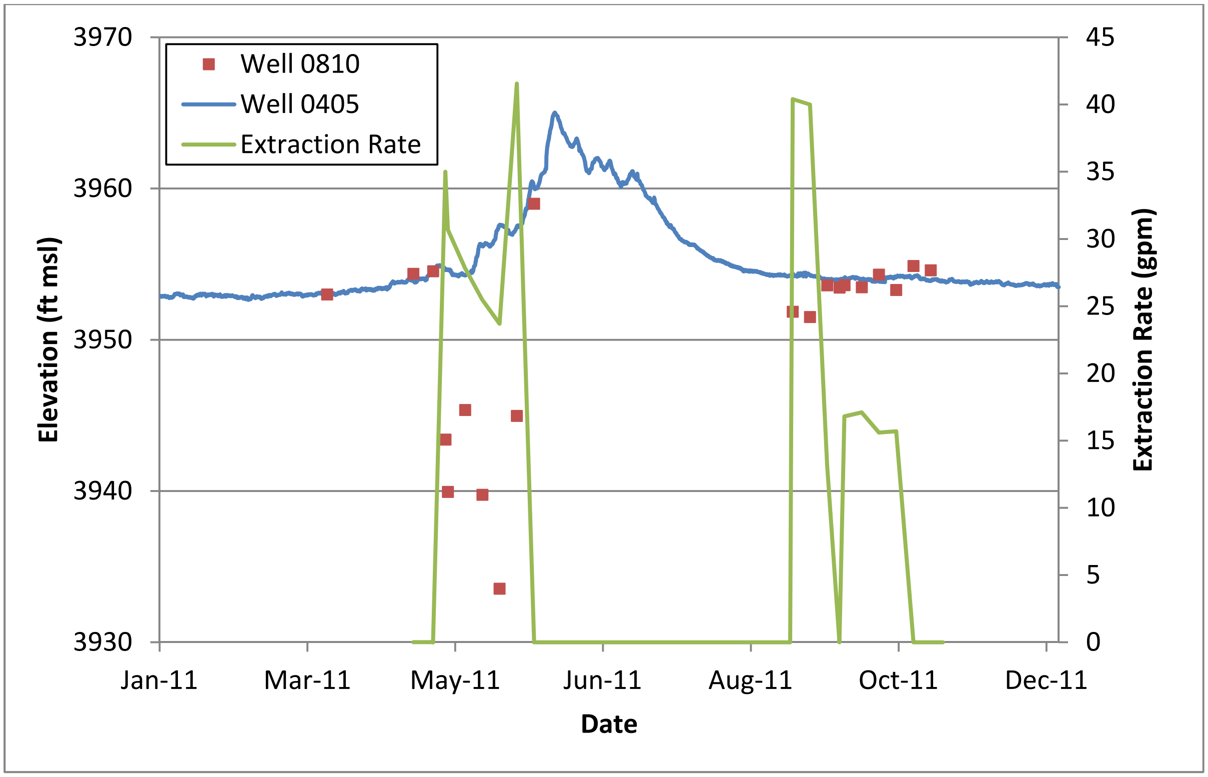


Figure A-1. Observed Drawdown at Well 0810

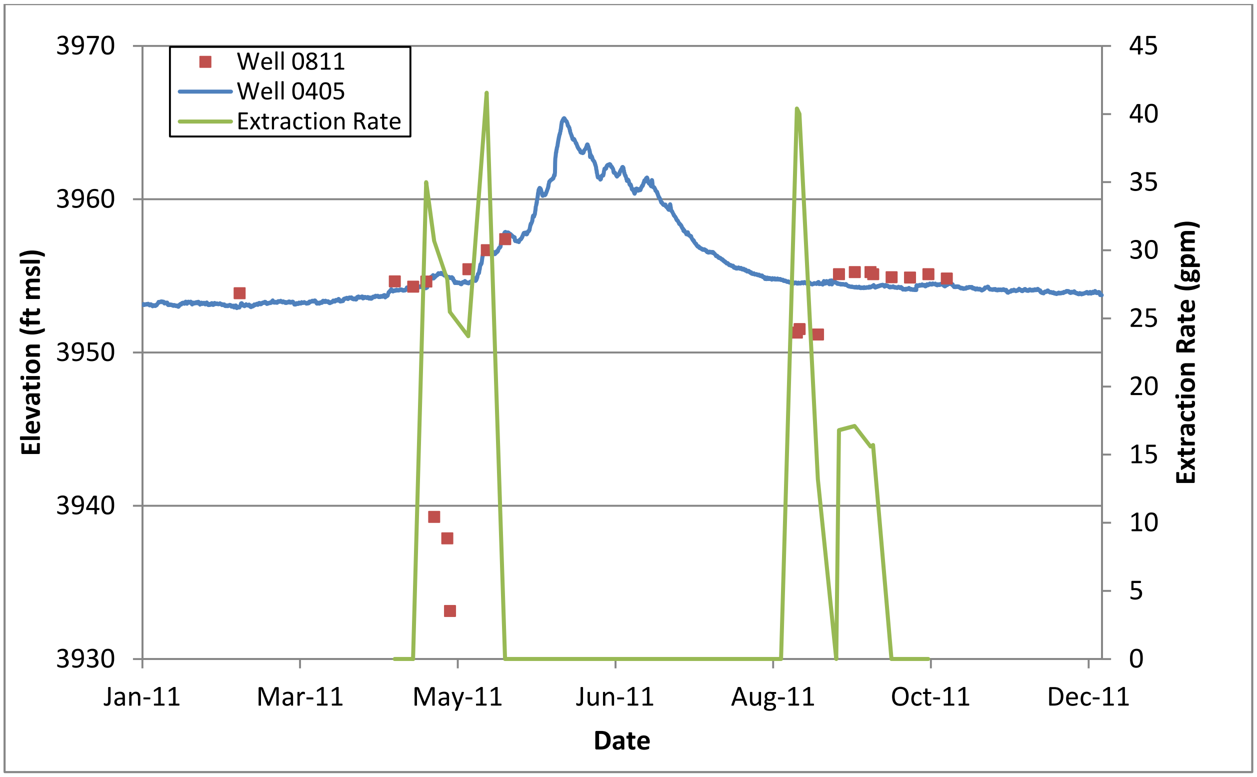


Figure A-2. Observed Drawdown at Well 0811

Appendix B.
Evaporation Pond Data 2011

Table B-1. Important Dates, Evaporation Pond Levels, and Activities Associated with the IA Treatment Systems During 2011

Date	Pond Level (ft)	Activity
1/30/11	8.5	RAC began pulling water from the evaporationb pond.
3/31/11	6.7	Tested extraction system; ran ~20 minuntes
4/12/11 – 4/13/11	5.3	Performed 1-hour pump tests on all CF5 extraction wells. Started extraction.
4/20/11	4.6	Started running evaporators.
4/26/11	6.9	Started continuous pumping from seven of eight CF5 wells at a total flowrate of 247 gpm.
4/27/11	6.9	Sampled CF5 wells 0810 through 0816 and PW02 (RIN 1104057).
5/2/11	8.5	Sampled evaporation pond at two depths at two locations (RIN1105058).
5/10/11	8.9	Repair performed to run second evaporator under weather station.
5/31/11	10.0	Well field shut down due to high river flow.
8/24/11	4.7	Started extracting at PW02 after flooding.
8/22/11 – 9/19/11	4.7 – 7.9	Mike Zimmerman Well Service developed CF4 and CF5 wells.
8/22/11 – 9/26/11	4.7 – 8.0	KAP Electric restored power to wellfield.
9/8/11 – 9/26/11	4.7 – 8.0	CB Earthworks upgraded plumbing in wellfield.
9/8/11	6.4	Started extracting from wells 0810, 0811, 8012, and 0813.
10/4/11 – 10/5/11	7.6	Sampled wells 0811, 0812, 0813, and PW02 (RIN1110061).
10/7/11	7.6	Started pumping from 0810 and PW02 at a limited schedule to minimize volume extracted to the pond.
11/11/11	6.1	Landshark was winterized for the season.
11/15/11	5.8	Winterized wells 0812, 0811, PW02, and 0810.
11/18/11	5.8	Winterized wells 0813, 0814, 0815, and 0816. The lateral lines were also drained.
11/21/11	5.5	Sampled evaporation pond (RIN1111062).
12/15/11	5.5	PW02 was shut off and the lines were drained and winterized.

Table B-2. Evaporation Pond Level and Volume for 2011

Date	Pond Level (ft)	Pond Volume (gal)
1/6/11	8.5	3,966,056
1/13/11	8.5	3,966,056
1/20/11	8.5	3,966,056
1/27/11	8.5	3,966,056
2/3/11	8.5	3,966,056
2/10/11	8.5	3,966,056
2/17/11	8.5	3,966,056
2/24/11	8.4	3,876,852
2/24/11	8.4	3,876,852
3/3/11	8.4	3,876,852
3/10/11	8.4	3,876,852
3/17/11	8.0	3,530,231
3/24/11	7.5	3,119,888
3/31/11	6.7	2,516,342
3/31/11	6.7	2,516,342
4/7/11	5.6	1,792,980
4/14/11	5.3	1,617,105
4/21/11	4.6	1,242,404
4/28/11	6.9	2,661,113
4/28/11	6.9	2,661,113
5/5/11	8.5	3,966,056
5/12/11	8.9	4,333,063
5/19/11	10.0	5,426,423
5/26/11	10.3	5,746,017
6/2/11	10.0	5,426,423
6/2/11	10.0	5,426,423
6/9/11	9.3	4,716,379
6/16/11	8.7	4,147,521
6/23/11	8.0	3,530,231
6/30/11	7.3	2,962,886
6/30/11	7.3	2,962,886
7/7/11	6.8	2,588,218

Table B-2. Evaporation Pond Level and Volume for 2011 (continued)

Date	Pond Level (ft)	Pond Volume (gal)
7/14/11	6.5	2,375,648
7/21/11	6.4	2,306,830
7/28/11	6.3	2,239,031
7/28/11	6.3	2,239,031
8/4/11	5.6	1,792,980
8/11/11	5.3	1,617,105
8/18/11	4.9	1,396,874
8/25/11	4.7	1,292,875
9/1/11	5.4	1,674,711
9/1/11	5.4	1,674,711
9/8/11	6.4	2,306,830
9/15/11	7.4	3,040,877
9/22/11	7.9	3,446,124
9/29/11	8.0	3,530,231
9/29/11	8.0	3,530,231
10/6/11	7.6	3,199,918
10/13/11	7.2	2,885,914
10/20/11	6.6	2,445,485
10/27/11	6.3	2,239,031
10/27/11	6.3	2,239,031
11/3/11	6.1	2,106,492
11/10/11	6.1	2,106,492
11/17/11	5.8	1,915,327
11/23/11	5.5	1,733,336
12/1/11	5.1	1,504,951
12/1/11	5.1	1,504,951
12/8/11	4.6	1,242,404
12/15/11	5.5	1,733,336
12/22/11	5.4	1,674,711
12/29/11	5.3	1,617,105
12/29/11	5.3	1,617,105

Table B-3. Evaporator Operations for April through November 2011

Date	Start	Stop	Total Hrs	Comments
4/28/11	8:30	16:15	7.8	
4/29/11	8:00	15:30	7.5	
4/30/11	9:45	16:45	7.0	
5/1/11	8:45	16:45	8.0	
5/2/11	9:00	16:30	7.5	
5/3/11	8:30	15:30	7.0	
5/4/11	8:00	10:30	2.5	Operated both evaporators.
	8:00	10:30	2.5	
5/5/11	8:30	16:30	8.0	Operated both evaporators.
	10:50	16:30	5.7	
5/6/11	9:00	16:00	7.0	Operated both evaporators.
	10:00	14:00	4.0	
5/7/11	9:45	13:30	3.8	Operated both evaporators.
	9:45	13:30	3.8	
5/8/11	9:00	16:45	7.7	
5/10/11	8:45	11:15	2.5	Operated both evaporators.
	11:45	16:30	4.8	
	13:45	16:30	2.8	
5/11/11	10:00	16:30	6.5	Operated both evaporators.
	10:00	16:30	6.5	
5/12/11	9:00	12:00	3.0	Operated both evaporators.
	10:30	12:00	1.5	
5/13/11	8:00	15:00	7.0	Operated both evaporators.
	8:00	15:00	7.0	
5/14/11	8:45	11:45	3.0	Operated both evaporators; evaporators shut down after the generator tripped; one evaporator restarted.
	8:45	11:45	3.0	
	13:45	16:00	2.3	
5/15/11	8:40	15:35	6.9	Operated both evaporators.
	8:40	15:35	6.9	
5/16/11	9:45	16:45	7.0	
5/21/11	9:30	16:30	7.0	
5/22/11	9:15	16:45	7.5	Operated both evaporators.
	9:15	16:45	7.5	

Table B-3. Evaporator Operations for April through November 2011 (continued)

Date	Start	Stop	Total Hrs	Comments
5/23/11	8:30	14:30	6.0	
5/25/11	11:00	16:00	5.0	Operated both evaporators.
	11:00	16:00	5.0	
5/26/11	10:15	12:50	2.6	Operated both evaporators.
	10:15	12:50	2.6	
5/27/11	7:45	16:30	8.75	Operated both evaporators.
	7:45	16:30	8.75	
5/28/11	9:30	16:00	6.5	Operated both evaporators.
	9:30	16:00	6.5	
8/29/11	10:15	16:30	6.25	
8/30/11	8:30	16:45	8.25	
8/31/11	8:30	16:20	7.0	
9/1/11	10:00	17:00	7.0	
9/2/11	9:30	16:00	6.5	
9/6/11	12:00	16:30	4.5	
9/7/11	13:00	14:00	1.0	
9/8/11	8:30	16:40	8.0	
9/9/11	7:30	14:00	6.5	
9/10/11	8:30	15:45	7.25	
9/12/11	9:00	16:45	7.75	
9/16/11	11:15	15:45	4.5	
9/19/11	9:00	16:30	7.5	
9/20/11	8:20	16:30	8.0	
9/21/11	13:30	16:30	3.0	
9/23/11	9:30	16:15	6.75	
9/24/11	9:30	16:15	6.75	
9/26/11	8:45	16:00	7.25	
9/27/11	9:30	16:15	6.75	
9/28/11	8:00	16:35	8.5	
9/29/11	10:10	16:30	6.5	
9/30/11	9:30	10:45	1.25	
10/1/11	9:30	16:30	7.0	
10/3/11	10:30	16:45	6.25	

Table B-3. Evaporator Operations for April through November 2011 (continued)

Date	Start	Stop	Total Hrs	Comments
10/7/11	10:30	15:00	4.5	
10/10/11	9:20	16:10	5.75	
10/11/11	9:30	16:30	7.0	
10/12/11	10:30	15:00	6.5	
10/13/11	11:15	16:20	5.0	
10/14/11	11:10	16:30	5.25	
10/15/11	9:45	16:15	6.5	
10/20/11	10:35	15:45	5.0	
10/21/11	10:30	16:00	5.5	
10/22/11	10:30	16:15	5.75	
10/24/11	10:45	16:30	5.75	
10/27/11	12:30	16:20	4.0	
10/29/11	11:30	14:30	5.0	
11/1/11	11:30	15:45	4.25	
11/8/11	12:00	15:30	3.5	
11/9/11	10:00	16:00	6.0	
Total	**NA**	**NA**	**463.9**	

NA = not applicable

Evaporation Pond Water Level Investigation

Pressure Transducer Installation

On June 23, 2011, a pressure transducer was installed into the evaporation pond located on top of the tailings pile. This instrument (Campbell Scientific CS455-L50) measures the water temperature and feet of water above the instrument, which was installed at the bottom of the pond (inside a section of vented (2-in. polyvinyl chloride) off of the pump hose at the eastern corner of the pond. The pressure transducer is connected to a data logger by a 50-ft cable. All data are stored in the data logger (Campbell Scientific CR206X) located inside a weather-resistant box that is mounted outside of the pump house. The pump house was also equipped with a solar panel and a 900 megahertz antenna, which allows for the stored data to be transmitted to the Moab site weather station that is located near the site Administrative Area.

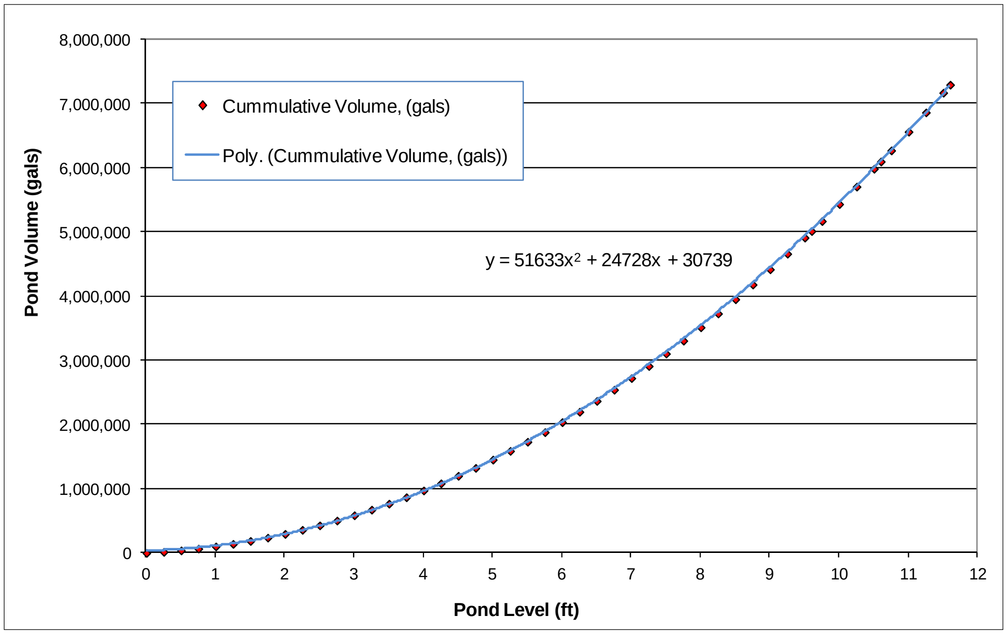
All data are accessed using Vista Data Vision (VDV, Version 4) at the following address: http://vistadata/VDV/VV_Frame.php.

The pond level data, which were measured down to seven significant figures, were converted to a pond level by taking the feet of water measured above the transducer and adding 3.61 ft.

