LMS/SHP/S04378

Office of Legacy Management

Annual Performance Report April 2007 Through March 2008 for the Shiprock, New Mexico, Site

September 2008

U.S. Department of Energy

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1.0 Introduction

This report evaluates the performance of the groundwater remediation system at the disposal and processing site in Shiprock, New Mexico, for the period of April 2007 through March 2008. The Shiprock site, a former uranium mill tailings facility under the Uranium Mill Tailings Radiation Control Act (UMTRCA), is currently managed by the U.S. Department of Energy Office of Legacy Management (DOE-LM). This evaluation is based on a comparison of the site conditions in March 2008 to the baseline site conditions presented in the *Baseline Performance Report* (DOE 2003). The baseline conditions were established using data collected primarily from March 2003. A detailed description of the site conditions is presented in the *Site Observational Work Plan* (SOWP) (DOE 2000), and the compliance strategy is presented in the *Groundwater Compliance Action Plan* (GCAP) (DOE 2002).

The Shiprock site is divided into two distinct areas, the floodplain and the terrace. An escarpment forms the boundary between the two areas. The floodplain remediation system currently consists of two groundwater extraction wells, a seep collection drain, two collection trenches, and an open pit sump system. The terrace remediation system currently consists of nine groundwater extraction wells, two collection drains (Bob Lee Wash and Many Devils Wash), and a terrace drainage channel diversion structure. All extracted groundwater goes into a lined evaporation pond on the terrace. The entire groundwater remediation system is shown in Figure 1–1.

1.1 Remediation System Performance Standards

This performance assessment is based on the analysis of groundwater-quality and groundwater-level data obtained from site monitor wells in addition to groundwater flow rates associated with the extraction wells, drains, and seeps.

Specific performance standards as established for the Shiprock floodplain groundwater remediation system in the *Baseline Performance Report* (DOE 2003) are summarized as follows:

- Groundwater flow directions in the vicinity of the extraction wells should be toward the extraction wells.
- Pumping on the floodplain should intercept contaminants of concern (COC) that would otherwise discharge to the San Juan River.

Figure 1–1. Location Map and Groundwater Remediation System

Specific performance standards as established for the Shiprock terrace groundwater remediation system in the *Baseline Performance Report* (DOE 2003) are summarized as follows:

- Terrace groundwater surface elevations should decrease as water is removed from the terrace system.
- Groundwater flow directions in the vicinity of the extraction wells should be toward the extraction wells. This was evaluated in the first 4 years of the project and is no longer required.
- The volume of water discharging to the interceptor drains located in Bob Lee Wash and Many Devils Wash should decrease over time as groundwater levels on the terrace decline.
- The flow rates of seeps located at the escarpment face (locations 0425 and 0426) should decrease over time as groundwater levels on the terrace decline.

1.2 COCs and Remediation Goals

Groundwater at the site is contaminated as a result of uranium-milling activities between 1954 and 1968. The COC for both the floodplain and terrace are ammonia (total as nitrogen), manganese, nitrate (nitrate + nitrite as nitrogen), selenium, strontium, sulfate, and uranium. The concentrations of COC in terrace and floodplain groundwater, based on the March 2008 sampling event, are shown in Figure 1–2 through Figure 1–8. Figure 1–9 through Figure 1–15 present changes in the extent of the floodplain and terrace contaminates plumes based on data from 2000/2001 and September 2007. A more complete sampling event is planned for the March 2009 sampling that will allow these plume maps to be further updated in the next performance report.

Floodplain compliance standards for uranium and nitrate are their respective UMTRCA standards of 0.044 and 10 milligrams per liter (mg/L). A secondary standard of 250 mg/L for sulfate exists under the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act. However, studies conducted by the Centers for Disease Control in conjunction with EPA have shown that no adverse effects from sulfate ingestion occur at concentrations of up to 1,200 mg/L (EPA 1999). The report notes that other studies have shown that concentrations of sulfate exceeding 2,000 mg/L may have little to no adverse effect on humans and animals. Because of high background sulfate concentrations at the site in floodplain groundwater (4,300 mg/L in background well 0797) and the high sulfate concentration of water entering the floodplain from flowing artesian well 0648 (up to 2,340 mg/L), the proposed cleanup goal for floodplain sulfate is 2,000 mg/L. Relatively high selenium concentrations in the floodplain make it unlikely that the UMTRCA standard of 0.01 mg/L for this constituent can be met while contaminated terrace water is still providing a source. DOE proposed an alternate concentration limit for selenium of 0.05 mg/L (DOE 2003), which is the EPA maximum contaminant level for drinking water. The cleanup objective for manganese is the maximum background concentration for the floodplain, which is currently 2.74 mg/L. There are no cleanup standards or background concentrations established for ammonia and strontium.

Groundwater compliance for the terrace is based on hydrologic control, and concentration standards do not apply.

1.3 Hydrogeological Setting

This section summarizes the floodplain and terrace groundwater systems. A more detailed description is available in the SOWP (DOE 2000).

1.3.1 Floodplain Alluvial Aquifer

The thick Mancos Shale of Cretaceous age forms the bedrock underlying the entire site. A floodplain alluvial aquifer occurs in unconsolidated medium- to coarse-grained sand, gravel, and cobbles that were deposited in former channels of the San Juan River above the Mancos Shale. The floodplain aquifer is hydraulically connected to the San Juan River; the river is a source of groundwater recharge to the floodplain aquifer in some areas, and it receives groundwater discharge in other areas. In addition, the floodplain aquifer almost certainly receives some inflow from a groundwater system in the terrace area. The floodplain alluvium is up to 20 feet (ft) thick and overlies Mancos Shale, which is typically soft and weathered for the first several feet below the alluvium.

Most groundwater contamination in the floodplain lies close to the escarpment east and north of the disposal cell. A plume extends northward from this contaminated area in an arc-shape as it crosses the floodplain and reaches the San Juan River near the floodplain extraction wells (Figure 1–2 through Figure 1–8). This plume configuration is best characterized by elevated concentrations of sulfate and uranium. Contamination does not occur along the escarpment base in the northwest part of the floodplain because relatively uncontaminated surface water from Bob Lee Wash discharges into the floodplain, recharging local groundwater and then flowing to the north and west. Surface water in Bob Lee Wash originates primarily as deep groundwater from the Morrison Formation that flows to the land surface via artesian well 0648. Well 0648 flows at approximately 65 gallons per minute (gpm) and drains eastward into lower Bob Lee Wash. Background groundwater quality in the floodplain aquifer has been defined by monitor wells installed in the floodplain approximately 1 mile upriver from the site.

1.3.2 Terrace Groundwater System

The terrace groundwater system occurs partly in unconsolidated alluvium in the form of medium- to coarse-grained sand, gravel, and cobbles deposited in the floodplain of the ancestral San Juan River. Terrace alluvial material is Quaternary in age; it varies from 0 to 20 ft thick and caps the Mancos Shale. Though less well mapped, some terrace groundwater also occurs in weathered Mancos Shale underlying the alluvium. The Mancos Shale is exposed in the escarpment overlooking the present floodplain.

The terrace groundwater system extends southwestward from the escarpment separating the terrace from the floodplain for up to 1 mile, where it is abruptly bounded by a buried escarpment. Terrace alluvial material is exposed at the terrace–floodplain escarpment, but to the southwest, it is covered by an increasing thickness of eolian silt, or loess. At the southwest edge of the terrace aquifer, along the base of the buried escarpment, up to 40 ft of loess overlies the alluvium; the alluvium in this area consists of coarse, ancestral San Juan River deposits.

Mancos Shale in the terrace area is weathered (fractured and soft) several feet below its contact with the alluvium. Groundwater is known to occur in the weathered shale, and it may flow through deeper portions of the shale that might be fractured, and along bedding surfaces.