Using this conversion, the pond levels measured previously (using a scale inside the eastern corner of the pond) to the installation of this transducer can be easily compared to the data measured by the transducer. Data retrieved using VDV can either be viewed in tabular form, graphically, or easily downloaded into an Excel spreadsheet.

Evaporation Pond

The evaporation pond was installed in 2003 and is approximately 4 acres in size. Detailed schematics are contained in the *Moab UMTRA Project Ground Water Operations and Maintenance Manual* (DOE-EM/GJTAC1973). The relationship between the volume of water stored in the pond and the pond level is graphically displayed below.



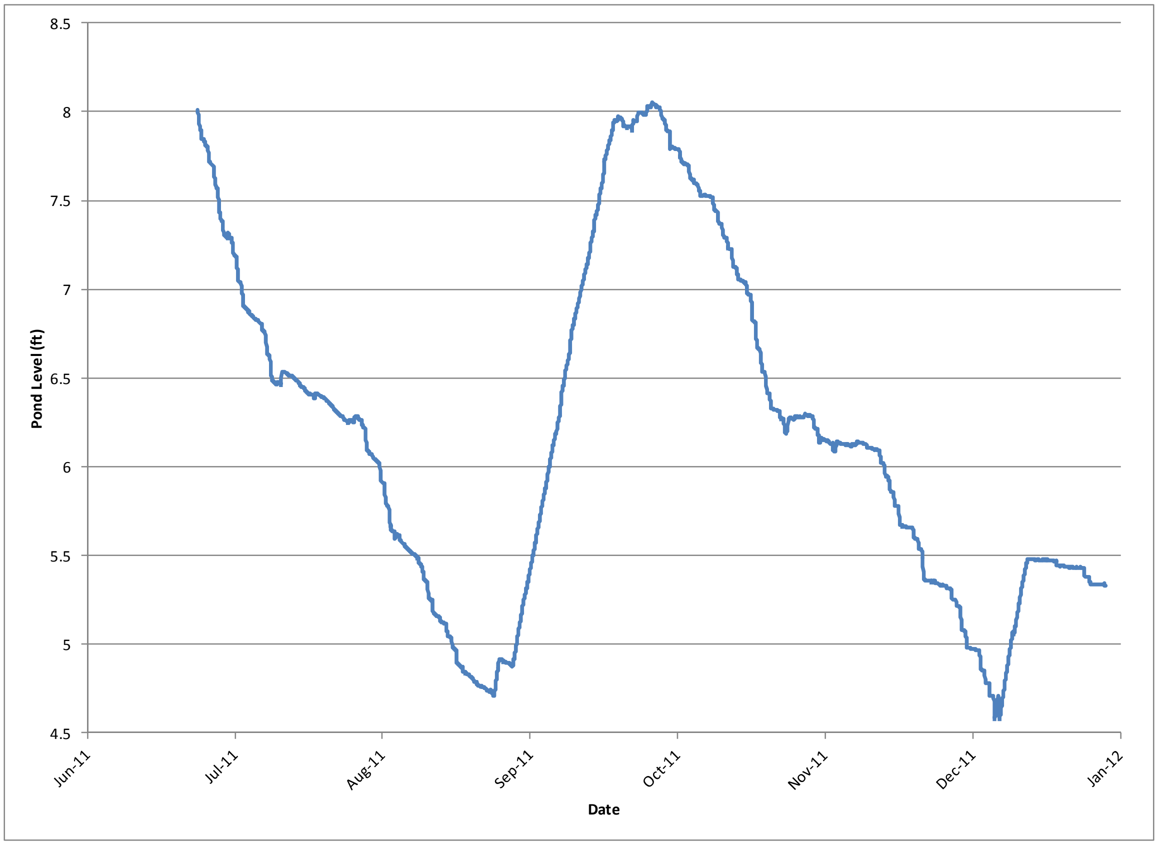
The volume of water stored in the pond at any time can be estimated using the following polynomial equation based on the rating curve:

$$\text{Equation 1: Volume (gal)} = ((51{,}633)(\text{Pond Level}))^2 + ((24{,}728)(\text{Pond Level})) + 30{,}739$$

A spreadsheet was generated to convert the pond level measured by the transducer (down to a hundredth of a foot) to the volume (in gallons) for all subsequent calculations.

2011 Evaporation Pond Levels

The following plot presents the pond level fluctuations as measured from late June 2011 through December 2011 by the pressure transducer. The sharp increases in the pond level between August 25 and September 19 and between December 8 and December 15 were the result of extracted ground water from the well field that was pumped to the pond. All sharp decreases represent water withdrawal from the pond by water truck, with the more gradual decreases the results of evaporation.



Water is added to the pond from the ground water extraction system or precipitation events, and removed from the pond by evaporation, RAC water trucks, and the evaporators. The time in which these pond inflows and outflows all impact the water budget has been well documented. Using the pond level data in conjunction with the time when the inflows and outflows from pond occurred, it was possible to estimate the following.

- Evaporation rate
- Accuracy of RAC water truck removal
- Accuracy of the volume of water added to the pond from precipitation events
- Evaporator efficiency

Because of the site flooding during 2011, there was no ground water extraction between May 31 and August 24, and it was possible to estimate the evaporation rate during this time period and determine the accuracy of the estimated volume removed by the RAC water trucks.

The evaporators were not operational until August 28, and flow meters were not installed on the discharge end of the pumps supplying the evaporators until September 2. Therefore, it was not possible to accurately estimate the evaporator efficiency prior to this date.

Evaporation Rates

The evaporation rate could be calculated when there were time periods of no ground water extraction adding to the pond volume or removal of the water from the pond. Extended time periods, at a minimum of 12 hours and preferably greater than 24 hours, were used to measure a representative evaporation rate.

To measure an accurate evaporation rate it was necessary to rely on data collected from the pressure transducer. The water level associated with the time period when the measurement could be made was input into a spreadsheet, along with the start and ending dates and times. The water level was converted into a pond volume using Equation 1 above, and the change in volume (in gal) divided by the time over which that volume change was measured (in minutes) to determine the evaporation rate (in gpm). For consistency purposes and to allow easy comparisons, all rates were converted into gpm. The rates measured from late June through December 2011 are presented below, along with tables containing the applicable data. Plots displaying the monthly water level data and the time frame when the evaporation rates were measured are provided at the end of this document.

June 2011

Due to the activity associated with the evaporation pond during this time, it was possible to measure the evaporation rate only late in the month and over very short time intervals. As the table displays below, the rate ranged from 14.8 to 22.7 gpm.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
6/26/2011	15:00	1260	7.723	3,299,753	28,565	22.7
6/27/2011	12:00		7.688	3,271,188		
6/28/2011	22:00	720	7.398	3,039,307	14,110	19.6
6/29/2011	10:00		7.380	3,025,197		
6/29/2011	16:00	840	7.305	2,966,761	12,392	14.8
6/30/2011	6:00		7.289	2,954,369		

July 2011

During the month of July 2011, there was no ground water pumped to the evaporation pond due to the flooding of the well field. As a result, all water lost from the pond was either removed by the water trucks for dust suppression or lost due to evaporation. When water is removed by water truck, the slope is much steeper compared to the more gradual slope displayed by evaporation. In addition, the days and volumes of water removed by the water trucks are well documented (Appendix A).

Taking this information into account, it was possible to measure the evaporation rate four times in July 2011 over extended periods of time. As the table displays, the rate ranged from 10.5 to 13.7 gpm.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
7/4/2011	0:00	4320	6.897	2,658,911	59,099	13.7
7/7/2011	0:00		6.816	2,599,812		
7/12/2011	0:00	7200	6.536	2,400,672	75,362	10.5
7/17/2011	0:00		6.427	2,325,310		
7/19/2011	0:00	8640	6.415	2,317,088	99,537	11.5
7/25/2011	0:00		6.268	2,217,551		
7/30/2011	0:00	2880	6.085	2,096,716	35,650	12.4
8/1/2011	0:00		6.030	2,061,066		

August 2011

During the majority of August 2011 the pond level dropped, as it was not possible to access the well field because of the ponded water that remained after the flooding. It was not until August 25 that the ground water extraction was restarted. As the table below displays, the evaporation rate ranged from 5.2 to 11.2 gpm.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
8/6/2011	0:00	4920	5.576	1,778,573	51,145	10.4
8/9/2011	10:00		5.490	1,727,428		
8/12/2011	18:00	2880	5.179	1,548,765	32,229	11.2
8/14/2011	18:00		5.121	1,516,536		
8/18/2011	21:00	7380	4.858	1,374,696	60,320	8.2
8/24/2011	0:00		4.742	1,314,376		
8/26/2011	14:00	3240	4.919	1,406,966	16,976	5.2
8/28/2011	20:00		4.887	1,389,990		

September 2011

In September 2011, there was consistent ground water extraction from the beginning of the month through September 19. In addition, there was a large volume of water removed by water truck during this month. As a result, there was only one opportunity to measure the evaporation rate, as shown below.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
9/24/2011	17:00	2340	7.998	3,528,539	15,211	6.5
9/26/2011	8:00		7.980	3,513,328		

October 2011

It was necessary to start dropping the pond level in October 2011 to increase the available storage for ground water extraction over the winter months.

The table displays the measured evaporation rate, ranged from 2.3 to 7.7 gpm.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
10/1/2011	18:00	2160	7.802	3,364,688	14,027	6.5
10/3/2011	6:00		7.785	3,350,661		
10/8/2011	14:00	2160	7.534	3,146,984	11,969	5.5
10/10/2011	2:00		7.519	3,135,015		
10/15/2011	18:00	1860	7.057	2,777,614	14,233	7.7
10/17/2011	1:00		7.038	2,763,382		
10/22/2011	16:00	2040	6.330	2,259,264	9,453	4.6
10/24/2011	2:00		6.316	2,249,811		
10/29/2011	20:00	1740	6.294	2,234,996	4,032	2.3
10/31/2011	1:00		6.288	2,230,964		

November 2011

In November 2011 (similar to October 2011) there was no ground water pumped to the evaporation pond, and the water level gradually dropped over the month due to water removal by the water trucks and evaporation. As displayed below, the evaporation rate ranged from 2.6 to 4.2 gpm.

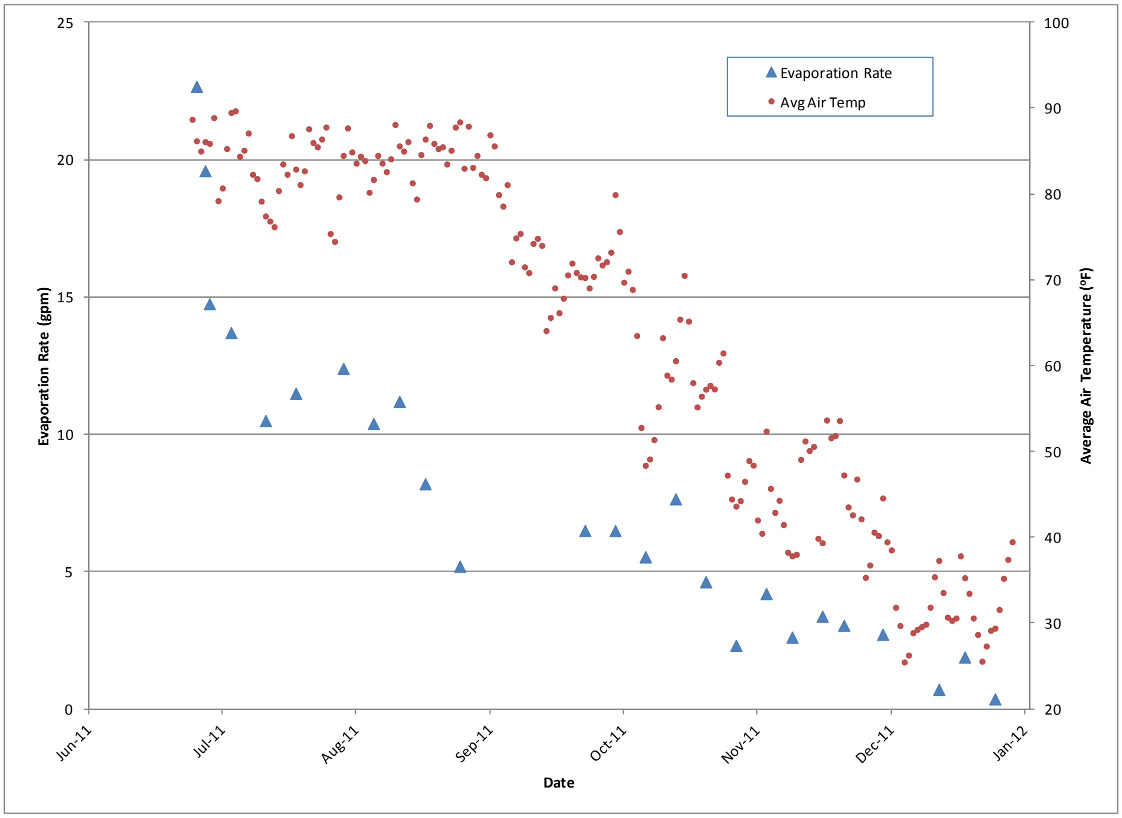
Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
11/5/2011	13:00	3900	6.141	2,133,330	16,385	4.2
11/8/2011	6:00		6.116	2,116,945		
11/11/2011	18:00	3240	6.107	2,111,062	8,483	2.6
11/14/2011	0:00		6.094	2,102,579		
11/18/2011	10:00	4140	5.677	1,839,601	13,989	3.4
11/21/2011	7:00		5.654	1,825,612		
11/23/2011	16:00	6420	5.364	1,653,855	19,576	3.0
11/28/2011	3:00		5.330	1,634,280		

December 2011

During December 2011 the pond level fluctuated as ground water was added to the pond and water removed from the pond by water truck through December 10. As expected, the measured evaporation rate was very low (ranged from 0.4 to 2.7 gpm based on the table below) as the air temperature dropped significantly compared to the previous months.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Evaporation Rate (gpm)
12/2/2011	21:00	3360	4.981	1,440,154	9,139	2.7
12/5/2011	5:00		4.964	1,431,015		
12/15/2011	16:00	8220	5.479	1,720,940	5,887	0.7
12/21/2011	9:00		5.469	1,715,053		
12/21/2011	14:00	8040	5.457	1,708,002	15,227	1.9
12/27/2011	4:00		5.431	1,692,776		
12/28/2011	16:00	3120	5.341	1,640,600	1,150	0.4
12/30/2011	20:00		5.339	1,639,450		

The following figure displays the evaporation rates measured from late June through December 2011, along with the average air temperature measured at the site weather station. As expected there was a corresponding drop in the evaporation rate as the average air temperature decreased.



Accuracy of Ground Water Flow into the Evaporation Pond

As a check on the accuracy of the volume of ground water being added to the pond at any given time, the volume of water as calculated by the change in the pond level was compared to the volume of water calculated by the applicable extraction well flow meters. These meters provide both an instantaneous flow rate and cumulative volume pumped. This comparison could be made during times when the evaporators were not operating and both evaporation and removal from the pond by water truck was minimal.

September 2 through 6, 2011

Long-term ground water extraction from Well PW02 was restarted in late August 2011. Between September 2 and 6 there was no water removal from the pond, and the evaporators were not utilized, making it possible to compare the volume added to the pond by the change in the pond level and the volume added based on the flow meter data. The table below presents the applicable data.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)
9/2/2011	17:00	5100	5.515	1,742,218	321,754
9/6/2011	6:00		6.035	2,063,971	

During this same time period, PW02 exclusively was extracting and delivering ground water to the evaporation pond at a recorded rate of 65.1 gpm, which is equivalent to a volume of 332,010 gal. The evaporation rate for the pond during this time ranged from 5.2 to 6.5 gpm. Assuming an average evaporation rate of 5.85 gpm, the volume lost was approximately was 29,835 gal. As shown below, there was a 5.7 percent difference between these values.

Evaporation Pond Volumes					Extracted Volume		Diff. (%)
Volume based on Pond Level Change (gal)	Evaporation Rate (gpm)	Volume removed by Evaporation (gal)	Volume removed by Water Truck (gal)	Total Volume (gal)	Extraction Rate (gpm)	Volume Extracted (gal)	
321,754	5.85	29,835	0	351,589	65.1	332,010	5.7

September 15, 2011

For a 2-hour time period on September 15, four of the extraction wells were operating while the evaporators were not operating, and no water was removed from the pond by water truck. This allowed for a brief check of other extraction well flow meters. The table below provides the evaporation pond volume change during this time period.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)
9/15/2011	10:00	120	7.346	2,998,635	17,174
9/15/2011	12:00		7.368	3,015,809	

Wells 810, 811, and 812 were extracting ground water at rates of 40.4, 27.4, and 24.2 gpm, respectively. During this time, well PW02 was also extracting ground water at a rate of 65.3 gpm, for a total extraction rate of 157.3 gpm. As shown below, the percent difference was 5.4.

Evaporation Pond Volumes					Extracted Volume		Diff. (%)
Volume based on Pond Level Change (gal)	Evaporation Rate (gpm)	Volume removed by Evaporation (gal)	Volume removed by Water Truck (gal)	Total Volume (gal)	Extraction Rate (gpm)	Volume Extracted (gal)	
17,174	5.85	702	0	17,876	157.3	18,876	5.4

September 17 through 19, 2011

Another comparison can be made for the time period between September 17 and 19 for PW02, during which time the evaporators were not operational, and there was no removal from the pond by water truck. The table below presents the pond level changes and applicable volume.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)
9/17/2011	18:00	2280	7.735	3,309,575	134,877
9/19/2011	8:00		7.898	3,444,452	

The average extraction rate from PW02 was 65.2 gpm, which results in a volume of 148,656 gal over this same time period. Again assuming an evaporation rate of 5.85 gpm, the resulting net volume associated with the pond was 148,125 gal and the percent difference was only 0.3 as shown below.

Evaporation Pond Volumes					Extracted Volume		Diff. (%)
Volume based on Pond Level Change (gal)	Evaporation Rate (gpm)	Volume removed by Evaporation (gal)	Volume removed by Water Truck (gal)	Total Volume (gal)	Extraction Rate (gpm)	Volume Extracted (gal)	
134,877	5.85	13,338	0	148,215	65.2	148,656	0.3

December 9 through 15, 2011

Between December 9 and 15, ground water was also added to the pond exclusively from PW02. The table below provides the applicable pond levels and resulting volume.