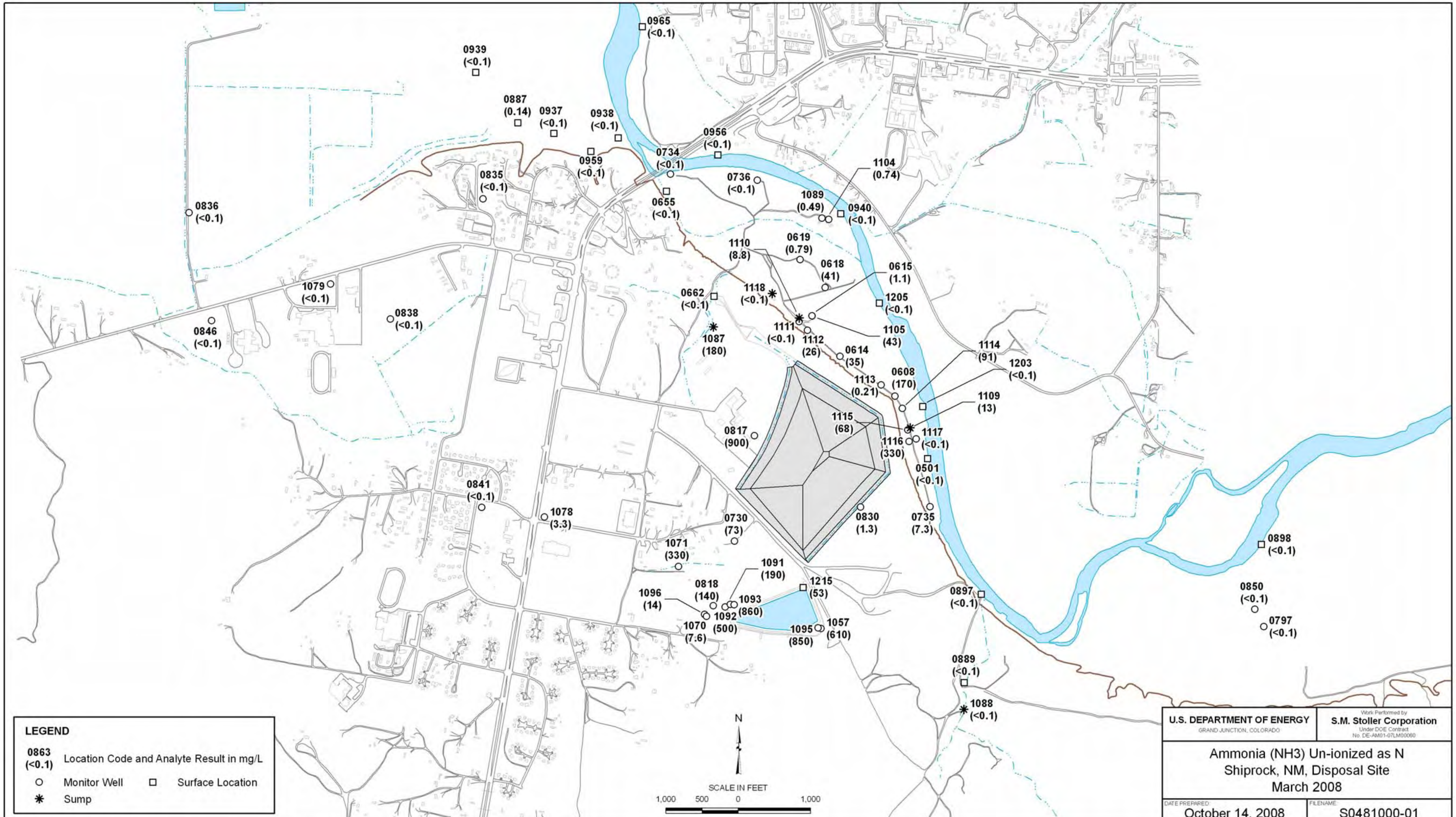

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Figure 1–2. Concentrations of Ammonia (NH3) Un-ionized as N in Terrace and Floodplain Groundwater, March 2008

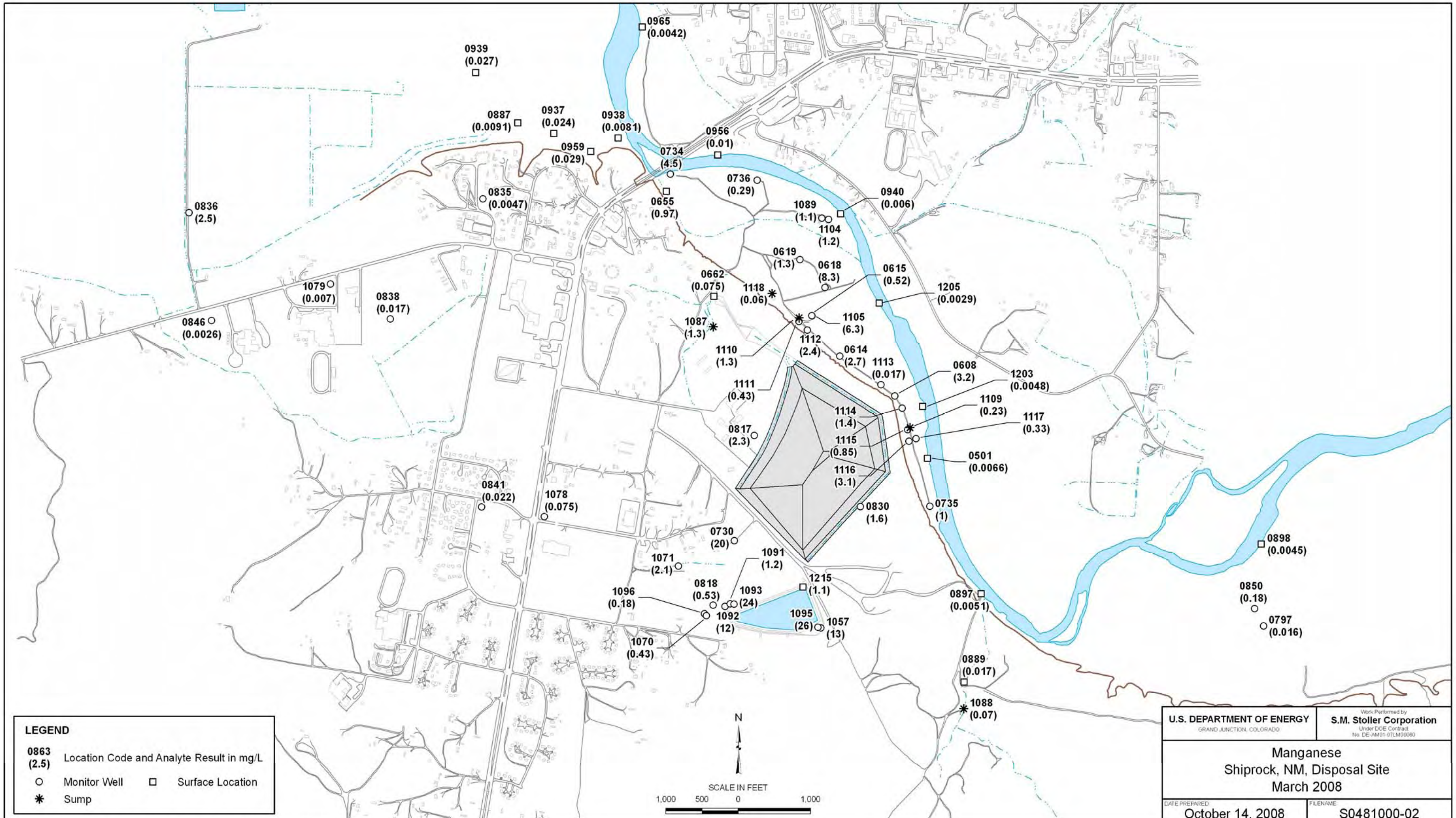

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Figure 1–3. Concentrations of Manganese in Terrace and Floodplain Groundwater, March 2008

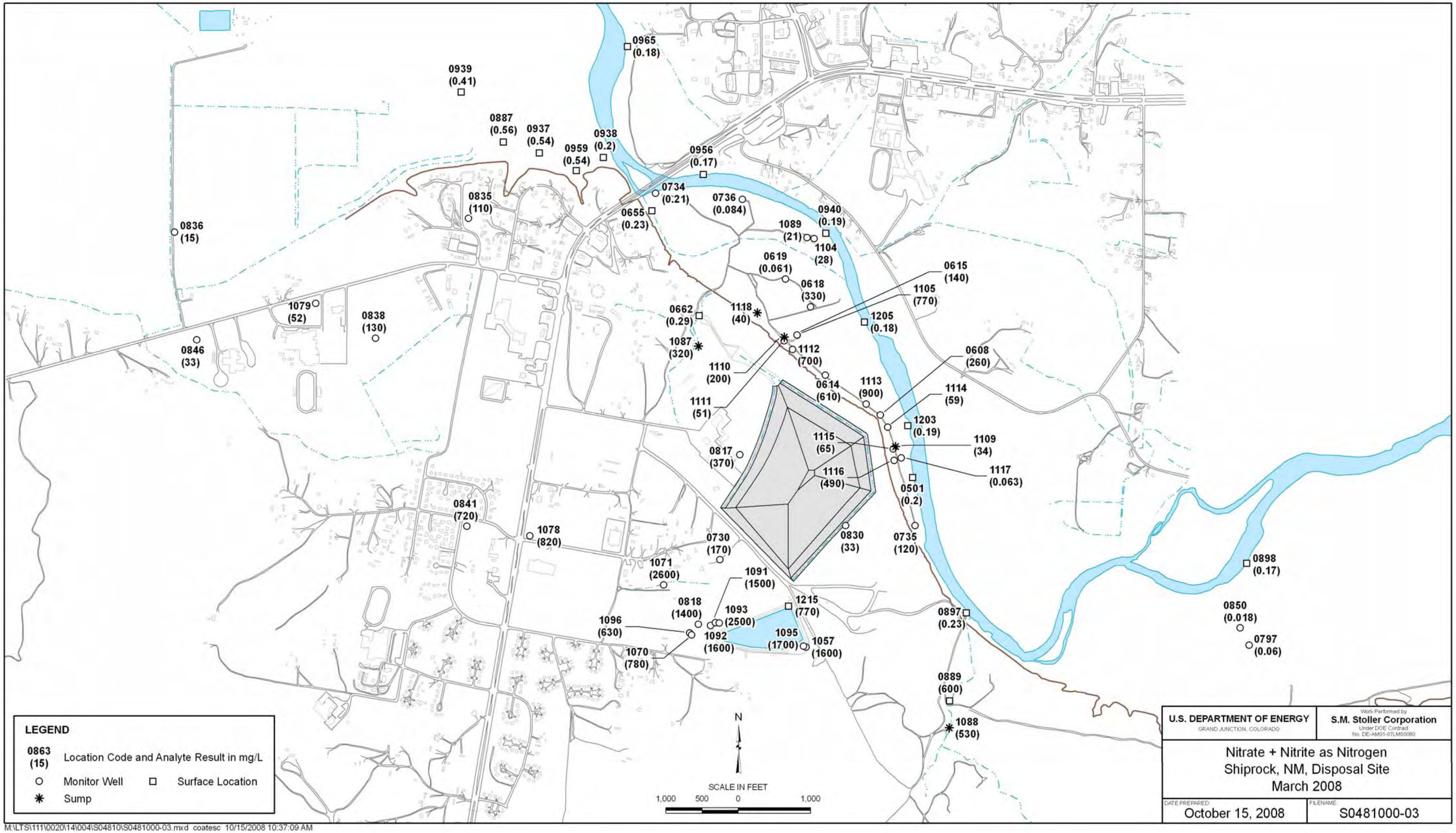

Figure 1–4. Concentrations of Nitrate + Nitrite as Nitrogen in Terrace and Floodplain Groundwater, March 2008