Date	Time	Time Change (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)
12/9/2011	15:00	8340	4.581	1,232,929	483,889
12/15/2011	10:00		5.472	1,716,818	

The evaporation rate was minimal (0.7 and 2.7 gpm) during this time. Assuming an evaporation rate of 1.7 gpm the volume lost was 14,178 gal. On December 12, a reported 42,000 gal was removed from the pond for dust control. As a result, there was a net volume of 540,967 gal associated with the pond.

Between the dates and times listed above, a total of 555,394 gal was added to the pond based on the PW02 flow meter volume totalizer. Comparing these two estimated volumes delivered to the pond and taking into account the water removed from the pond (in the table below), there was a 2.8 percent difference.

Evaporation Pond Volumes					Extracted Volume		Diff. (%)
Volume based on Pond Level Change (gal)	**Evaporation Rate (gpm)**	**Volume removed by Evaporation (gal)**	**Volume removed by Water Truck (gal)**	**Total Volume (gal)**	**Extraction Rate (gpm)**	**Volume Extracted (gal)**	
483,889	1.7	14,178	42,000	540,067	NA	555,394	2.8

Accuracy of the Volume of Water Added to the Pond During Precipitation Events

Between June and December 2011, there were a few precipitation events that occurred when there was no ground water being added to the pond or the evaporators were operating. In addition, there is no withdrawal of water from the pond by water truck and it can be assumed that there is no evaporation taking place. A review of the site weather station data show that there was 1 day in June, 5 days in July, 1 in October, and 2 in November when these conditions were met. These comparisons were limited to precipitation events that produced a minimum of 0.1 inches.

The pond liner covers an area of 176,400 square ft (245 by720 ft), which is considered to be the drainage area for the pond. The volume added to the pond was calculated by converting the measured precipitation from inches to feet, multiplying this value by the area of the pond, and then converting this value from cubic ft to gallons. This volume was then compared to the volume based on the change in the pond level, along with a percent difference.

June 2011

After the transducer was installed in late June, there was a precipitation event on June 30 that resulted in 0.2 in. of rainfall. The table below presents the volumes measured and resulting percent difference.

Date	Time	Volume Based on Level Change			Volume Generated from Rainfall		Diff. (%)
		Pond Level (ft)	**Volume (gal)**	**Volume Change (gal)**	**Precipitation Measured (in.)**	**Volume Added (gal)**	
6/30/2011	6:00	7.289	2,954,369	19,374	0.2	21,991	3.2
6/30/2011	13:00	7.314	2,973,743				

July 2011

The month of July had five time periods when there was greater than 0.1 in. of precipitation. As displayed in the table below, the percent difference between the volume based on the measured precipitation and the volume change measured in the pond ranged from 1.6 to 15.3.

Date	Time	Volume Based on Level Change			Volume Generated from Rainfall		Diff. (%)
		Pond Level (ft)	Volume (gal)	Volume Change (gal)	Precipitation Measured (in.)	Volume Added (gal)	
7/10/2011	17:00	6.464	2,350,756	10,356	0.17	18,693	14.4
7/10/2011	21:00	6.479	2,361,112				
7/11/2011	16:00	6.470	2,354,896	45,776	0.39	42,883	1.6
7/11/2011	21:00	6.536	2,400,672				
7/18/2011	15:00	6.387	2,297,959	14,339	0.16	17,593	5.1
7/18/2011	20:00	6.408	2,312,298				
7/25/2011	21:00	6.246	2,202,844	9,353	0.16	17,593	15.3
7/26/2011	2:00	6.260	2,212,197				
7/26/2011	23:00	6.251	2,206,182	18,741	0.29	31,887	13.0
7/27/2011	4:00	6.279	2,224,923				

October 2011

There was one precipitation event in late October that produced 0.37 in. of precipitation, which produced a percent difference of only 7.2 compared to the volume associated with the pond level change as displayed below.

Date	Time	Volume Based on Level Change			Volume Generated from Rainfall		Diff. (%)
		Pond Level (ft)	Volume (gal)	Volume Change (gal)	Precipitation Measured (in.)	Volume Added (gal)	
10/25/2011	21:00	6.196	2,169,602	54,315	0.37	40,684	7.2
10/26/2011	13:00	6.278	2,223,917				

November 2011

In November, there were two events that resulted in 0.17 and 0.39 in. of precipitation according to the site weather station. As the data in the table suggest, the volumes were comparable.

Date	Time	Volume Based on Level Change			Volume Generated from Rainfall		Diff. (%)
		Pond Level (ft)	Volume (gal)	Volume Change (gal)	Precipitation Measured (in.)	Volume Added (gal)	
11/1/2011	20:00	6.136	2,130,048	17,095	0.17	18,693	2.2
11/2/2011	2:00	6.162	2,147,143				
11/4/2011	21:00	6.085	2,096,716	36,614	0.39	42,883	3.9
11/5/2011	13:00	6.141	2,133,330				

Efficiency of Evaporation Units

To accurately estimate the efficiency of the evaporator units, it was necessary to use a time frame when there was no withdrawal from the pond while the unit was operable. Data regarding the extraction rate for wells feeding the evaporator storage tank along with the extraction rate of the wells (if any) that were pumping ground water directly into the pond were required.

The last critical piece of information is the flow rate and volume of water discharging from the evaporator pump that feeds the evaporator. These data were not available until after September 6, at which point flow meters were installed on the discharge lines of the pumps supplying the evaporators.

It should be noted that the evaporators are controlled by a built in weather station that shuts down the pumps when the wind direction or speed are outside the pre-set parameters. As a result, there were time periods when the evaporator was not running that could not be accounted for. Therefore, the efficiency estimates below represent the minimum efficiency that was achieved for that day.

September 10, 2011

Just before the starting the evaporator on this day, well PW02 was operating overnight between September 9 and 10 at a reported rate of approximately 65 gpm. To verify this extraction rate, the pond level change (due to the volume delivered by this well) was measured over this time period. Only minimal evaporation was assumed during this time of the day. The table below provides the data, which closely agree with the flow meter reading at the well head of PW02 (64.7 gpm compared to 65 gpm).

Date	Time	Time Diff (min)	Pond Level (ft)	Volume (gal)	Volume Change (gal)	Rate (gpm)
9/10/2011	0:00	480	6.601	2,446,189	31,056	64.7
9/10/2011	8:00		6.645	2,477,245		

Wells 811 (35 gpm), 812 (29 gpm), and 813 (52 gpm) were started at 8:00 in the morning to provide water to the tank that supplies the evaporator pump. When including the ground water extracted from PW02 the total extraction rate from the well field was 180.7 gpm.

Records indicate that the evaporator was operating with a flow of 95 gpm (which is equivalent to a volume of 39,900 gal over the 7-hour time frame was the evaporator was running). The difference of 85.7 gpm, or 35,994 gal, represents the volume of water added directly to the pond bypassing the evaporator.

The volume of water added to the pond during this time was 68,531 gal based on the pond level changes (below).

Date	Time	Pond Level (ft)	Volume (gal)	Volume Change (gal)
9/10/2011	9:00	6.654	2,483,621	68,531
9/10/2011	16:00	6.750	2,552,152	

Taking into account 35,994 gal was added directly, 32,537 gal was added after running through the evaporator. A review of the evaporation rate data summary plot, the evaporation rate measured on September 24 was 6.5 gpm and occurred when the average air temperature was comparable to the average air temperature that occurred on September 10. The result is a loss of 2,730 gal due to evaporation.

A total of 7,363 gal was evaporated from the system during this time interval. Subtracting the volume naturally evaporated (2,730 gal), the evaporator was responsible for removing 4,633 gal. If the evaporator was 100 percent efficient, then 39,900 gal would have been removed. As a result, the evaporator was 11.6 percent efficient on this date under these conditions.

September 23, 2011

Wells 810 (40.0 gpm), 812 (23.1 gpm), and PW02 (53.0 gpm) were extracting ground water on September 23 with a total extraction flow rate of 116.1 gpm. The evaporator was started at 10:00 and ran until 16:00 at a recorded flow rate of 98 gpm. As a result, a total of 35,280 gal was run through the evaporator over the 6 hours. The difference of 18.1 gpm, or 6,516 gal, represents the volume of water added directly to the pond bypassing the evaporator.

A review of the data indicates that during the time frame the evaporator was running, the change in the pond level suggested 37,713 gal was added (below).

Date	Time	Pond Level (ft)	Volume (gal)	Volume Change (gal)
9/23/2011	10:00	7.898	3,444,452	37,713
9/23/2011	16:00	7.943	3,482,165	

Taking into account 6,516 gal was added directly, 31,197 gal was added after running through the evaporator. With 35,280 gal run through the evaporator, a total of 4,083 was removed from the system during this time interval. A review of the evaporation rate data summary plot, the evaporation rate measured was assumed to be 6.5 gpm, resulting in a loss of 2,340 gal due to evaporation.

Subtracting the volume naturally evaporated (2,340 gal), the evaporator was responsible for removing 1,743 gal from the pond. If the evaporator was 100 percent efficient, then 35,280 gal would have been removed. As a result, the evaporator was 4.9 percent efficient on this date under these conditions.

September 24, 2011

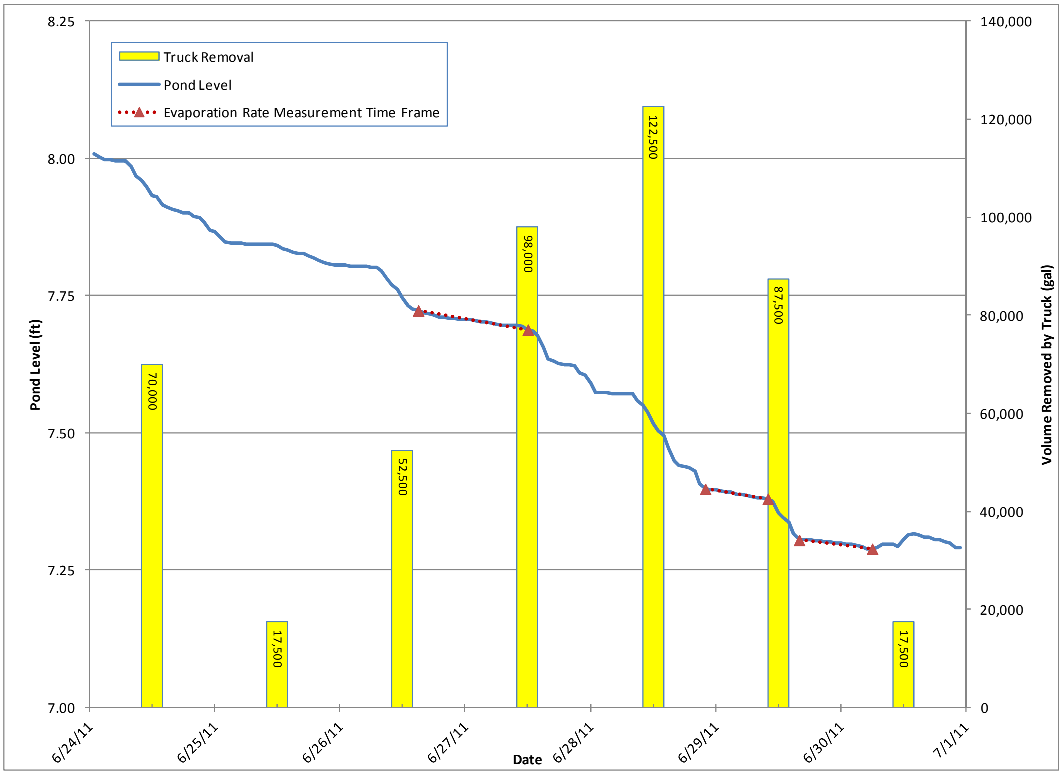
Wells 810 (40 gpm), 812 (23 gpm), and PW02 (53 gpm) were extracting ground water on September 24 with a total extraction flow rate of 116 gpm. The evaporator was started at 10:00 and ran until 16:00 at a recorded flow rate of 95 gpm. As a result, a total of 34,200 gal was run through the evaporator over the 6 hours. The difference of 21 gpm, or 7,560 gal, represents the volume of water added directly to the pond bypassing the evaporator.

A review of the data indicates that during the time frame the evaporator was running, the change in the pond level suggested 37,097 gal was added (below).

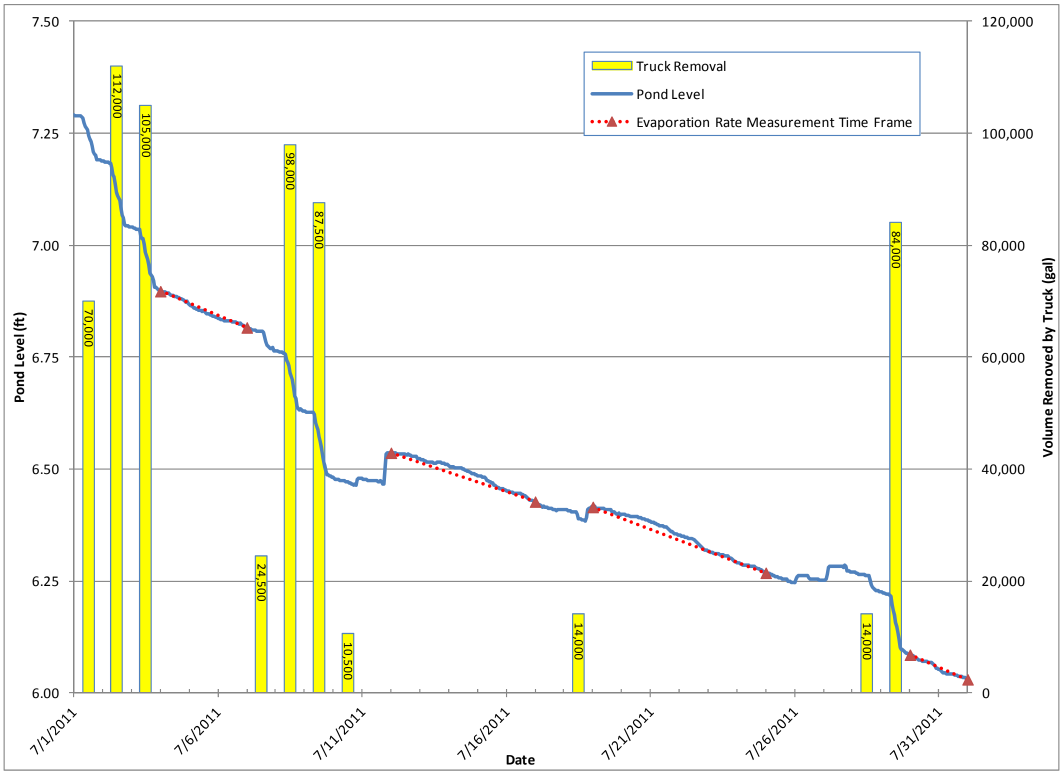
Date	Time	Pond Level (ft)	Volume (gal)	Volume Change (gal)
9/24/2012	10:00	7.948	3,486,368	37,097
9/24/2012	16:00	7.992	3,523,465	

Taking into account 7,560 gal was added directly, 29,537 gal was added after running through the evaporator. With 34,200 gal run through the evaporator, a total of 4,663 was removed from the system during this time interval. A review of the evaporation rate data summary plot, the evaporation rate measured was 6.5 gpm, resulting in a loss of 2,340 gal due to evaporation.

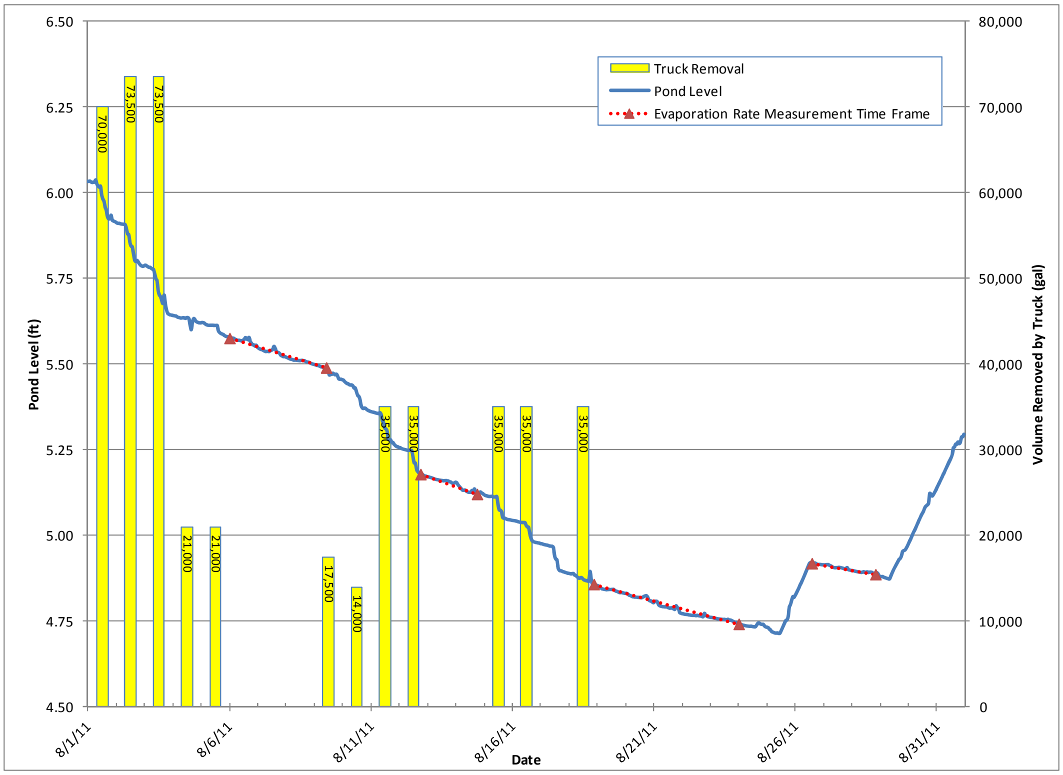
Subtracting the volume naturally evaporated (2,340 gal), the evaporator was responsible for removing 2,323 gal from the pond. If the evaporator was 100 percent efficient, then 34,200 gal would have been removed. As a result, the evaporator was 6.8 percent efficient on this date under these conditions.



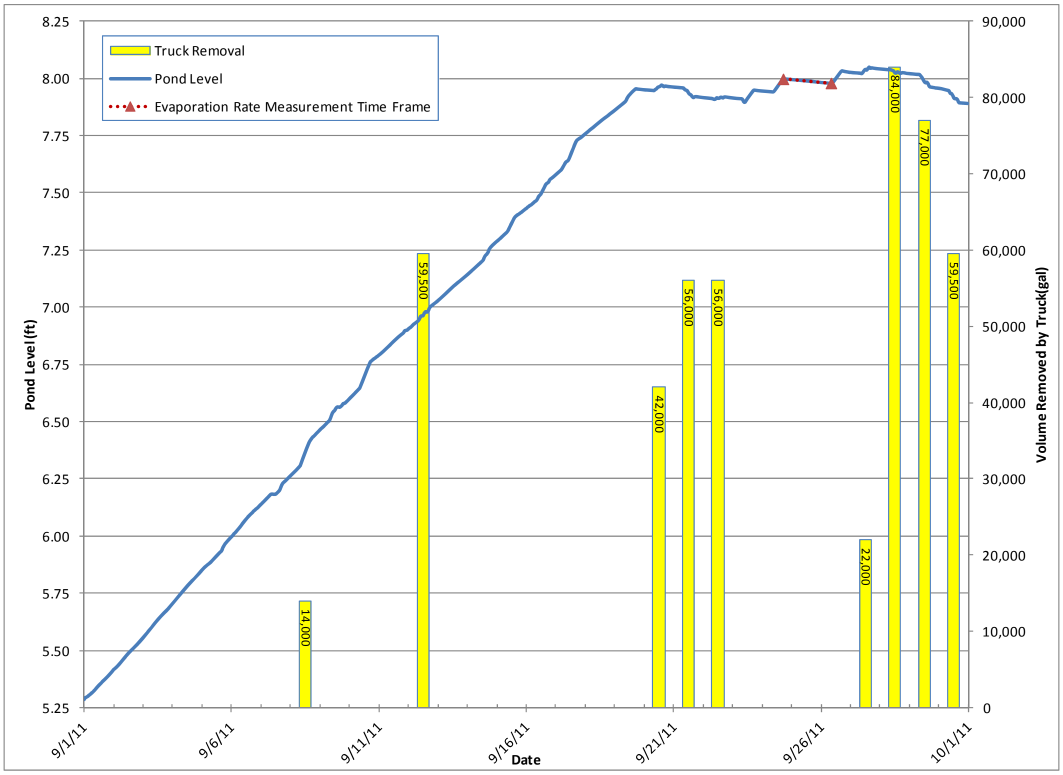
June 2011 Evaporation Pond Level and Volume Removed by Water Truck



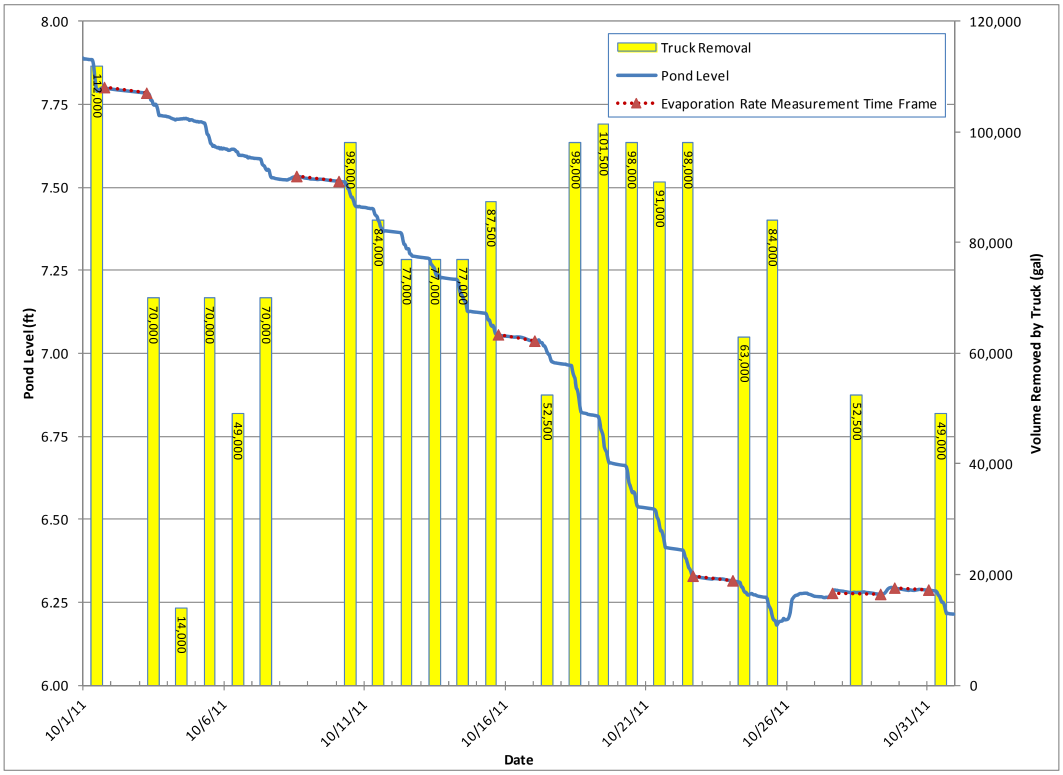
July 2011 Evaporation Pond Level and Volume Removed by Water Truck



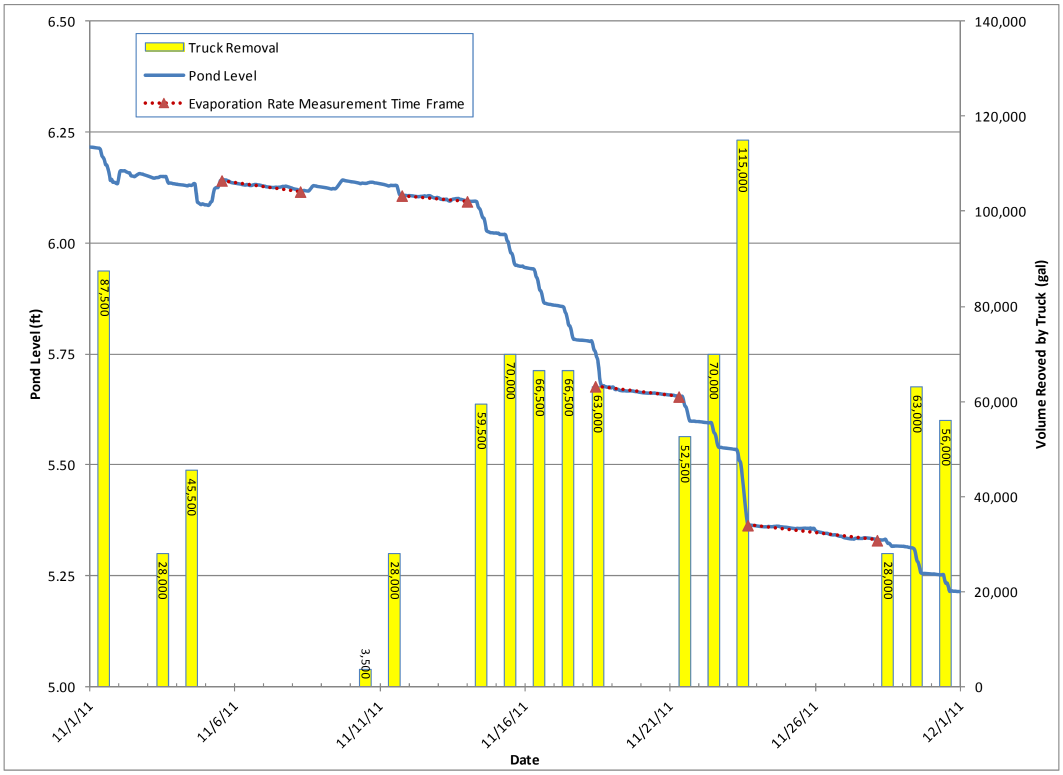
August 2011 Evaporation Pond Level and Volume Removed by Water Truck



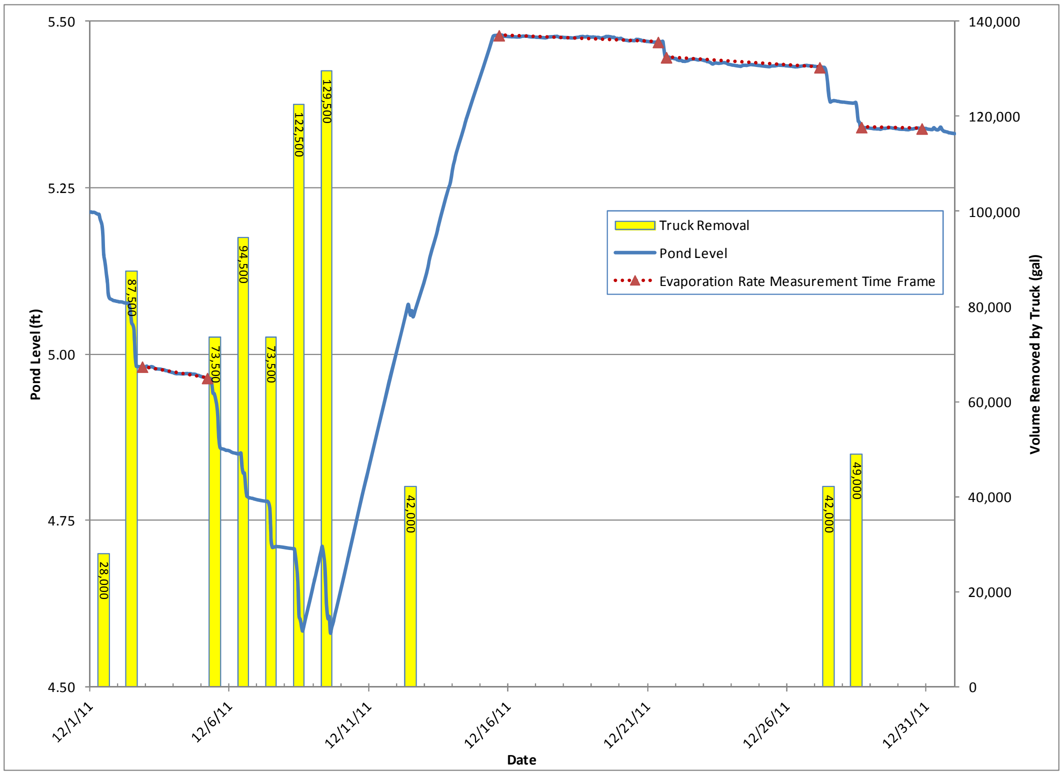
September 2011 Evaporation Pond Level and Volume Removed by Water Truck



October 2011 Evaporation Pond Level and Volume Removed by Water Truck



November 2011 Evaporation Pond Level and Volume Removed by Water Truck



December 2011 Evaporation Pond Level and Volume Removed by Water Truck

Appendix C.
Tables and Data for Injection 2011

Table C-1. CF4 Well Construction

Well	Well Type/ Relative Depth	Diameter (in.)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0770	Remediation/Deep	6	3,968.86	14.9 – 34.8	35.2
0771	Remediation/Deep	6	3,969.04	15.0 – 34.9	35.3
0772	Remediation/Deep	6	3,969.21	15.2 – 35.1	35.5
0773	Remediation/Deep	6	3,969.15	15.2 – 35.1	35.5
0774	Remediation/Deep	6	3,968.77	15.5 – 35.4	35.8
0775	Remediation/Deep	6	3,969.18	15.1 – 35.0	35.4
0776	Remediation/Deep	6	3,968.97	15.2 – 35.1	35.5
0777	Remediation/Deep	6	3,968.76	15.3 – 35.2	35.6
0778	Remediation/Deep	6	3,968.93	15.1 – 35.0	35.4
0779	Remediation/Deep	6	3,968.34	15.7 – 35.6	36.0
0780	Observation/Shallow	6	3,968.45	20.3 – 30.1	30.5
0781	Observation/Deep	6	3,968.56	44.8 – 54.5	55.0
0782	Observation/Deep	6	3,968.46	31.0 – 40.8	41.2
0783	Observation/Shallow	2	3,968.82	8.6 – 18.6	19.1
0784	Observation/Shallow	2	3,968.73	9.4 – 19.4	19.9
0785	Observation/Shallow	2	3,968.24	9.6 – 19.6	19.9
0786	Observation/Shallow	6	3,968.14	20.5 – 30.3	30.7
0787	Observation/Deep	6	3,968.43	35.4 – 45.2	45.7
0790	Well Point/Shallow	1	3,953.91	2.0 – 3.0	3.0
0791	Well Point/Intermediate	1	3,953.91	4.3 – 5.3	5.3
0792	Well Point/Deep	1	3,953.91	9.3 – 10.3	10.3
0793	Well Point/Shallow	1	3,952.69	2.0 – 3.0	3.0
0794	Well Point/Intermediate	1	3,952.69	4.3 – 5.3	5.3
0795	Well Point/Deep	1	3,952.69	9.3 – 10.3	10.3

Table C-2. Chronology of CF4 Activities in 2011

Date	River Flow (cfs)	Activity
2/24/11	3,280	Sampled observation wells and well points for laboratory analysis (RIN1102055).
3/1/11	3,300	Began injecting into all CF4 wells.
3/15/11	4,000	Lin Bell repaired leak in sand filter shed.
3/28/11	4,590	Started pumping 24 hours/day.
4/27/11 – 4/28/11	9,470 – 10,400	Sampled observation wells for laboratory analysis (RIN1104057).
5/9/11	16,400	Shut down injection due to high river flow.
8/3/11	8,760	Turned injection on and tested it with the new bag filter. Rain 4 Rent and CB on site.
8/22/11	4,820	No injection due to excavation activities performed near injection line.
8/24/11 – 8/26/11	4,540 – 4,750	Injection wells redeveloped by Mike Zimmerman Well Service.
9/19/11 – 9/26/11	5,000 – 6,400	Injection suspended due to high turbidity and nearby construction activities.
10/3/11 – 10/5/11	4,620 – 4,930	Sampled observation wells and well points for laboratory analysis (RIN1110061).
10/7/11 – 10/8/11	5,640 – 6,130	Injection suspended to replace bag filters and due to turbid water resulting from precipitation.
12/7/11	3,870	Winterized injection system.
12/7/11 – 12/9/11	3,700 – 3,900	Collected parameters in CF4 observation wells for ammonia probe analysis. Sampled observation wells and well points for laboratory analysis (RIN1112063).