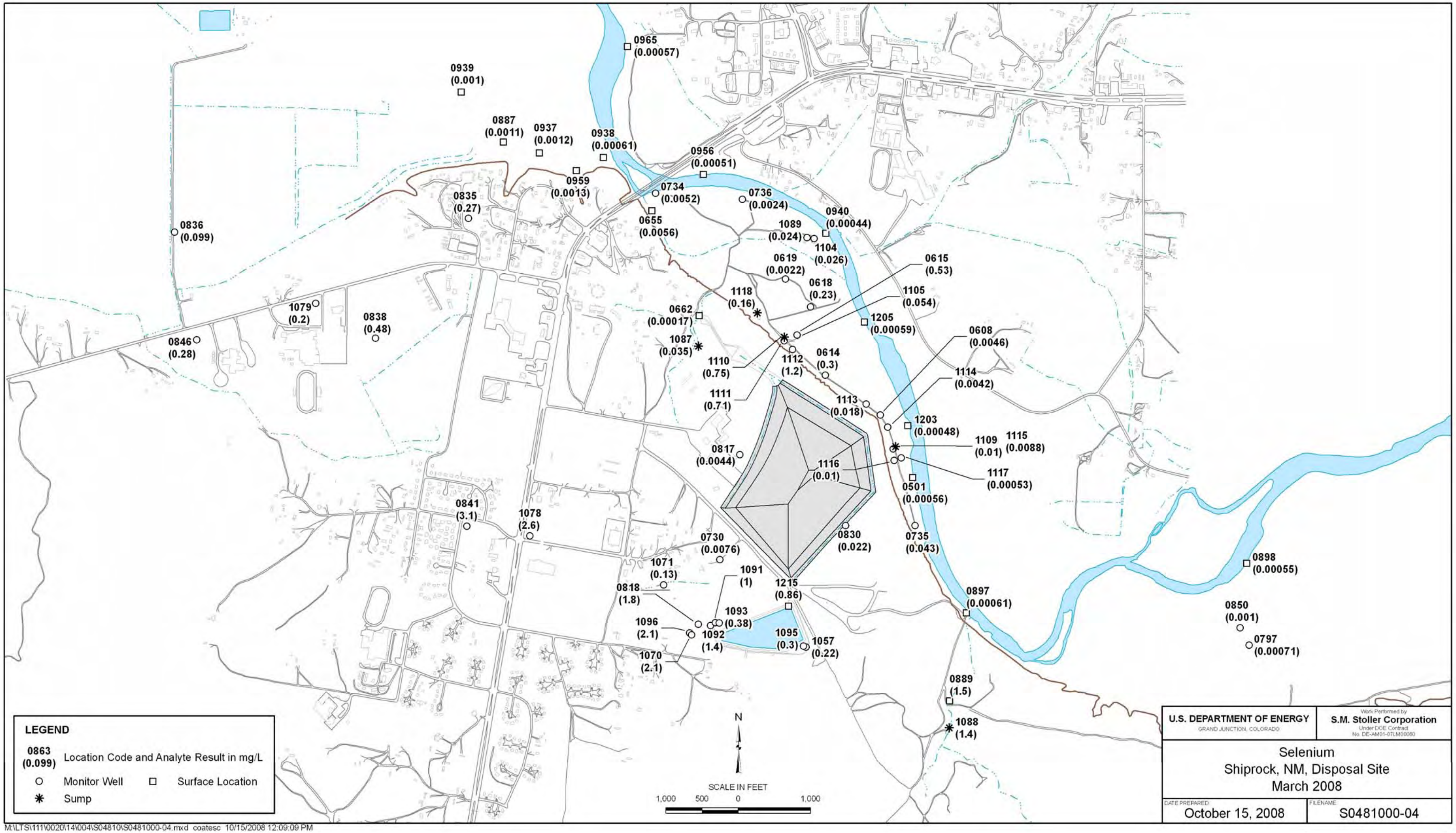

Figure 1–5. Concentrations of Selenium in Terrace and Floodplain Groundwater, March 2008

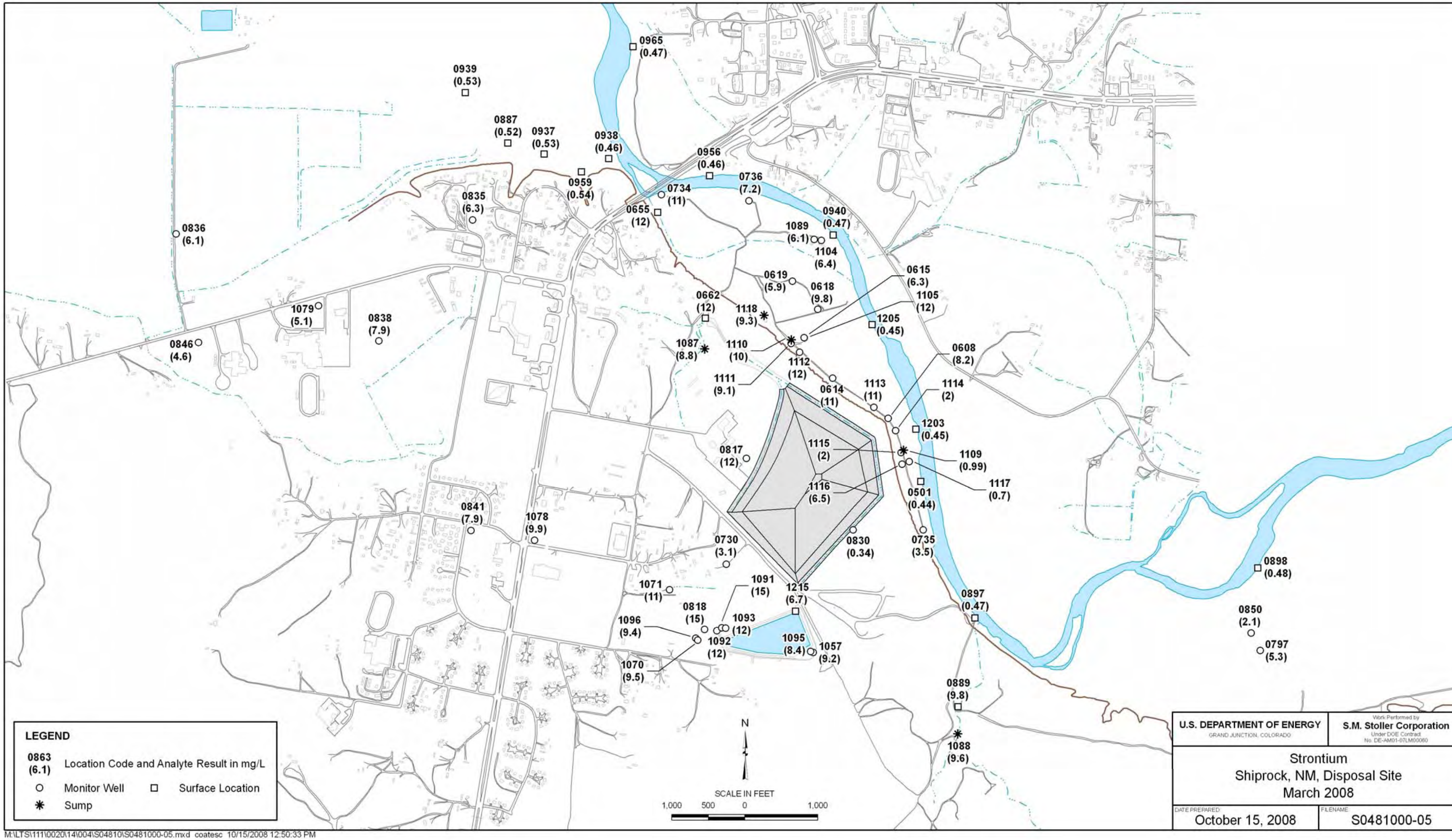

Figure 1–6. Concentrations of Strontium in Terrace and Floodplain Groundwater, March 2008

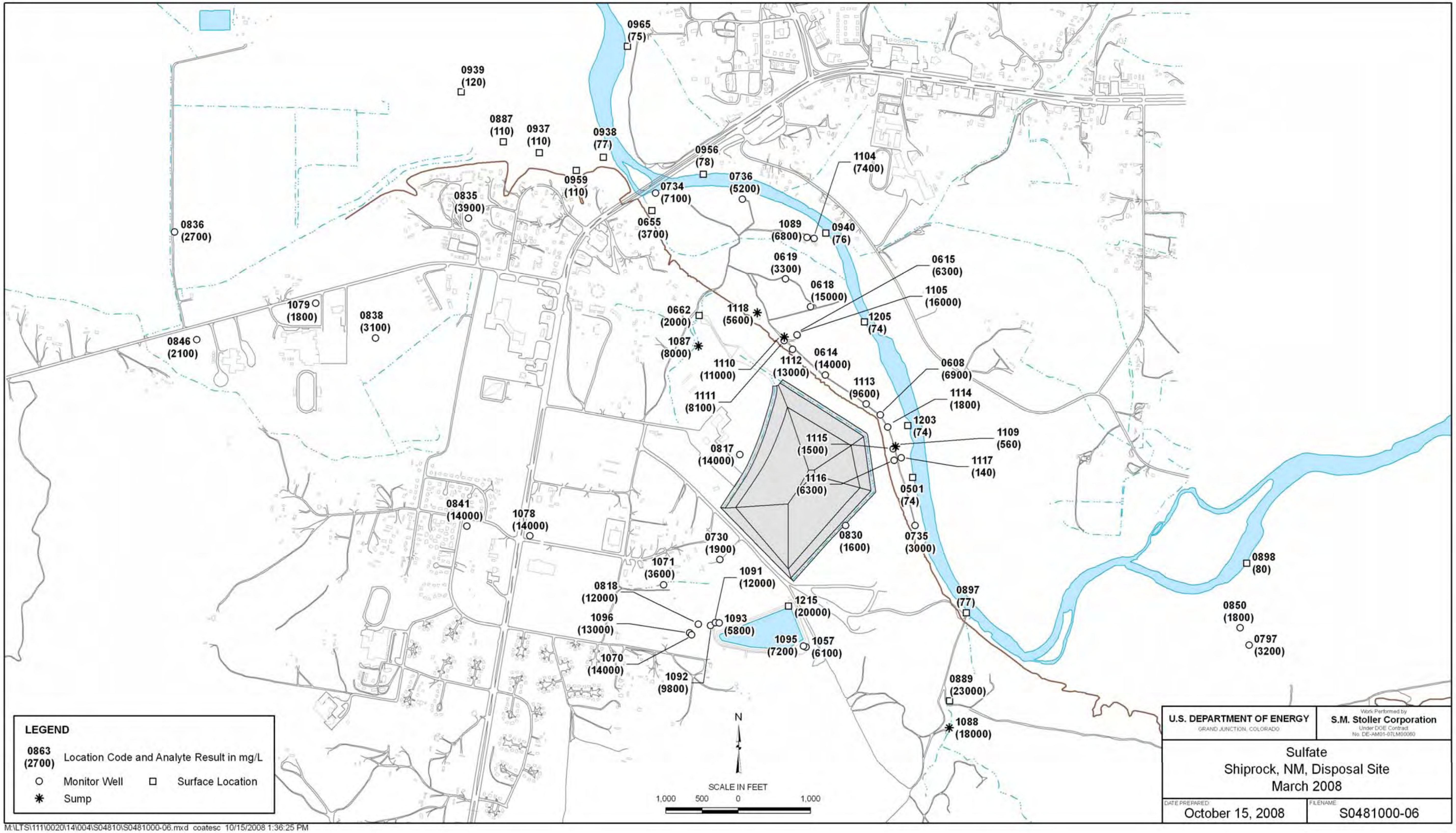

Figure 1–7. Concentrations of Sulfate in Terrace and Floodplain Groundwater, March 2008