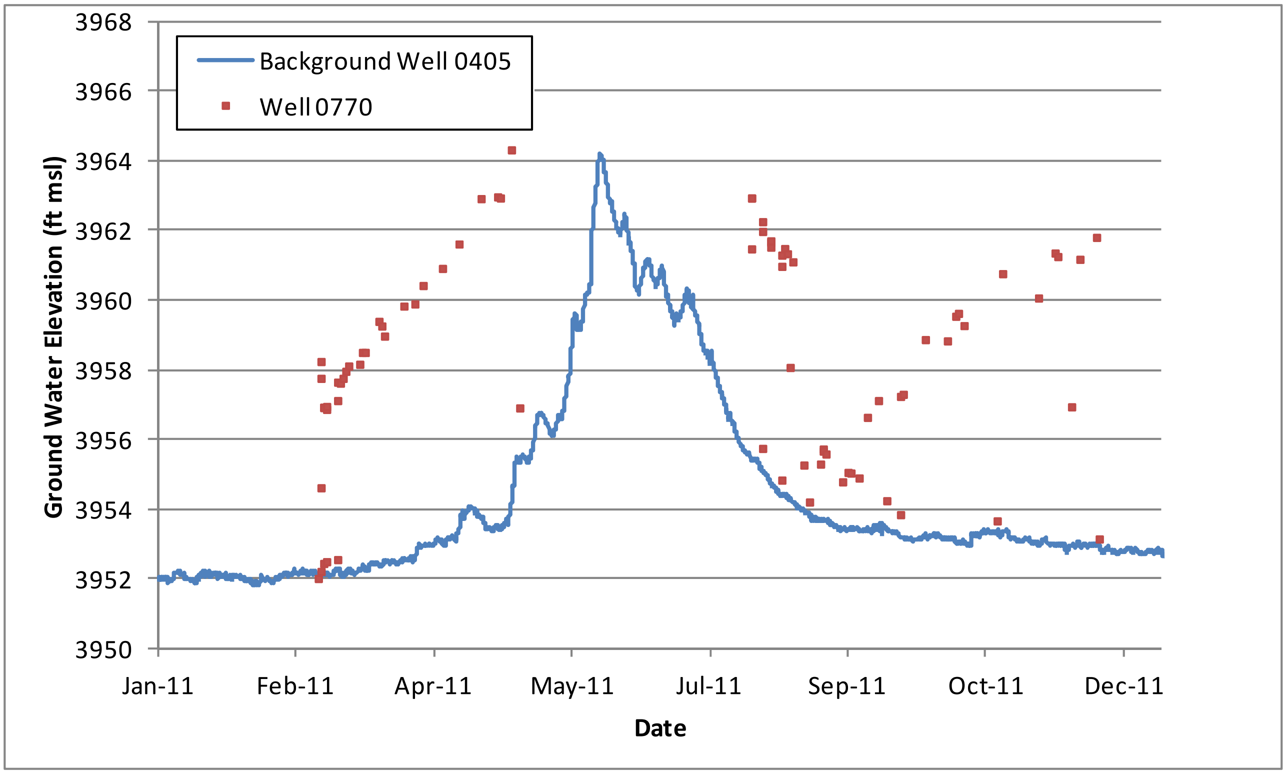


Figure C-1. Freshwater Mounding in Remediation Well 0770 During Injection

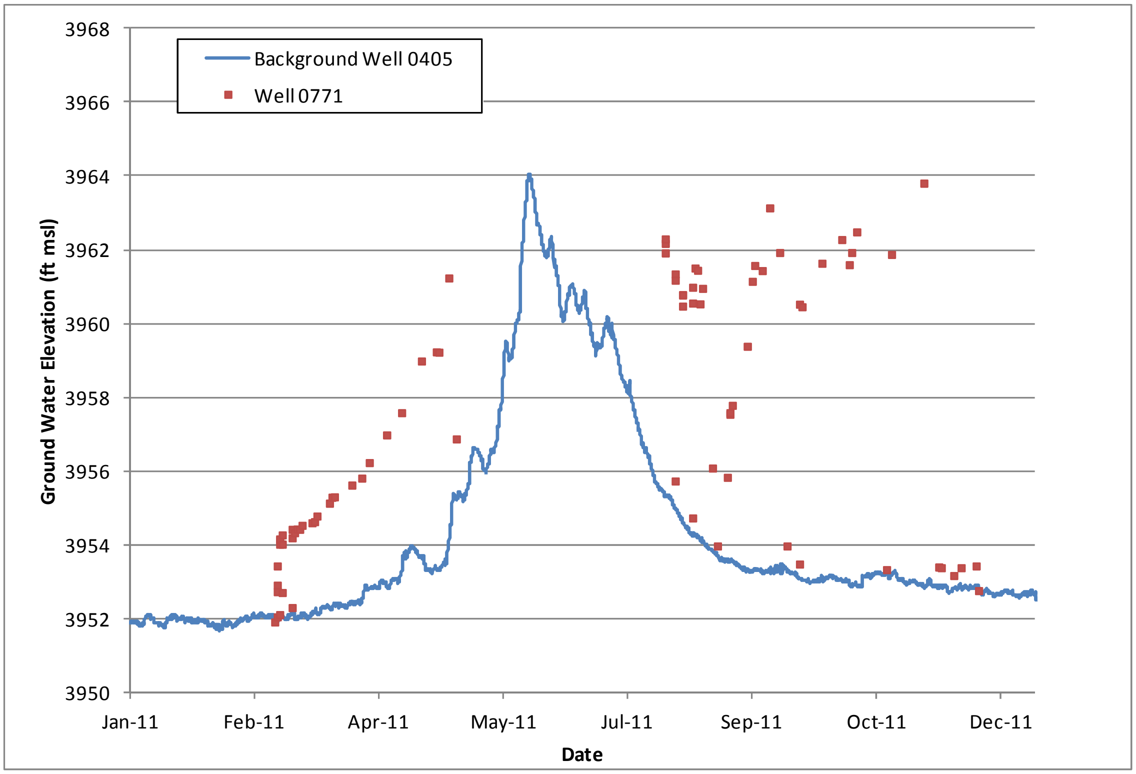


Figure C-2. Freshwater Mounding in Remediation Well 0771 During Injection

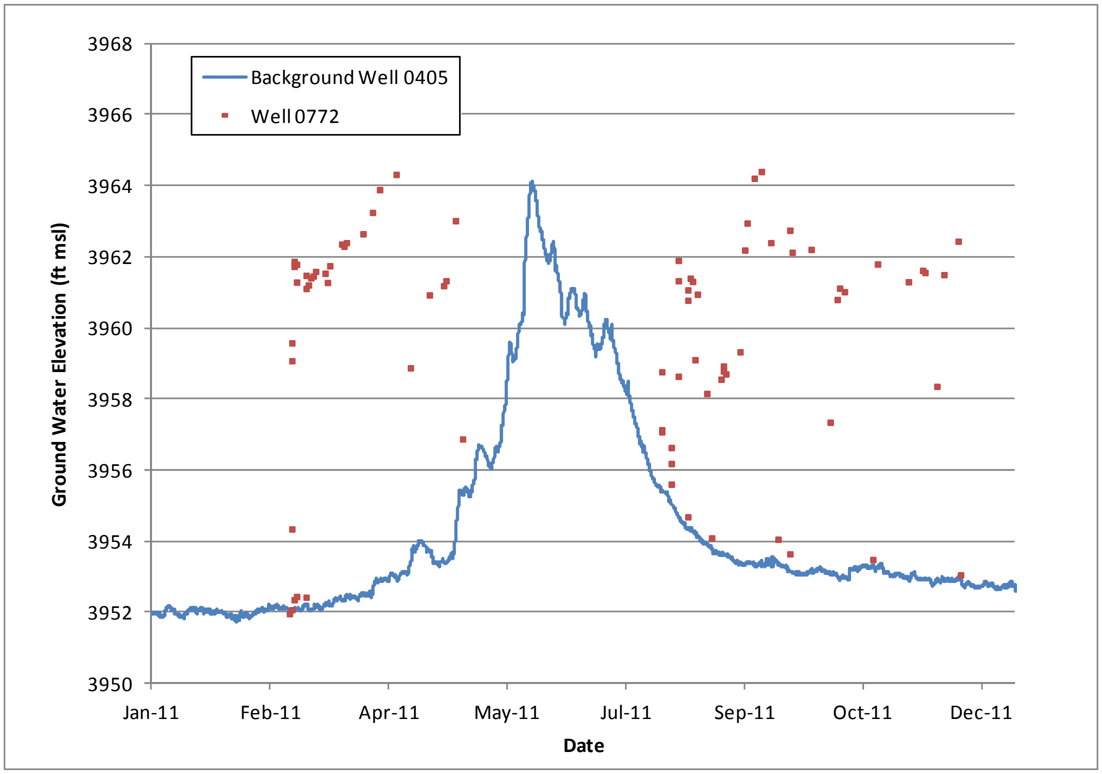


Figure C-3. Freshwater Mounding in Remediation Well 0772 During Injection

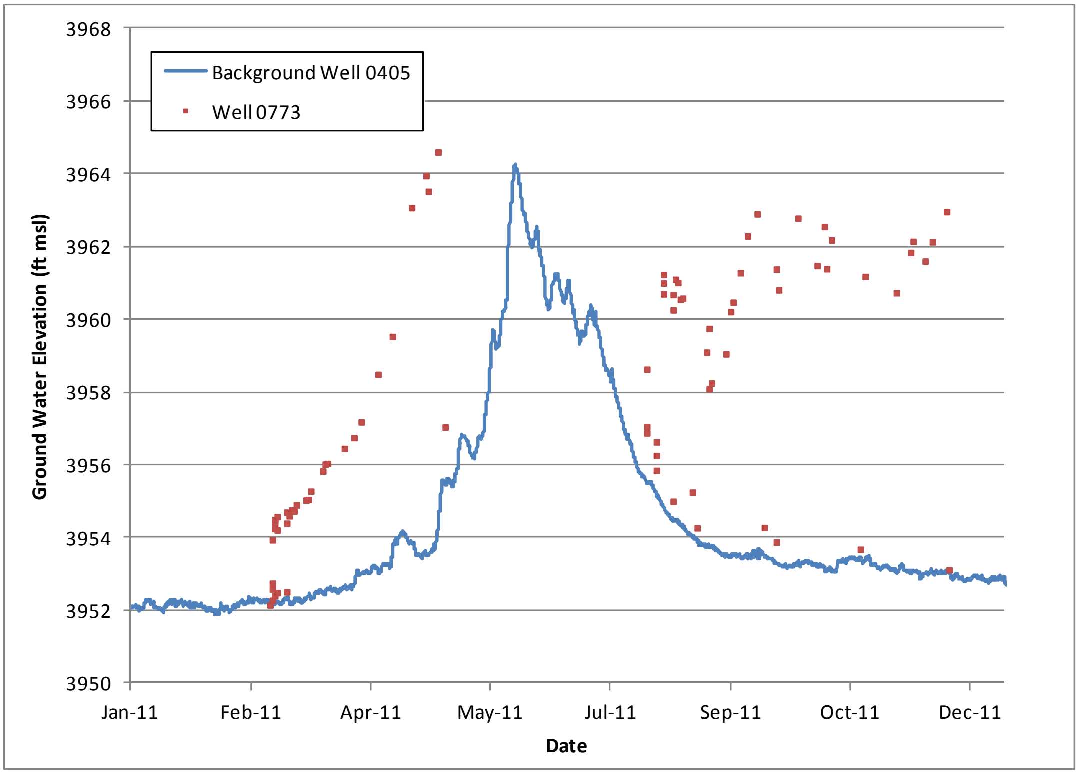


Figure C-4. Freshwater Mounding in Remediation Well 0773 During Injection

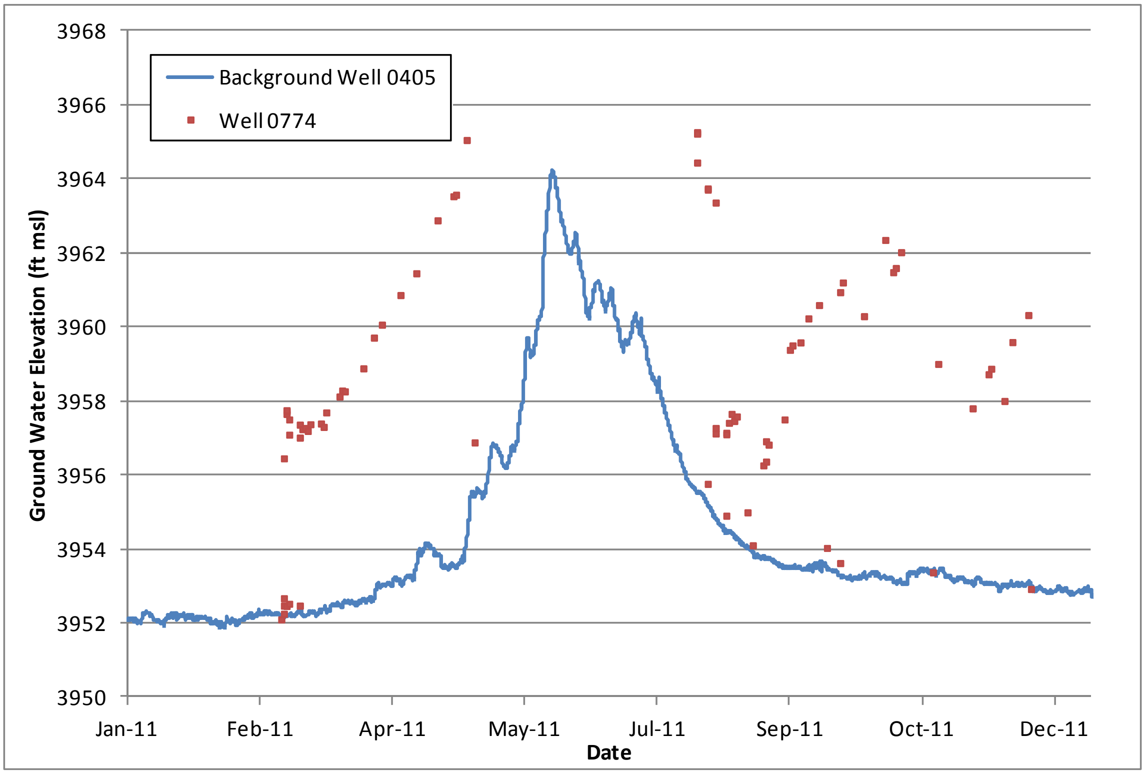


Figure C-5. Freshwater Mounding in Remediation Well 0774 During Injection

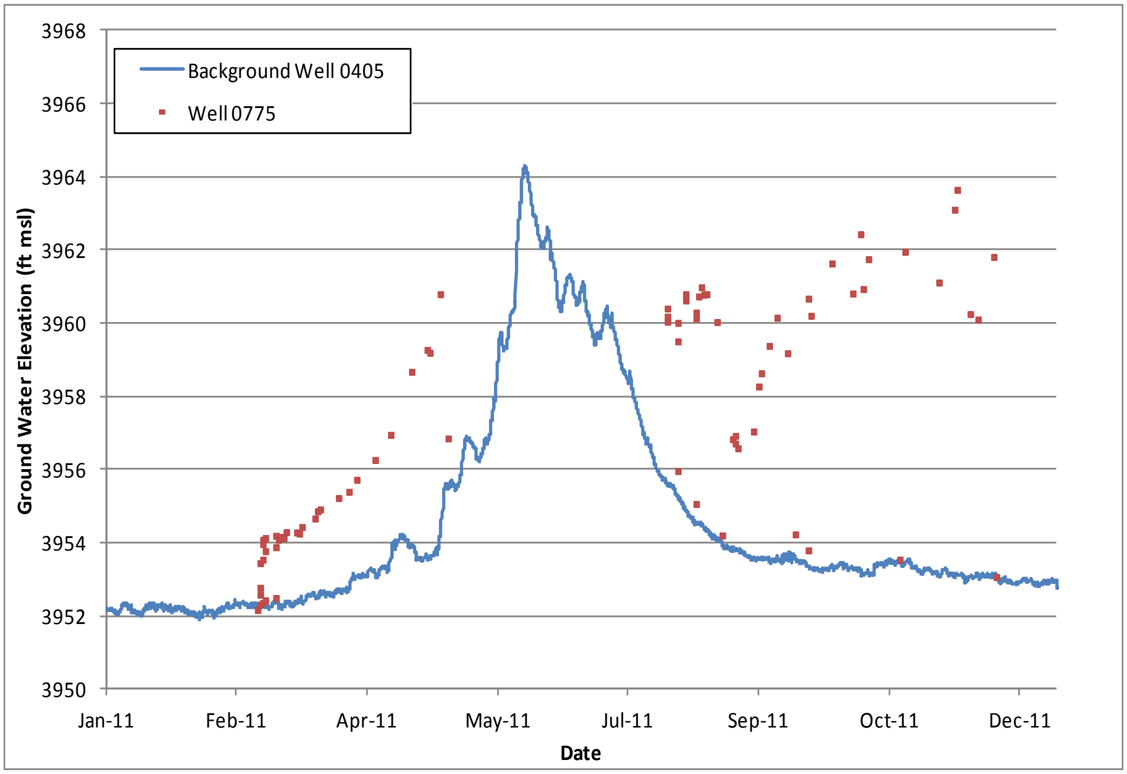


Figure C-6. Freshwater Mounding in Remediation Well 0775 During Injection

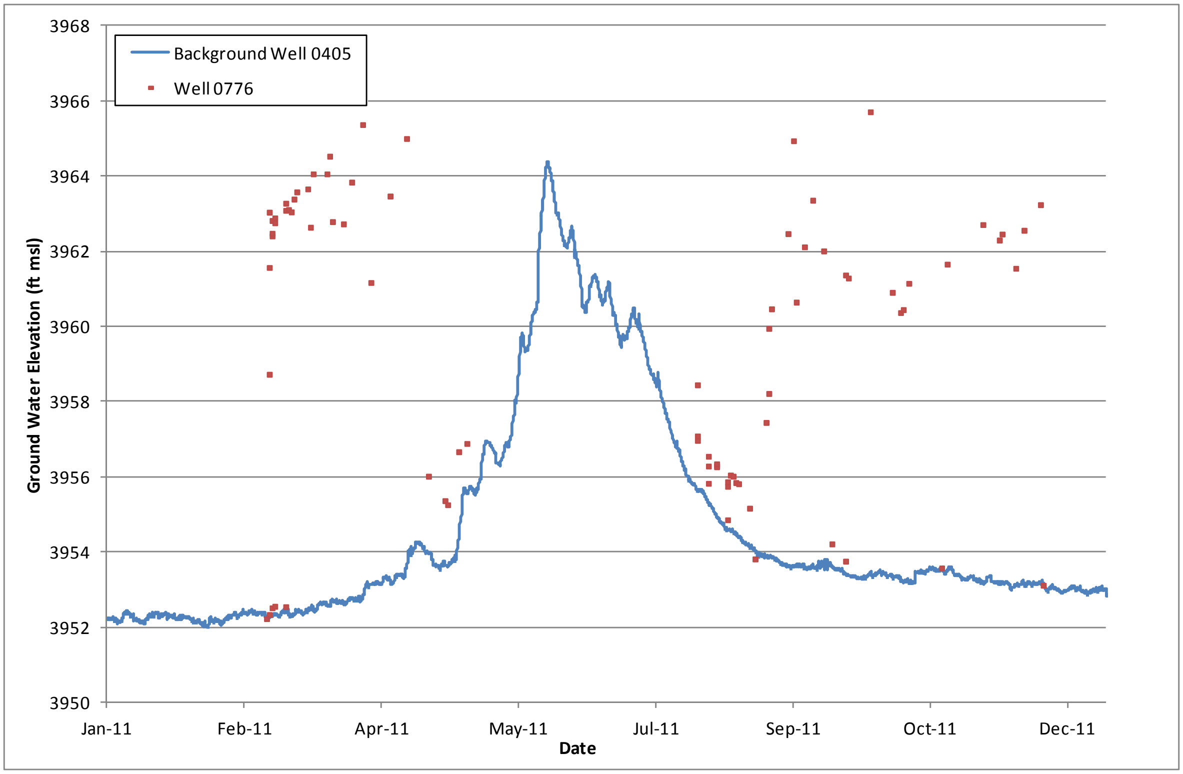


Figure C-7. Freshwater Mounding in Remediation Well 0776 During Injection

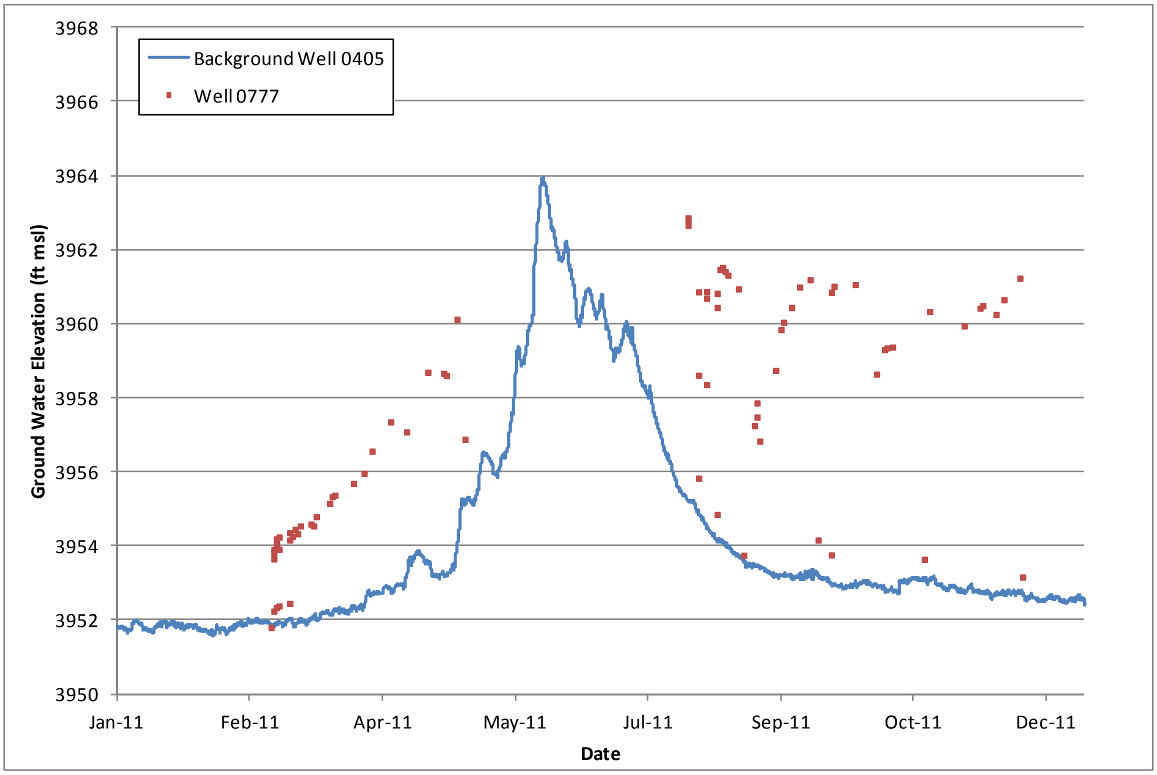


Figure C-8. Freshwater Mounding in Remediation Well 0777 During Injection

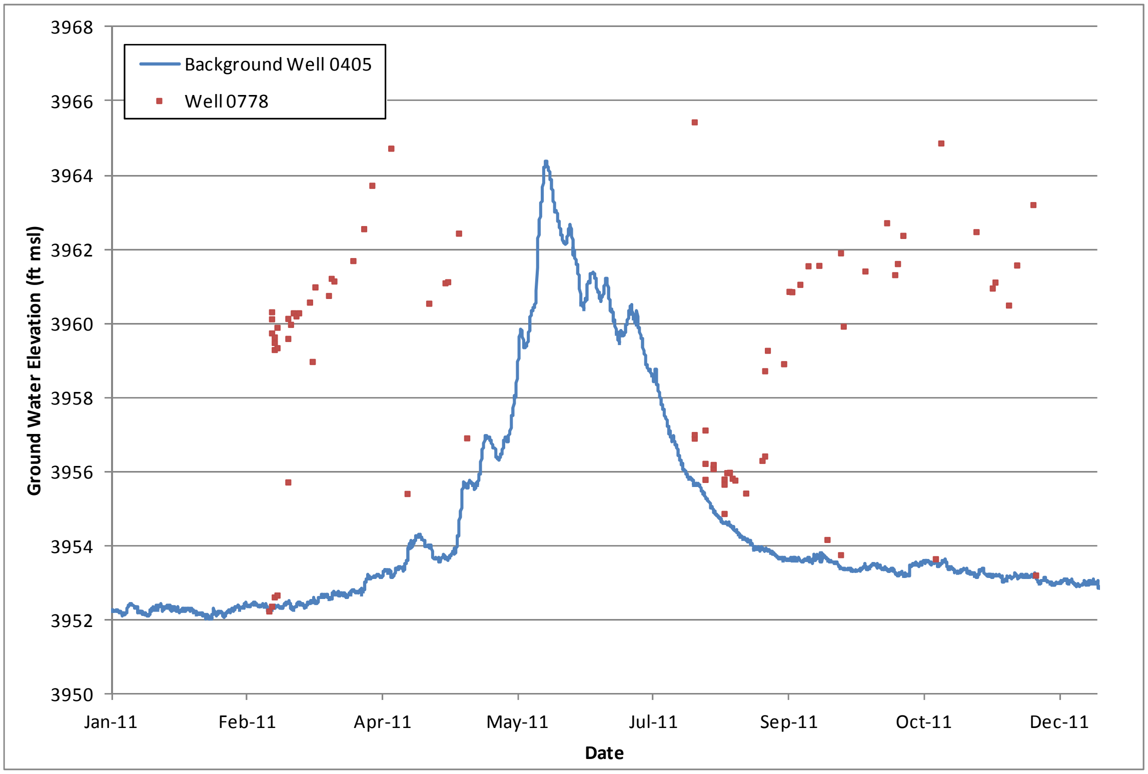


Figure C-9. Freshwater Mounding in Remediation Well 0778 During Injection

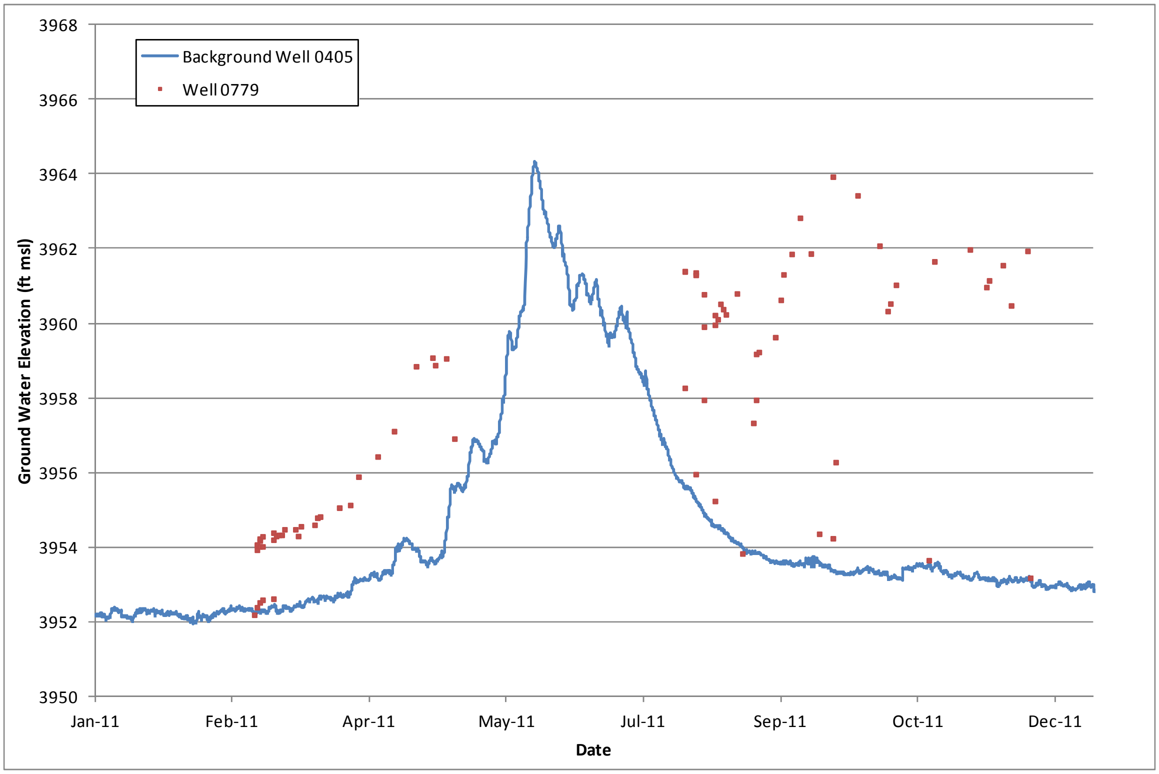
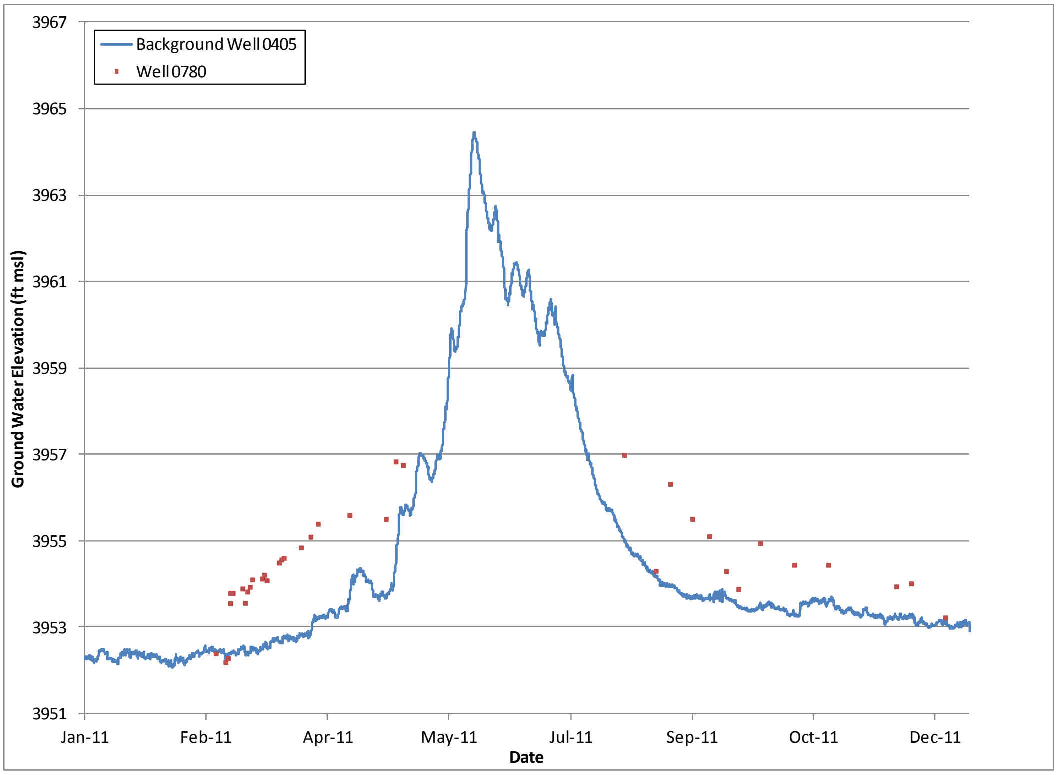
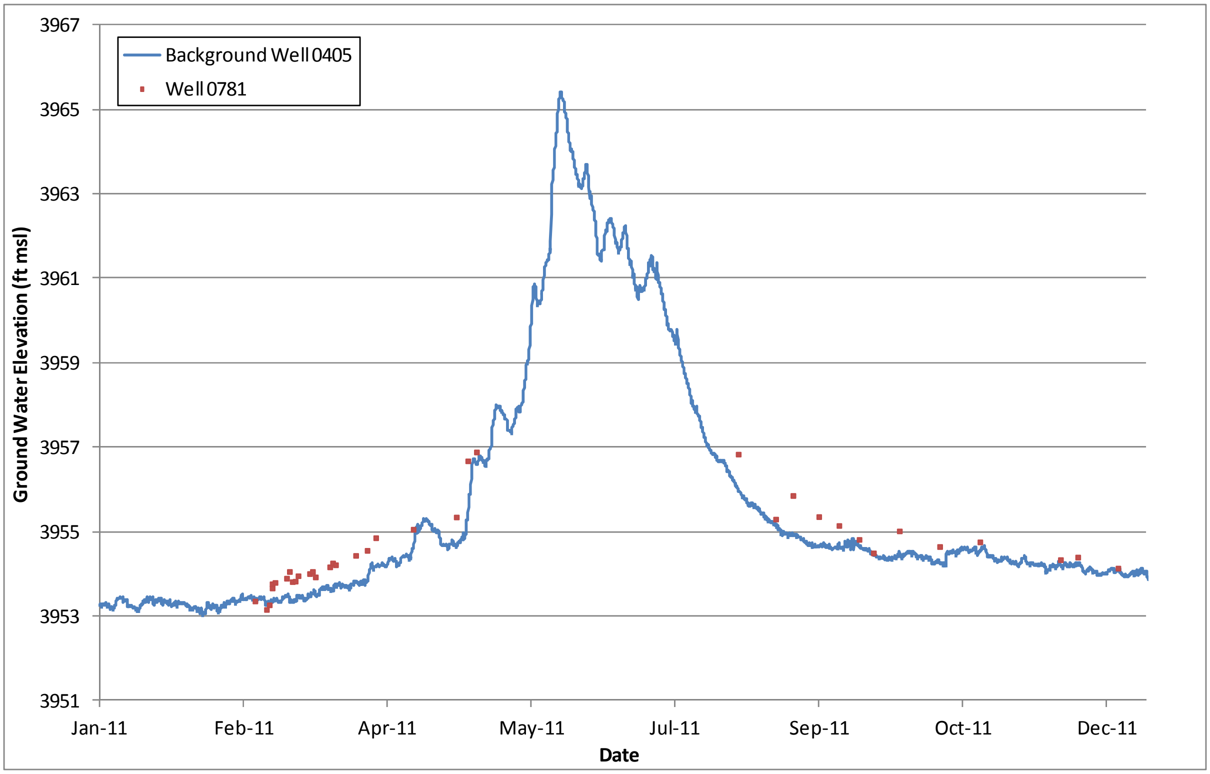