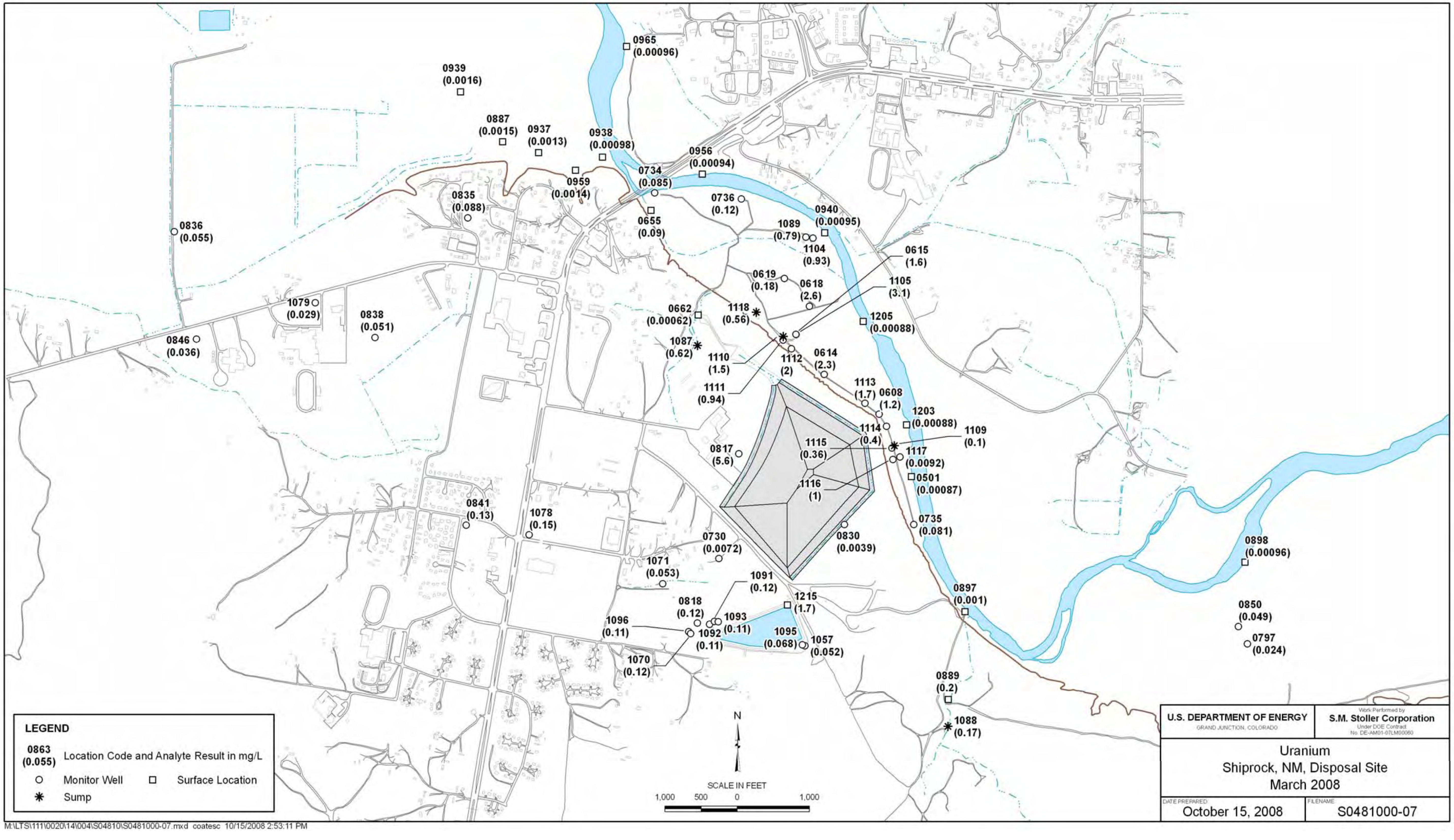

Figure 1–8. Concentrations of Uranium in Terrace and Floodplain Groundwater, March 2008