Figure C-10. Freshwater Mounding in Remediation Well 0779 During Injection



C-11. Freshwater Mounding in Observation Well 0780



C-12. Freshwater Mounding in Observation Well 0781

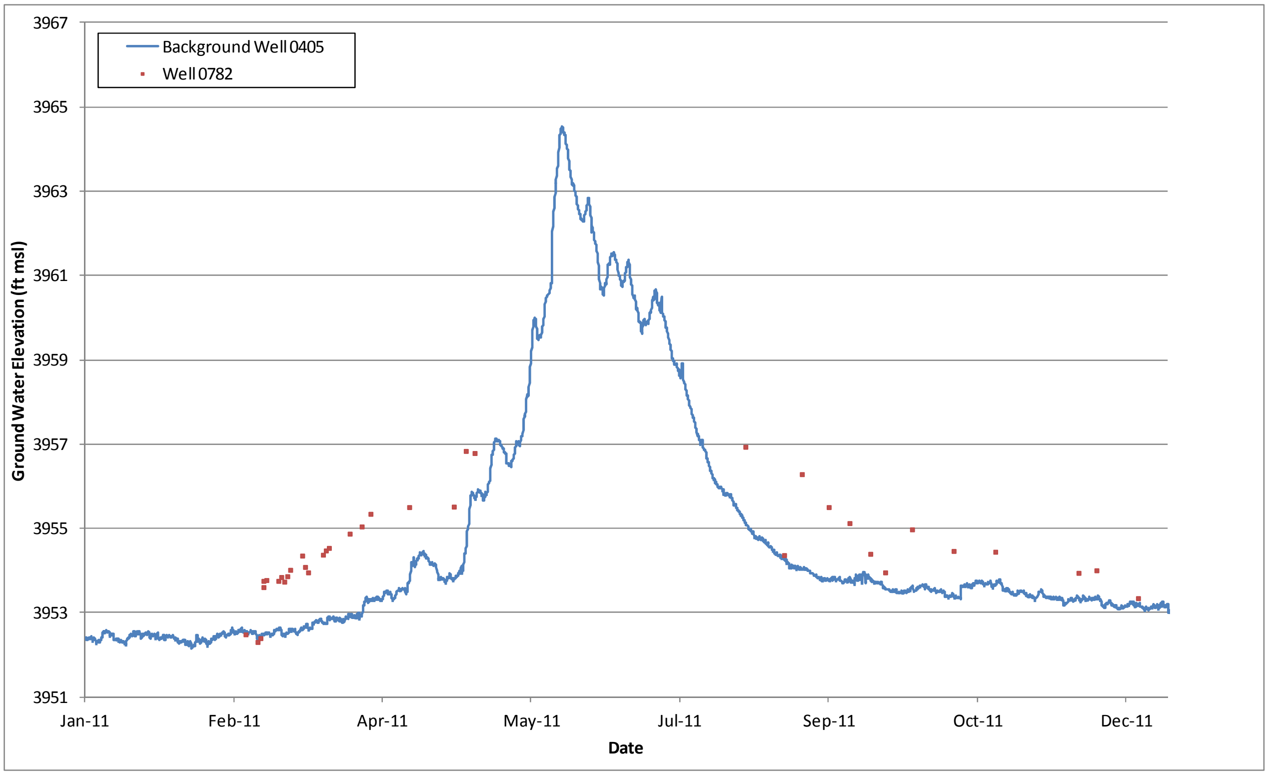


Figure C-13. Freshwater Mounding in Observation Well 0782

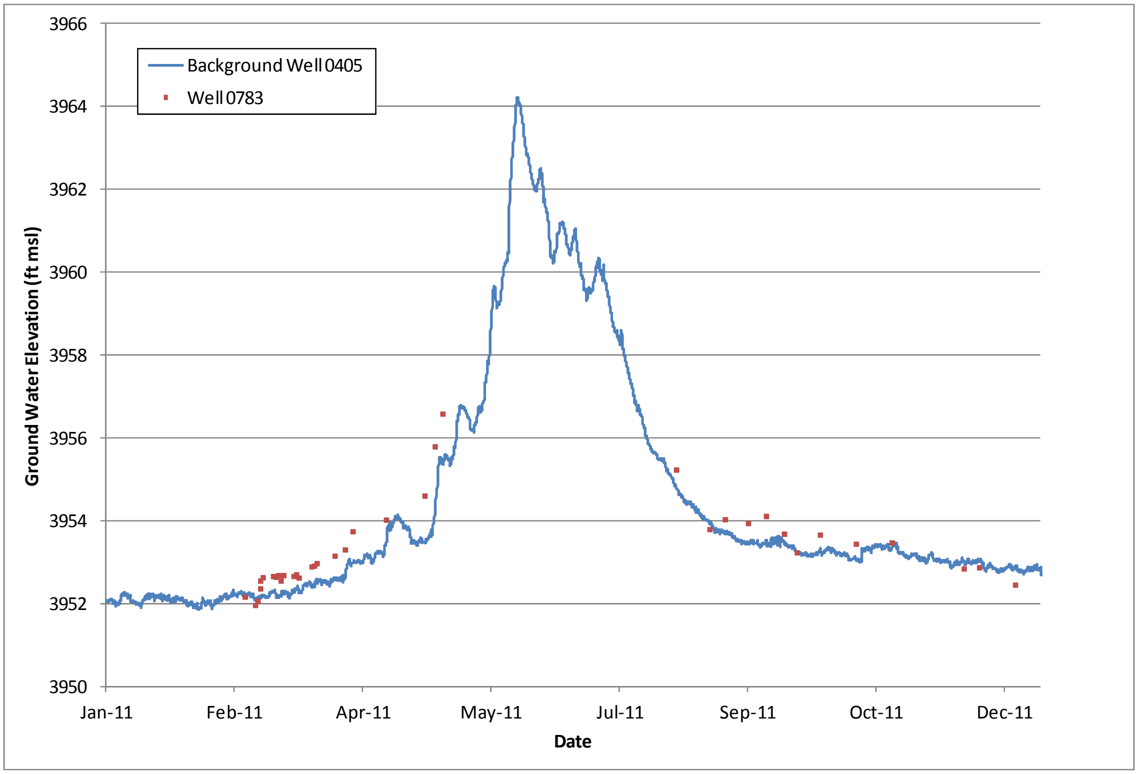


Figure C-14. Freshwater Mounding in Observation Well 0783

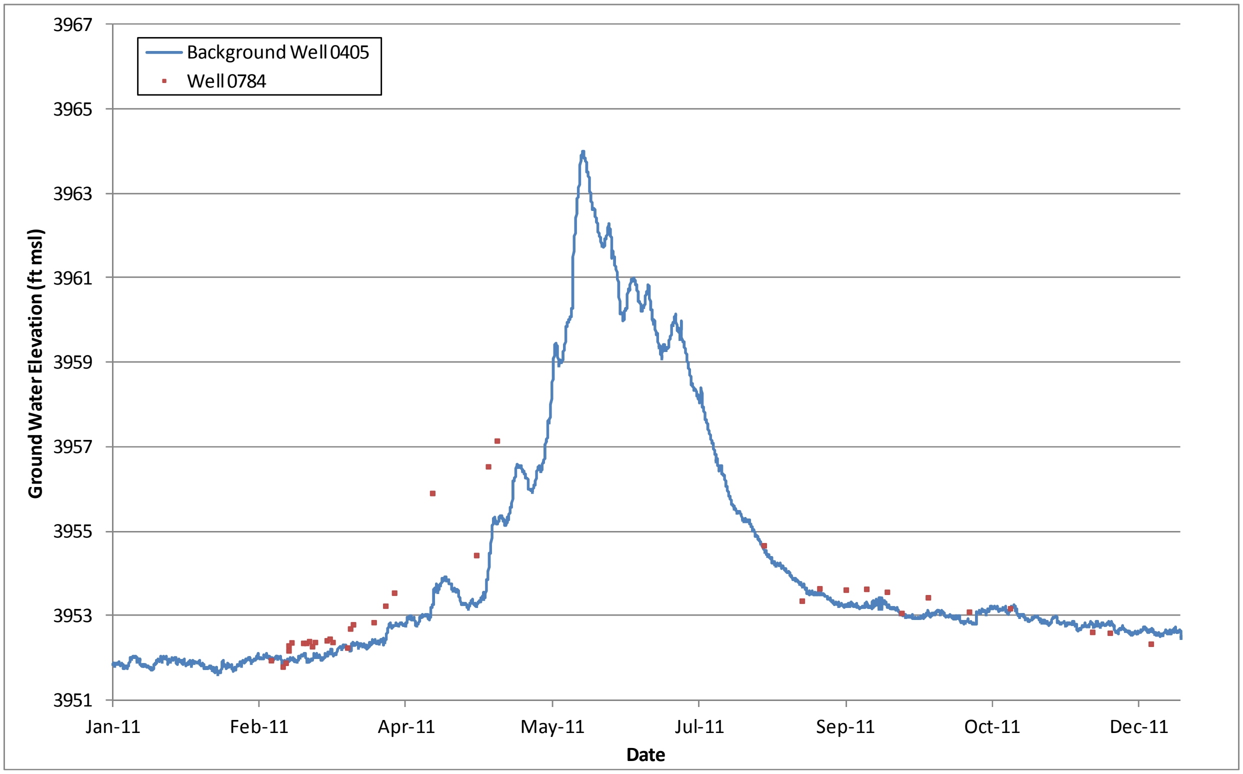


Figure C-15. Freshwater Mounding in Observation Well 0784

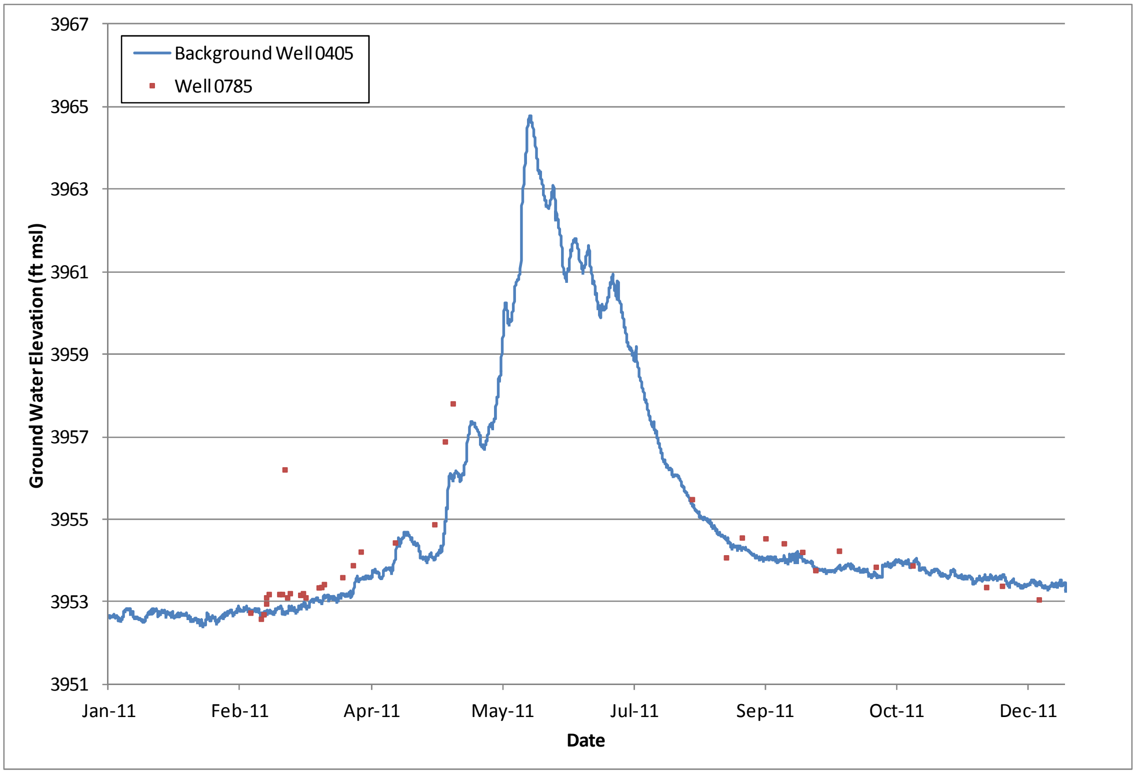


Figure C-16. Freshwater Mounding in Observation Well 0785

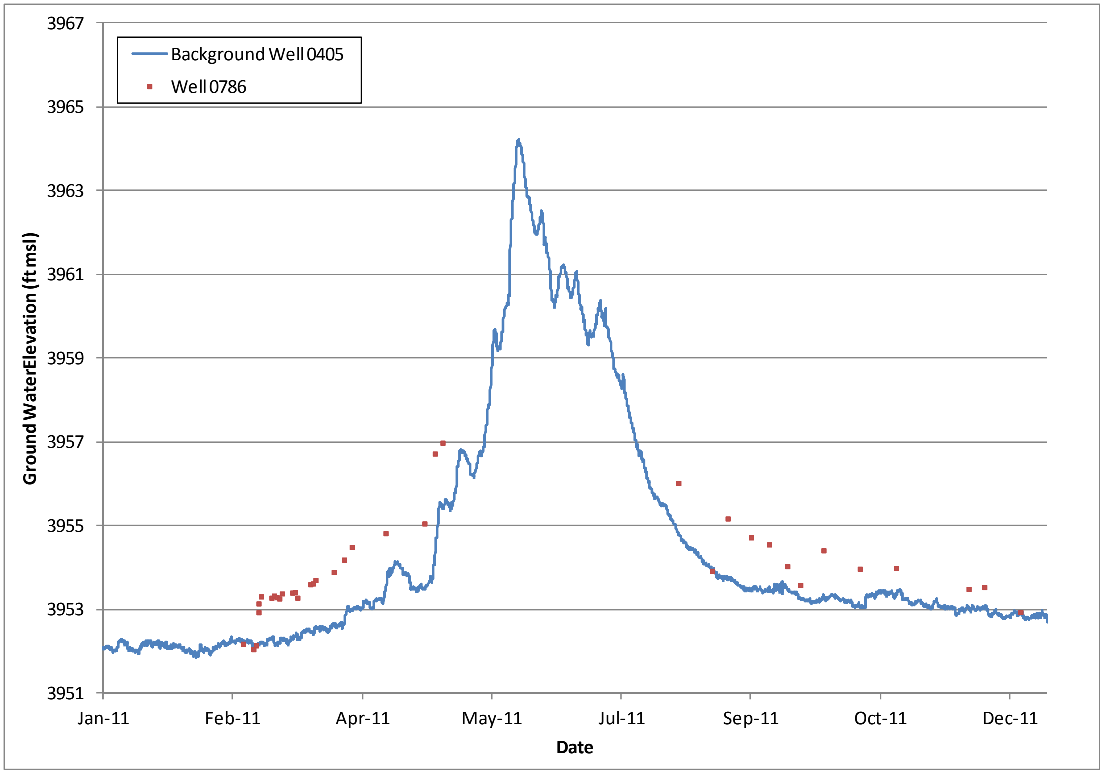


Figure C-17. Freshwater Mounding in Well 0786

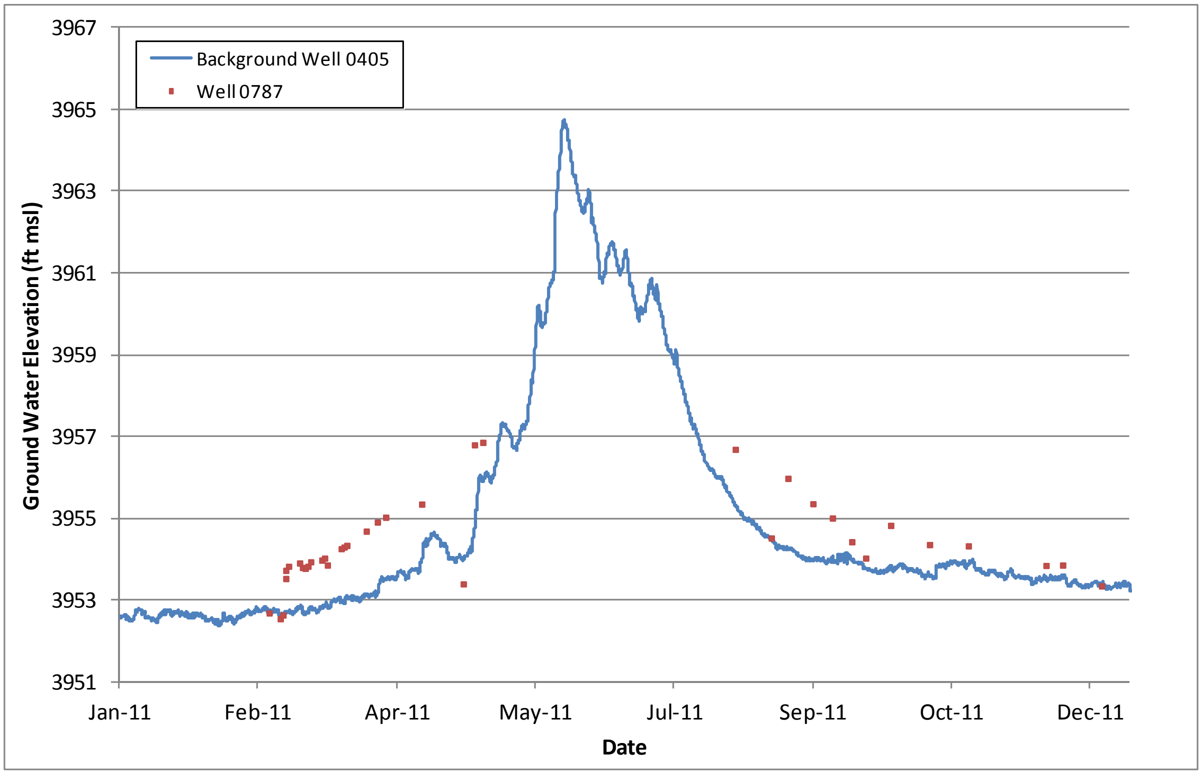


Figure C-18. Freshwater Mounding in Well 0787

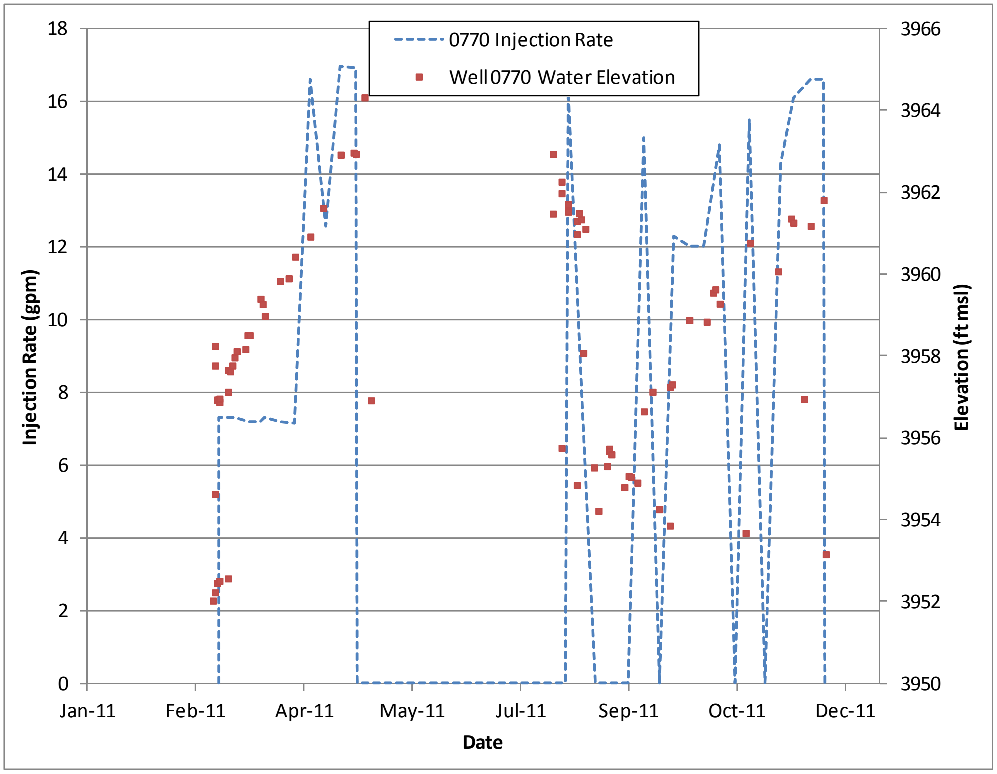


Figure C-19. Remediation Well 0770 Injection Rate vs. Water Elevation

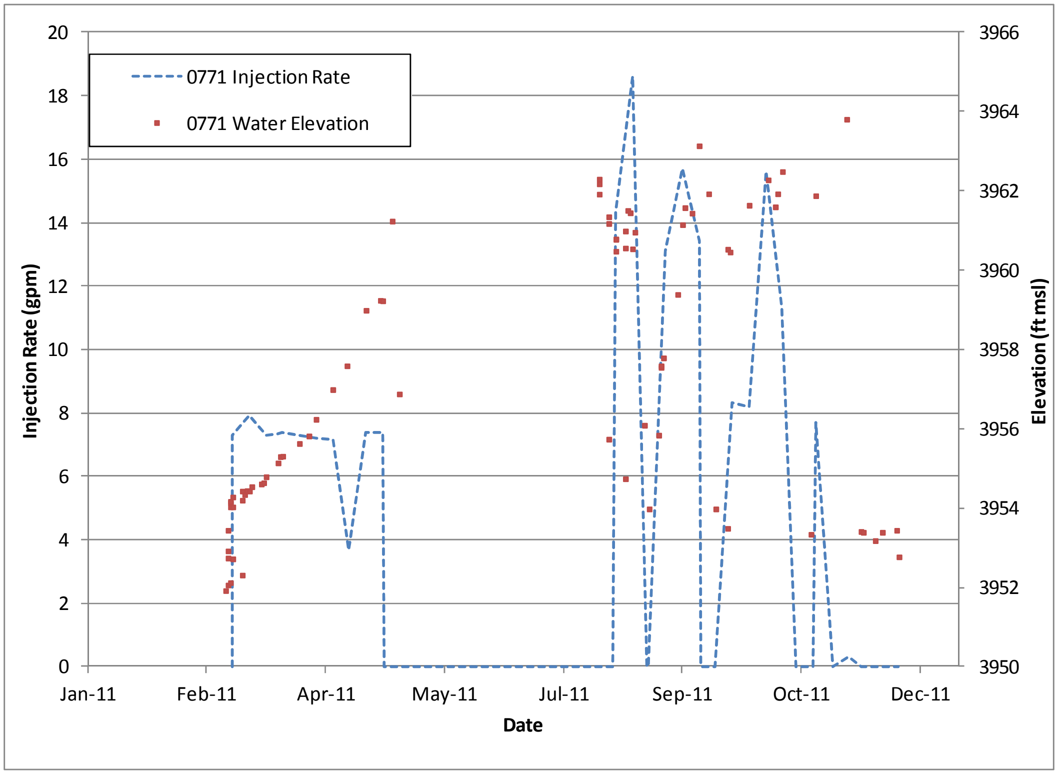


Figure C-20. Remediation Well 0771 Injection Rate vs. Water Elevation

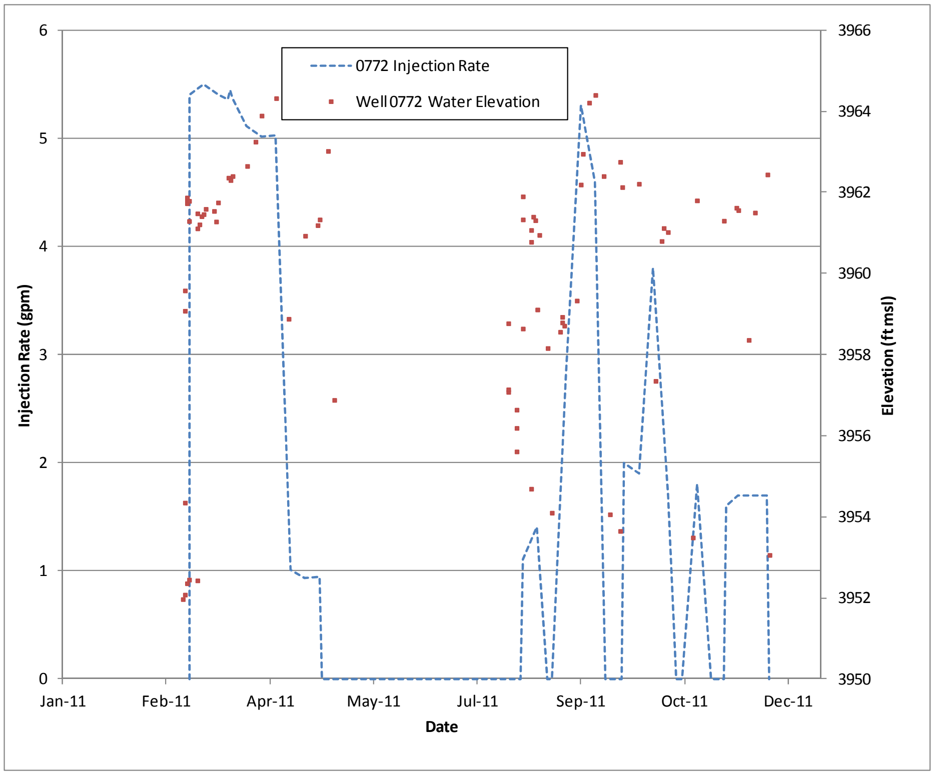


Figure C-21. Remediation Well 0772 Injection Rate vs. Water Elevation

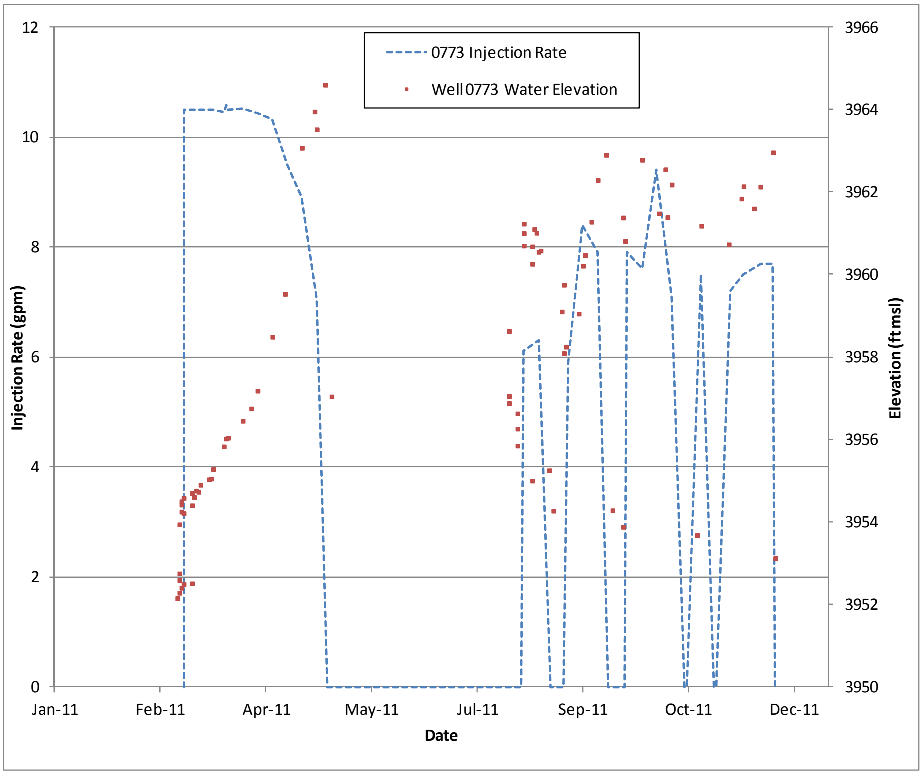


Figure C-22. Remediation Well 0773 Injection Rate vs. Water Elevation

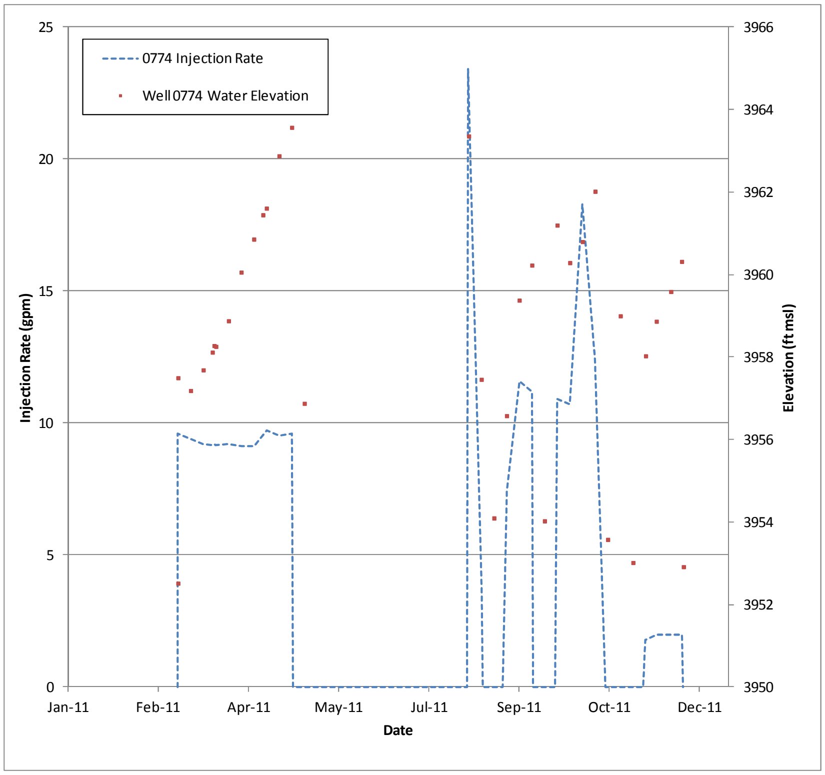


Figure C-23. Remediation Well 0774 Injection Rate vs. Water Elevation

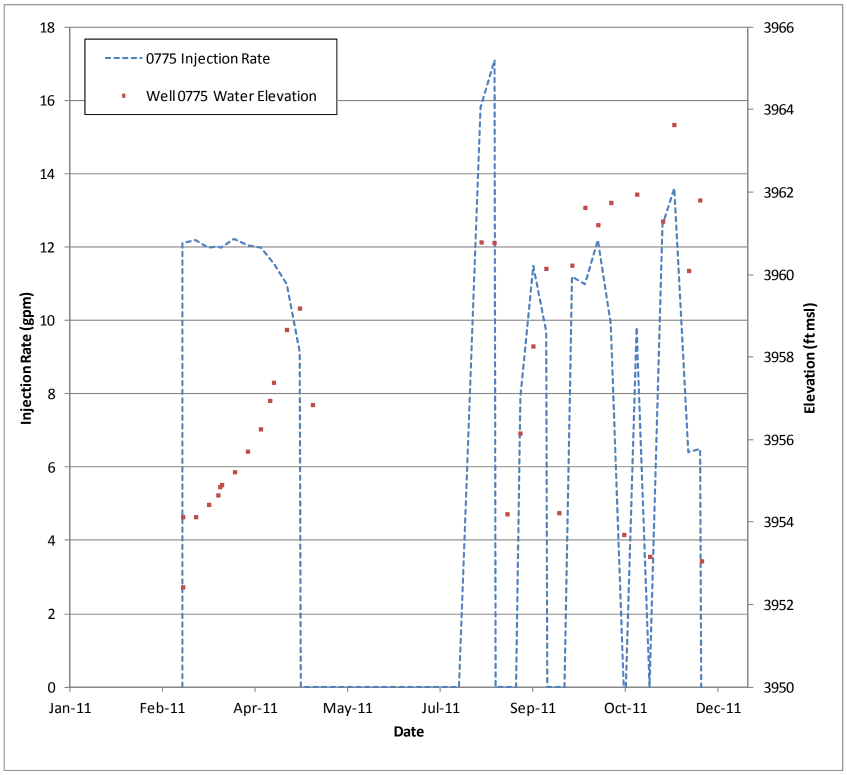
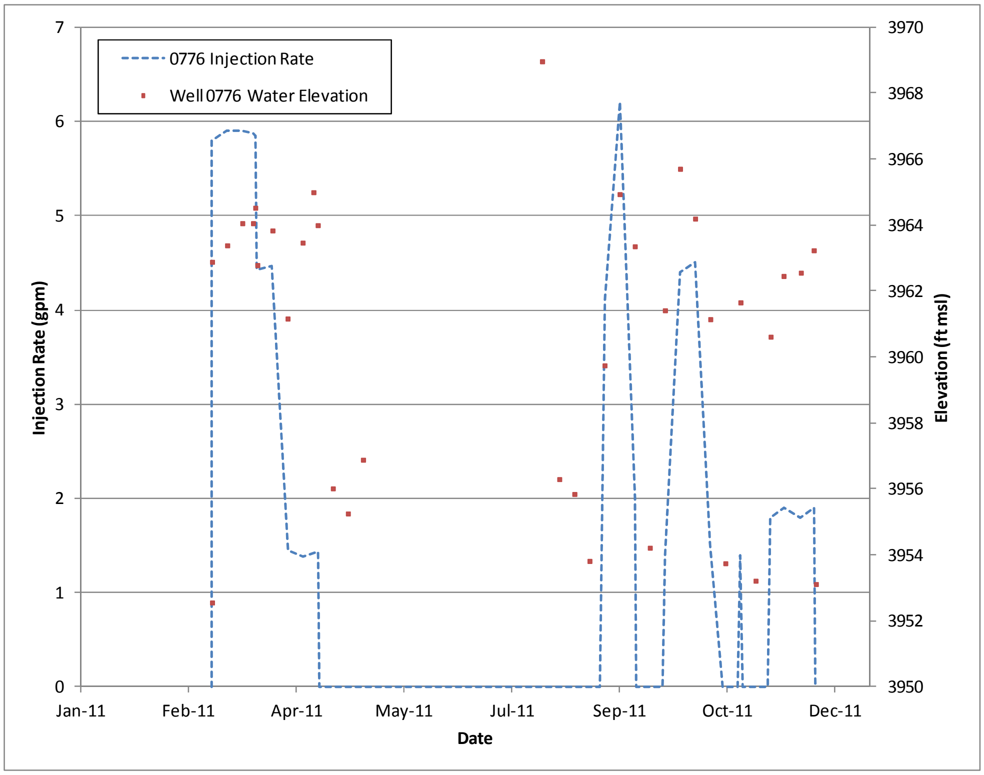
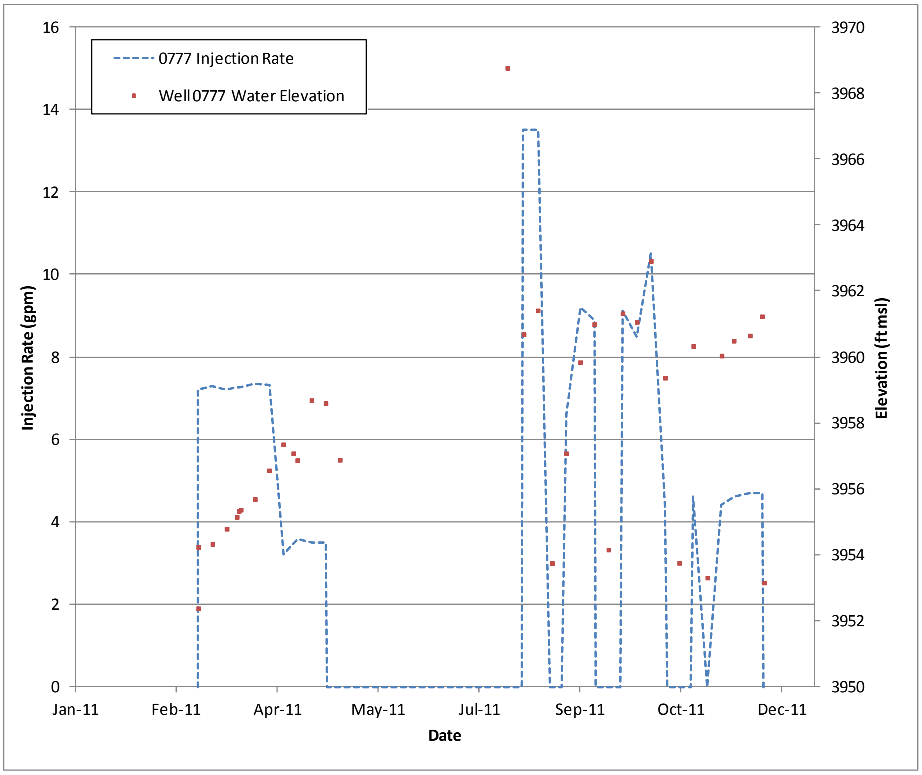


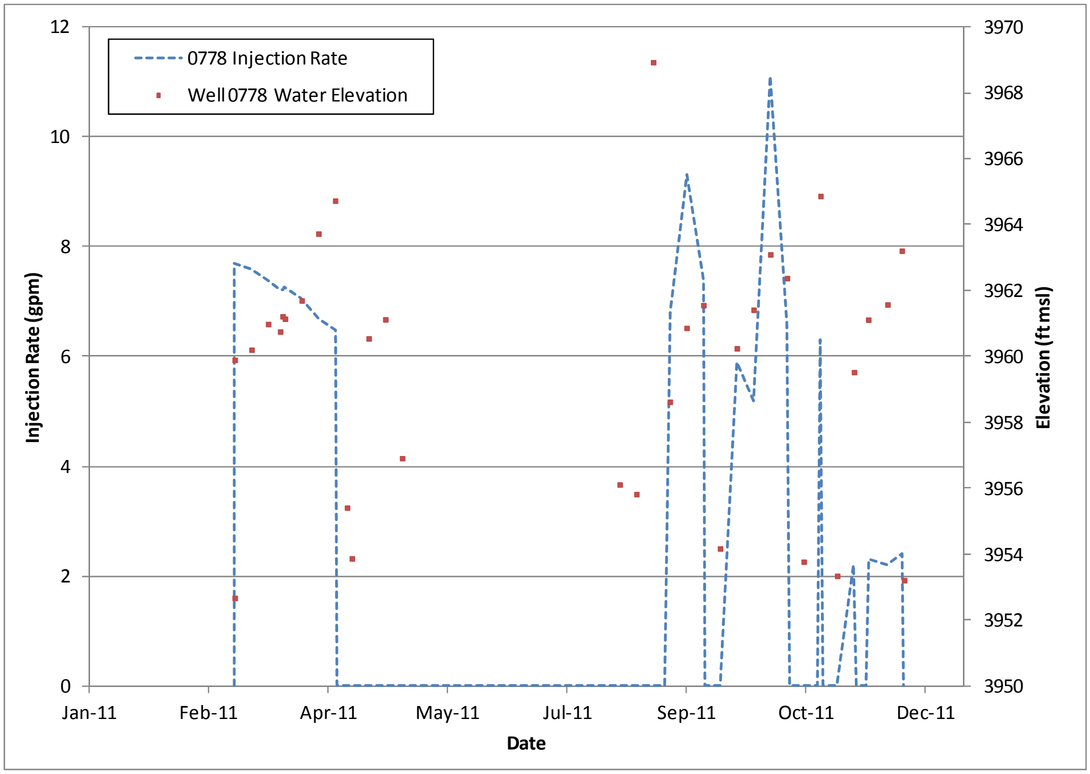
Figure C-24. Remediation Well 0775 Injection Rate vs. Water Elevation



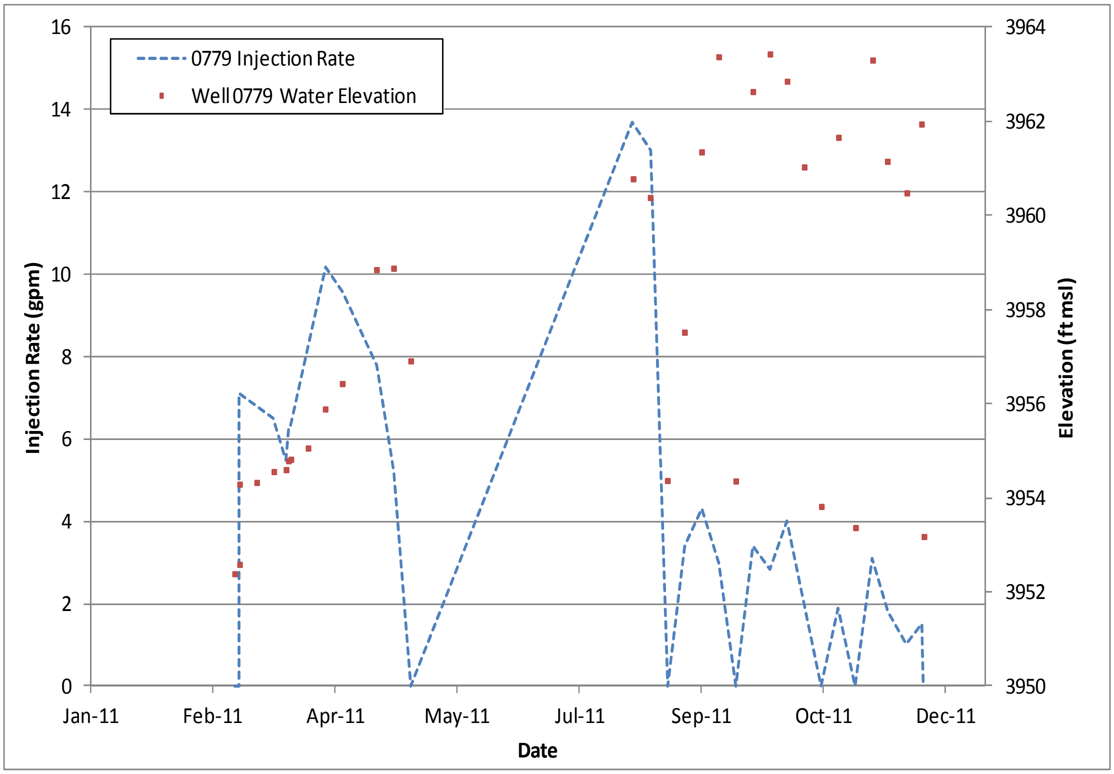
C-25. Remediation Well 0776 Injection Rate vs. Water Elevation



C-26. Remediation Well 0777 Injection Rate vs. Water Elevation



C-27. Remediation Well 0778 Injection Rate vs. Water Elevation



C-28. Remediation Well 0779 Injection Rate vs. Water Elevation