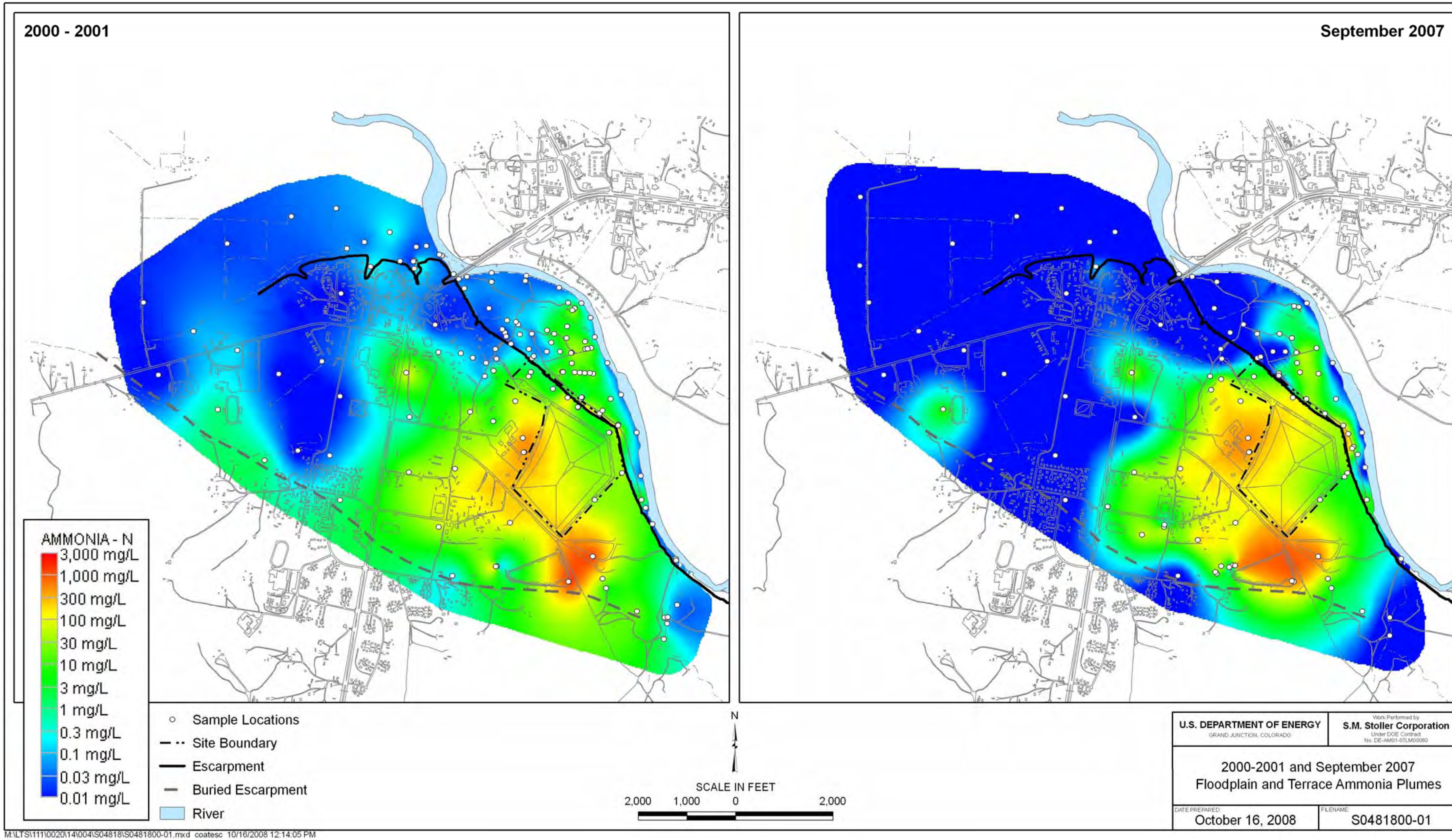

Figure 1–9. 2000/2001 and September 2007 Floodplain and Terrace Ammonia Plumes

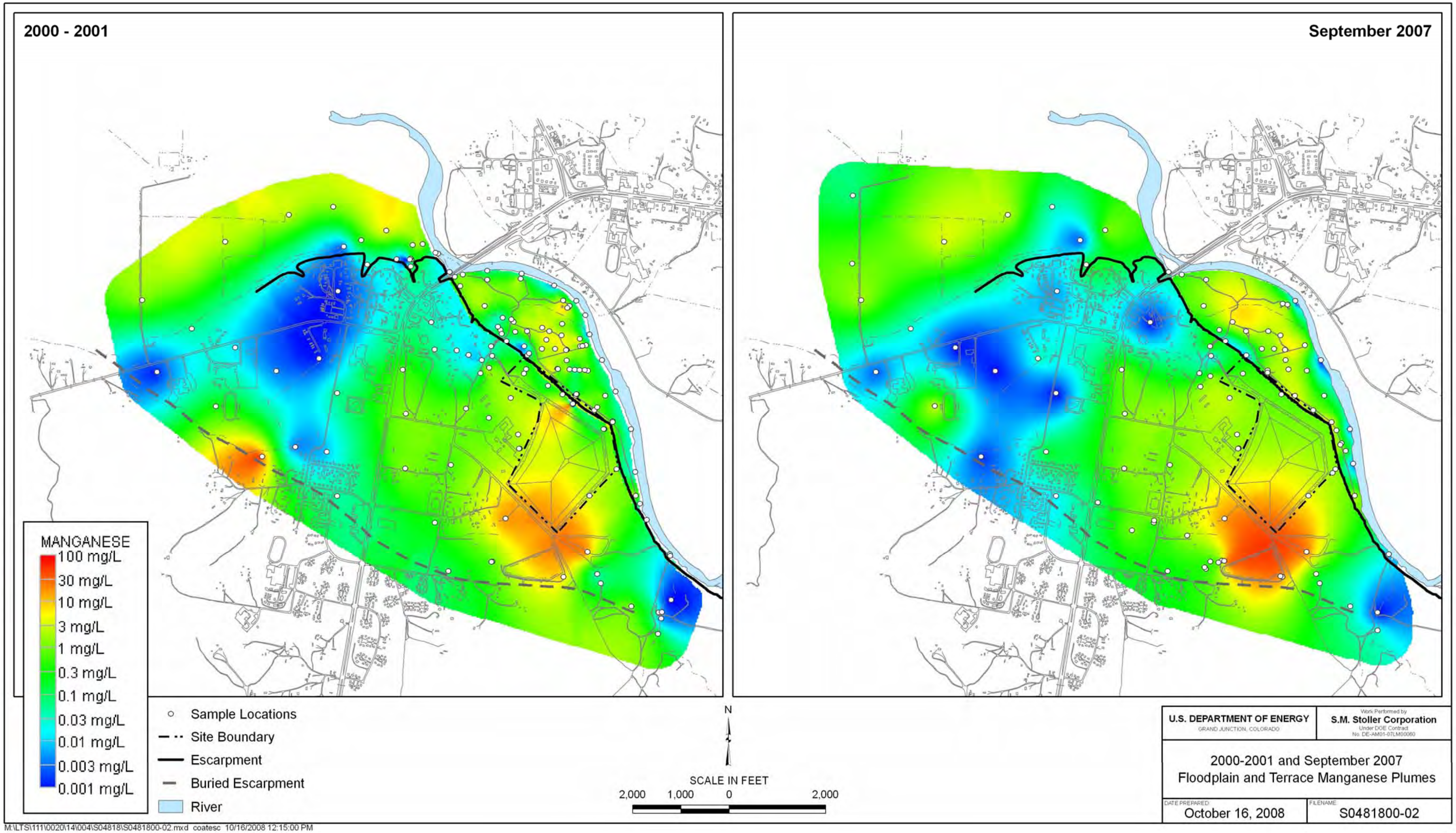

Figure 1–10. 2000/2001 and September 2007 Floodplain and Terrace Manganese Plumes

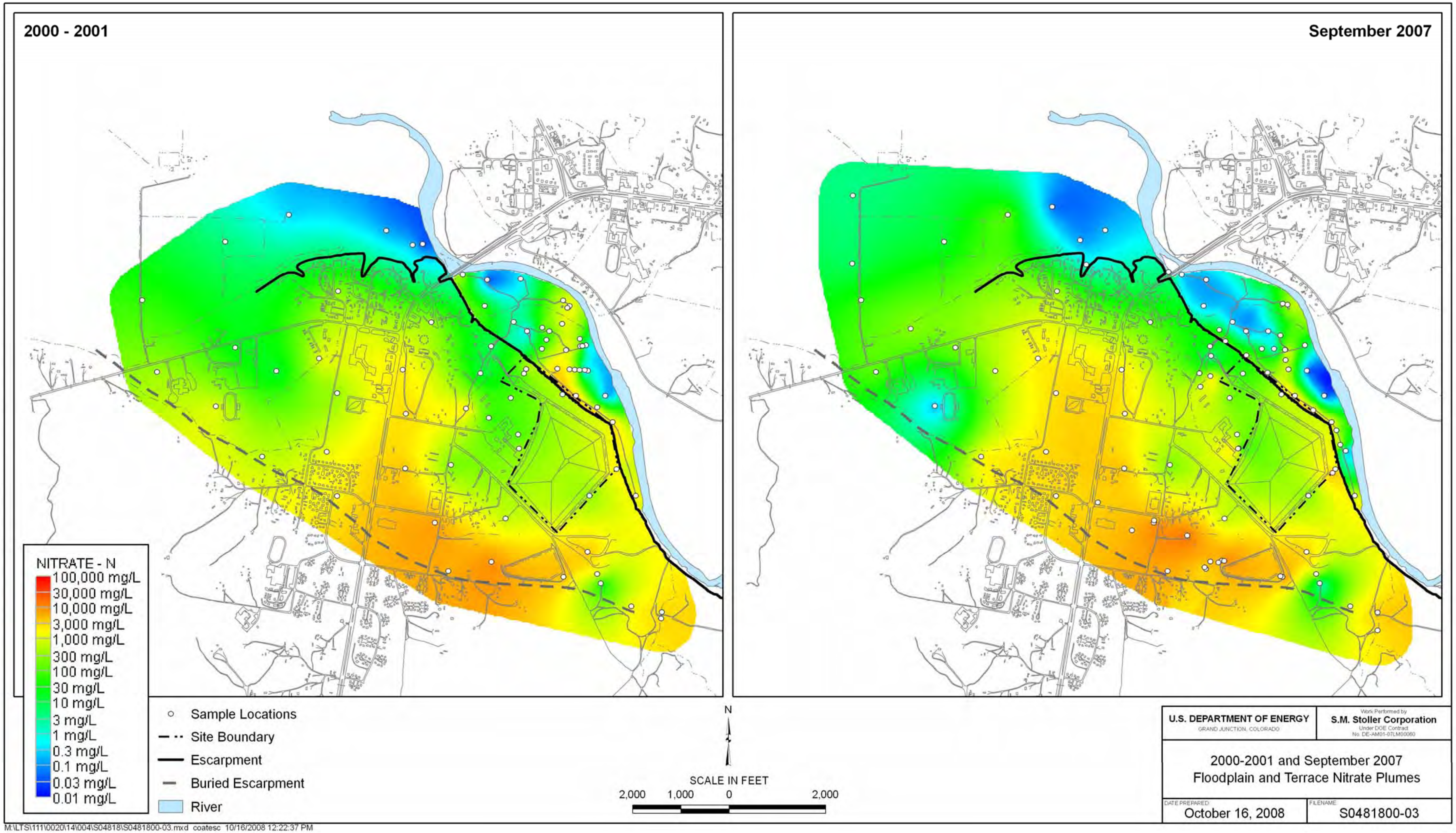

Figure 1–11. 2000/2001 and September 2007 Floodplain and Terrace Nitrate Plumes

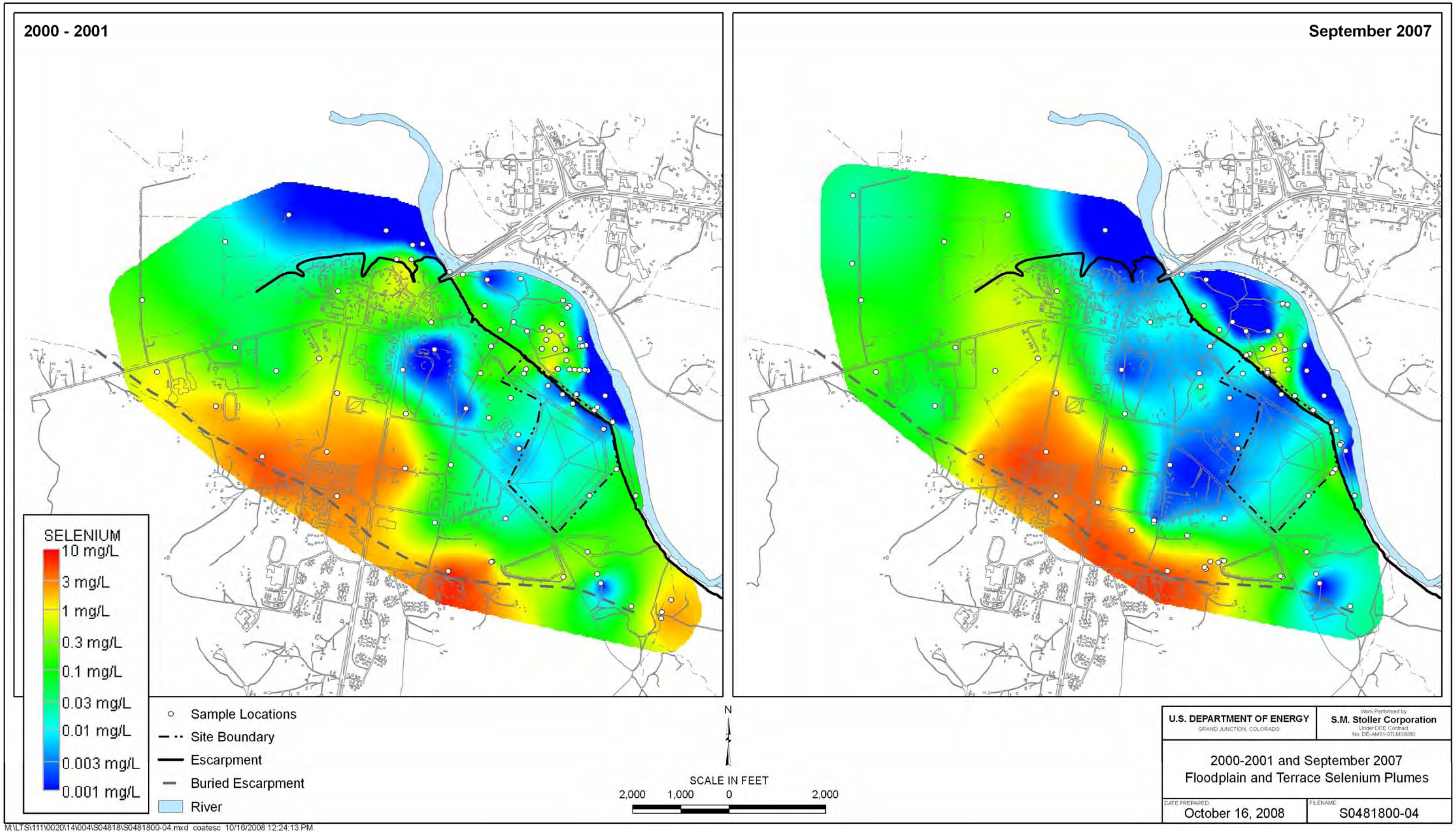

Figure 1–12. 2000/2001 and September 2007 Floodplain and Terrace Selenium Plumes

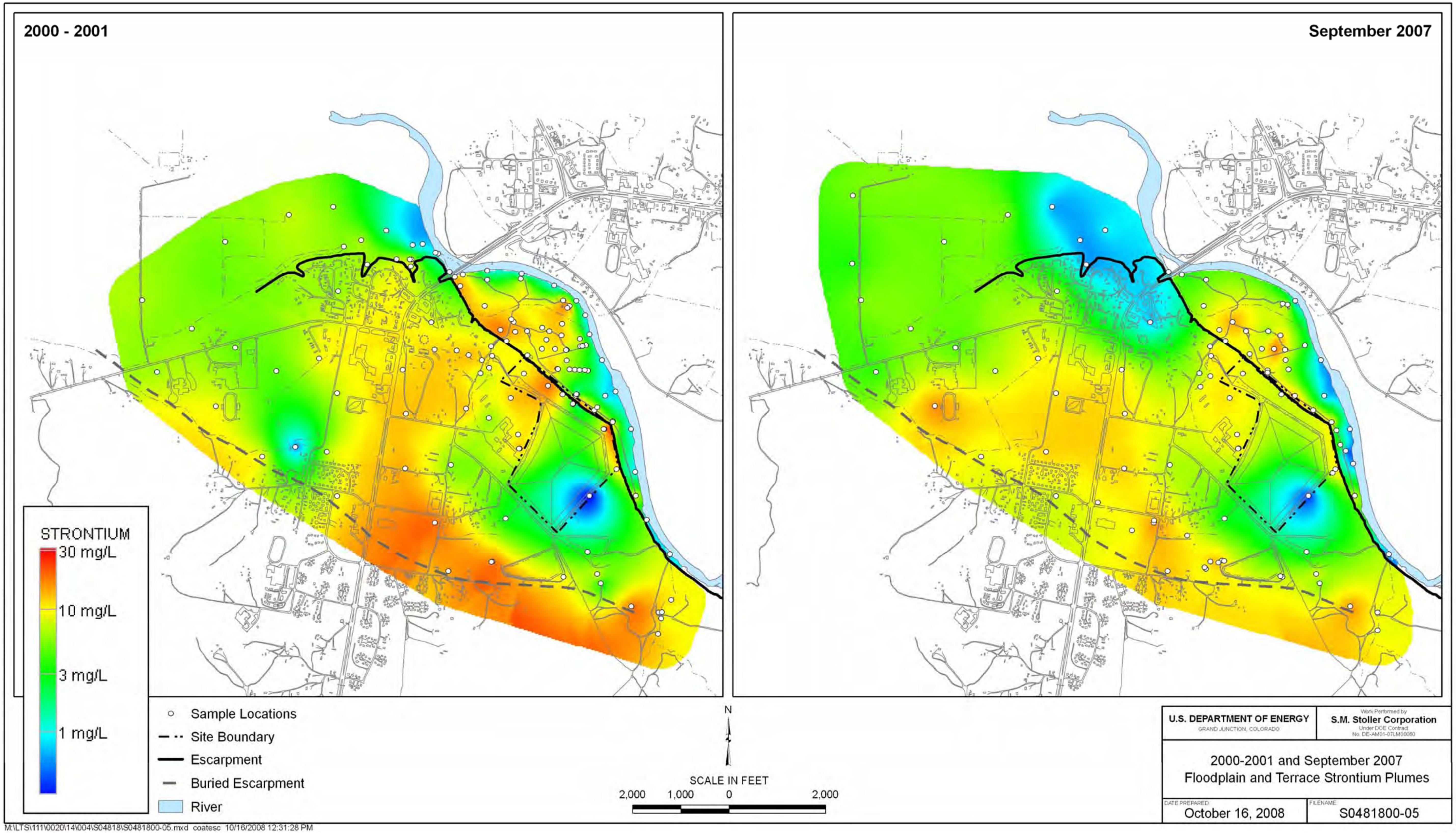

Figure 1–13. 2000/2001 and September 2007 Floodplain and Terrace Strontium Plumes

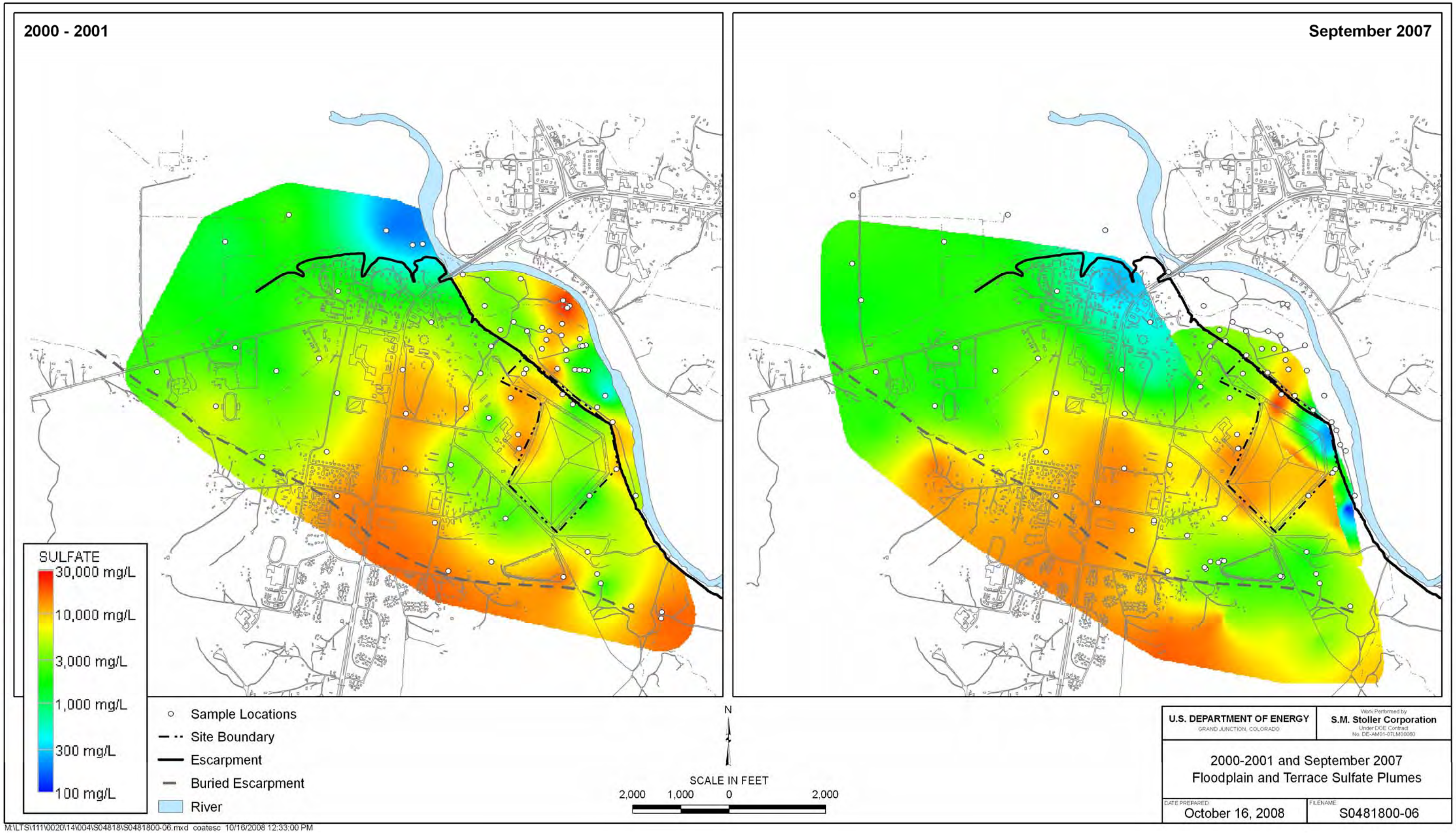

Figure 1–14. 2000/2001 and September 2007 Floodplain and Terrace Sulfate Plumes

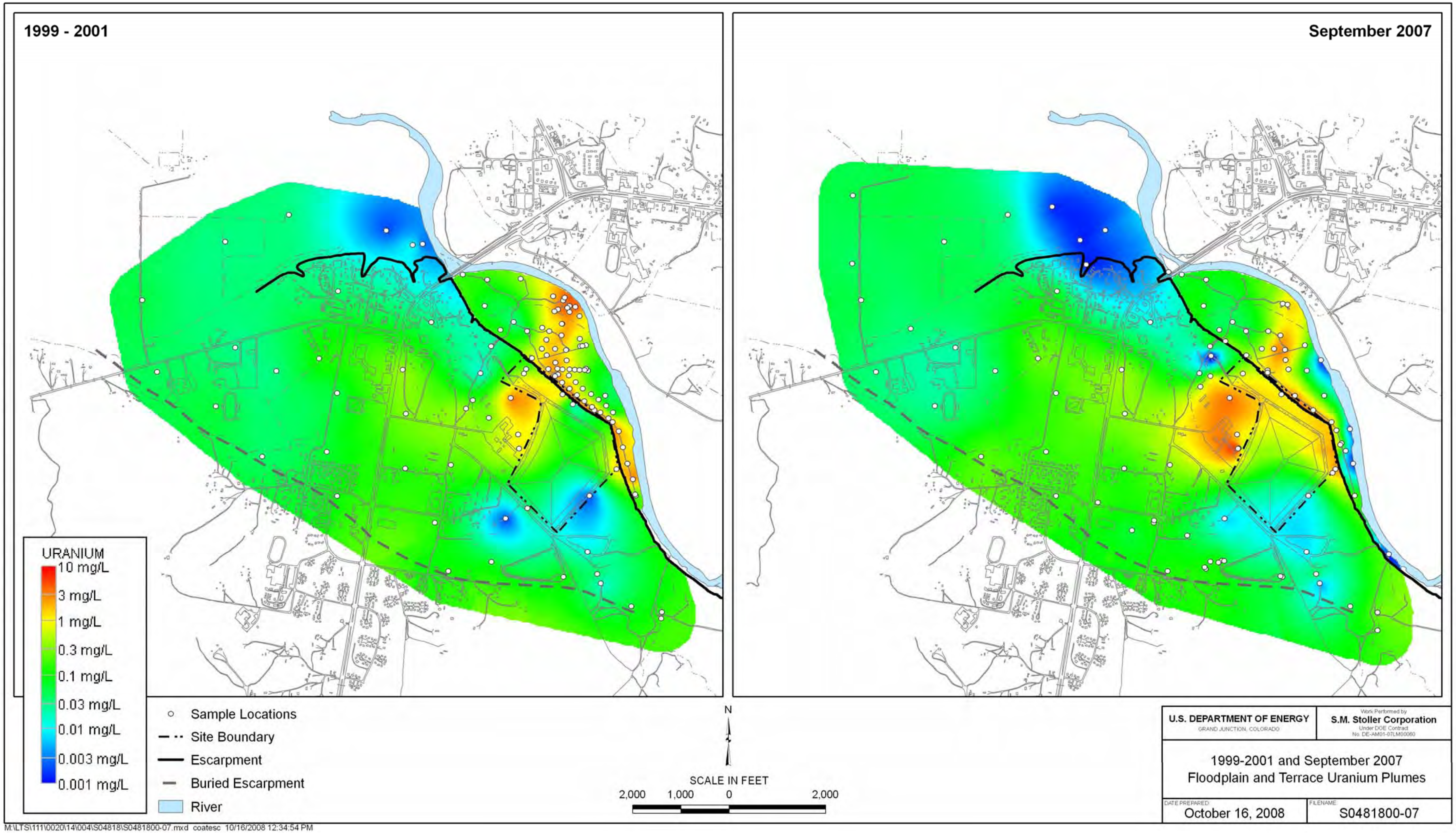

Figure 1–15. 2000/2001 and September 2007 Floodplain and Terrace Uranium Plumes

2.0 Subsurface Conditions

This section summarizes hydraulic and water-quality characteristics of the floodplain and terrace groundwater systems in March 2008, approximately 5 years after the startup of the treatment system. Figure 2–1 shows the locations of wells, remediation system, and surface sampling locations at the Shiprock site.

2.1 Floodplain Subsurface Conditions

The discussion of the floodplain's current subsurface conditions is based on the collection and analysis of groundwater samples and groundwater-level data through March 2008. Analyses of groundwater-level trends, groundwater flow directions, and contaminant distributions in the floodplain are discussed below. Results are compared to baseline conditions established in March 2003 in the *Baseline Performance Report* (DOE 2003) to evaluate the effectiveness of the floodplain treatment system.

2.1.1 Groundwater-Level Trends and Flow Directions

Three-point analyses of groundwater-level data were initiated using March 2003 information, which were subsequently compared to March 2004 and March 2005 data, to determine horizontal gradients and flow directions across the floodplain system and to demonstrate that the flow of groundwater was predominantly toward the extraction wells. Analysis of groundwater-level and flow data was also important in observing the recharge and discharge effects of the floodplain aquifer caused by interaction with the San Juan River's flow dynamics and by the seasonal variability of river flow and precipitation. Results of the three-point analyses over the 2-year period showed very little change in groundwater flow directions and demonstrated that the flow system in the floodplain was operating as expected, taking into account the variability mentioned above. There was also adequate indication that flow was toward the extraction wells.

Groundwater levels in the floodplain aquifer are manually recorded during routine groundwater sampling events (Figure 2–2). Groundwater-level fluctuations in the floodplain wells over the past 5-years have been on the order of 2 ft. Higher groundwater levels appear to have coincided with elevated flows in the San Juan River during the March sampling event.

Groundwater elevations in the floodplain aquifer are also measured every 4 hours by pressure transducers installed in four monitor wells (0617, 0736, 0857, and 1008) and connected to dataloggers. These data for the reporting period are shown in Figure 2–3, along with stream flow in the San Juan River, for comparison.

Flow data was obtained from U.S. Geological Survey Gaging Station 09368000 (in the San Juan River at Shiprock). The river flow on the day the March 2003 water-level data were measured was 649 cubic feet per second (cfs), while the flow on the day the March 2008 data were measured was 3,770 cfs. In terms of stage, or water surface elevation, the San Juan River flow measured in 2008 was significantly higher than the stage measured in 2003.

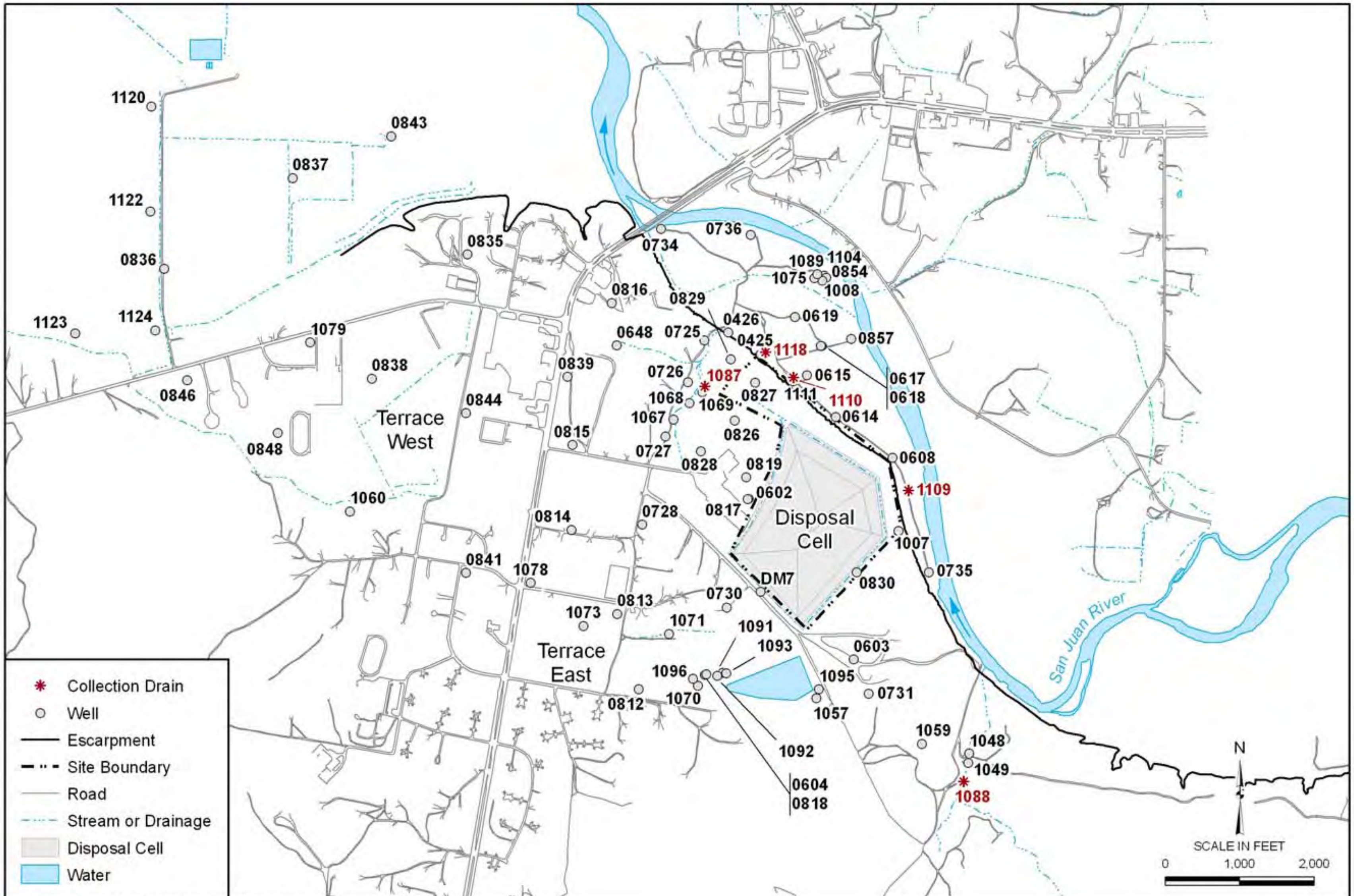

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Figure 2–1. Locations of Wells and Sampling Points at the Shiprock Site

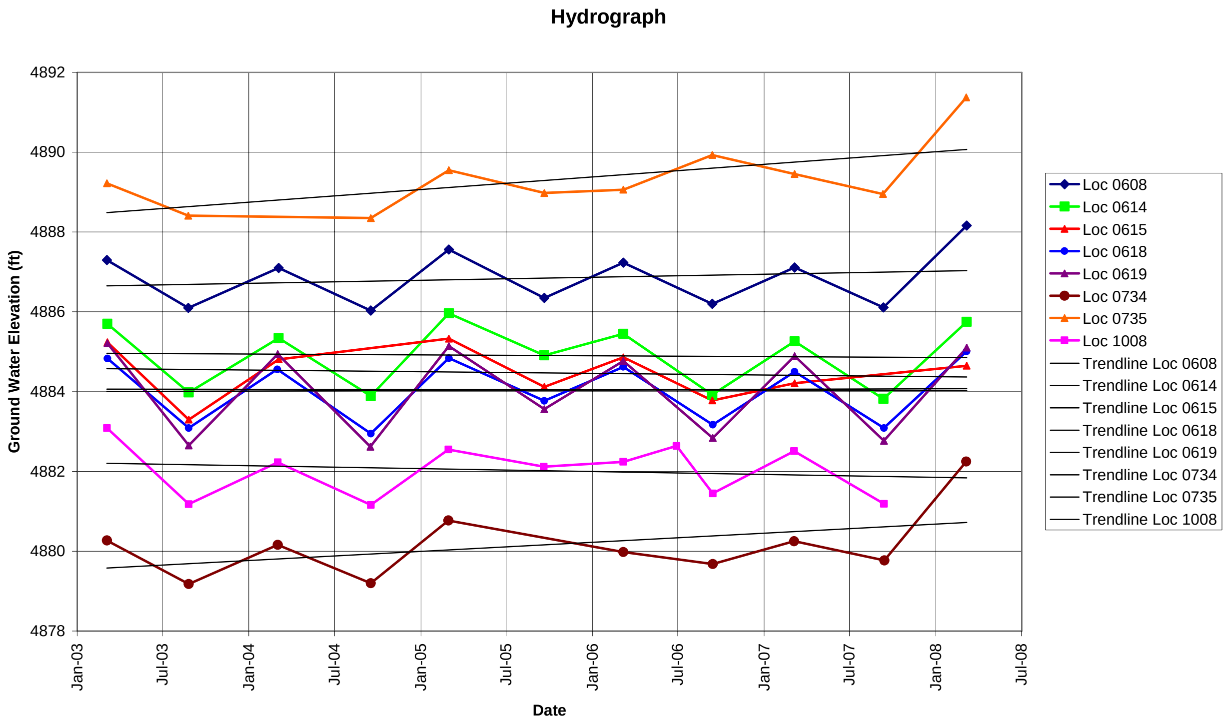

Figure 2–2. Floodplain Groundwater Elevations from Manual Measurements

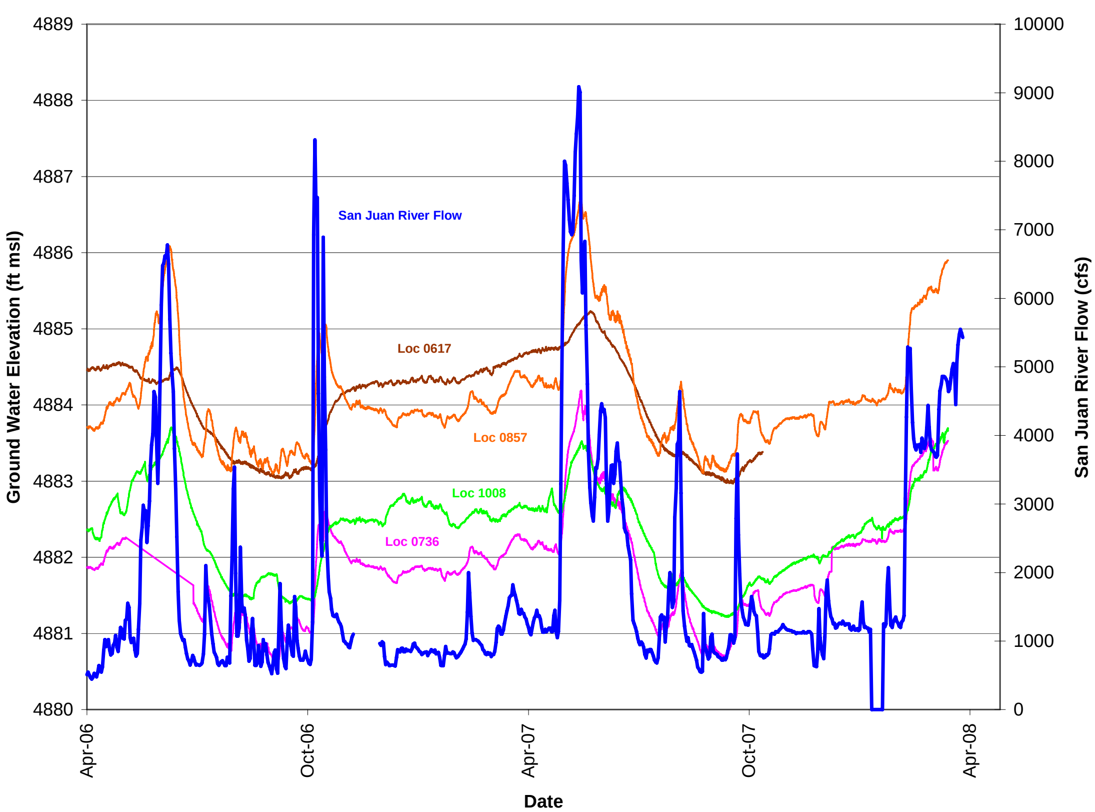

Figure 2–3. Floodplain Groundwater Elevations From Datalogger Measurements

The datalogger plots show a very close correlation between groundwater levels and the San Juan River's flow patterns, indicating relatively rapid recharge and discharge of the aquifer related to change in river flow and surface water levels (Figure 2–3). It is known that most of the water entering the floodplain aquifer does so via San Juan River losses along the southernmost tip of the aquifer. Thus, it is logical to assume that inflow from the river increases during high runoff, and that this produces flow directions east of the disposal cell that are in a more northward to northwestward direction than normal. The potential for greater mixing of relatively clean water from the river with contaminated groundwater emanating from the Mancos Shale would likely increase under such circumstances, which possibly leads to greater dilution of groundwater contaminants in the aquifer and enhances the natural flushing of contaminants from the floodplain aquifer.

2.1.2 Contaminant Distributions

Groundwater samples were collected from selected floodplain monitor wells in September 2007 and March 2008. The locations of the wells are shown in Figure 2–1.

Variations in constituent concentration versus time from March 2003 (baseline) through March 2008 are shown in Figure 2–4 through Figure 2–10. Linear trend lines are shown on the graphs to indicate changes in concentrations over the past 4 years. There is a certain amount of periodic variation in concentrations of constituents that is not necessarily indicative of the overall longer-term trend. Concentrations of constituents in groundwater in the floodplain alluvium are affected by seasonal changes in climate, river stage influence, discharge of groundwater from the artesian well that flows into Bob Lee Wash and then onto the floodplain, and pumping rates of the extraction wells and drainage trenches.

Ammonium concentrations in groundwater have generally decreased over the past 5 years (Figure 2–4). The maximum concentration in monitor well 0608 adjacent to the disposal cell has decreased from 190 mg/L to 170 mg/L over the past year; this compares with 303 mg/L in March 2003. Concentrations in all other wells are less than 50 mg/L and generally stable.

Concentrations of manganese have been variable over the past 5 years, ranging from 0.29 mg/L to 8.30 mg/L during the March 2008 sampling event (Figure 2–5). There is noticeable but inconsistent variation on a seasonal basis in some of the wells. Over the past 5 years, there has been a downward trend in manganese concentrations in groundwater in seven of the nine wells.

Nitrate concentrations in groundwater ranged from less than 1 mg/L to 610 mg/L and have increased slightly in two of the nine monitor wells over the past 5 years (Figure 2–6). Concentrations remained relatively stable at five of the locations. Again, there has been seasonal variation in some of the wells contrary to the longer-term trends.

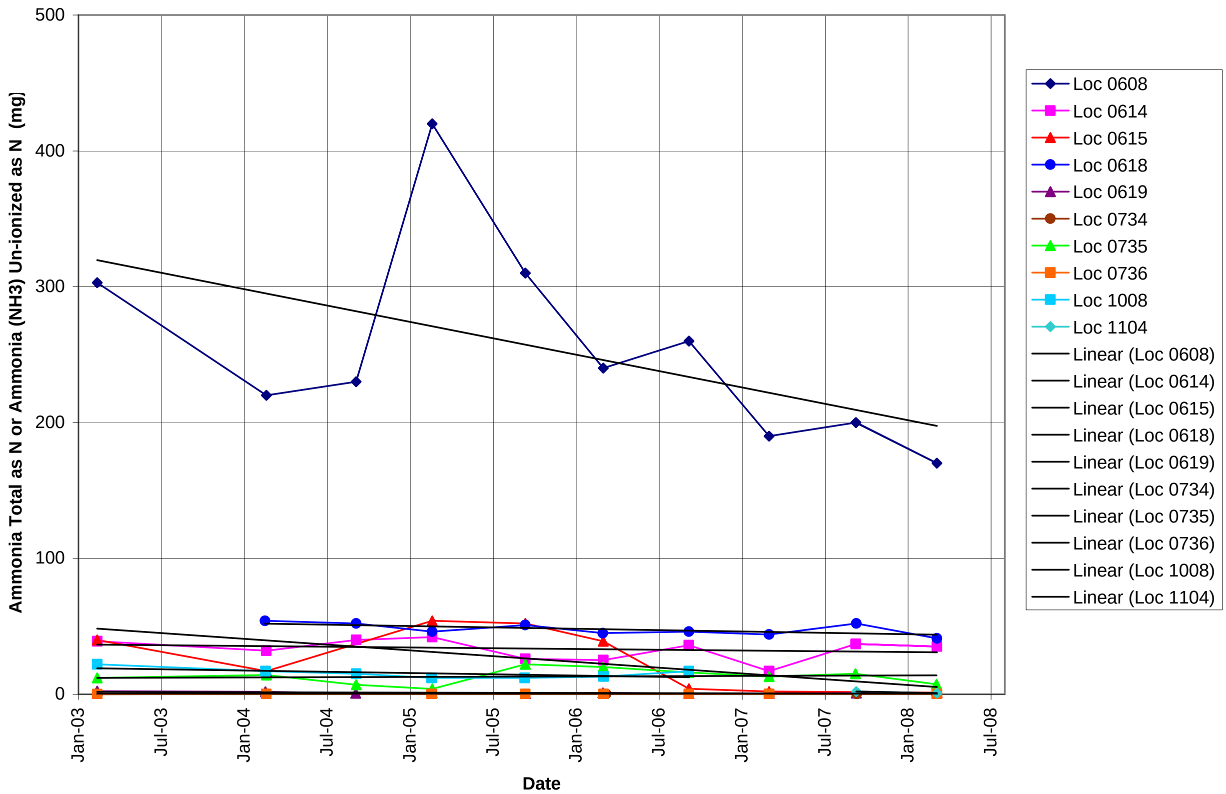

Figure 2–4. Floodplain Ammonia (Total as Nitrogen) Groundwater Concentrations Versus Time

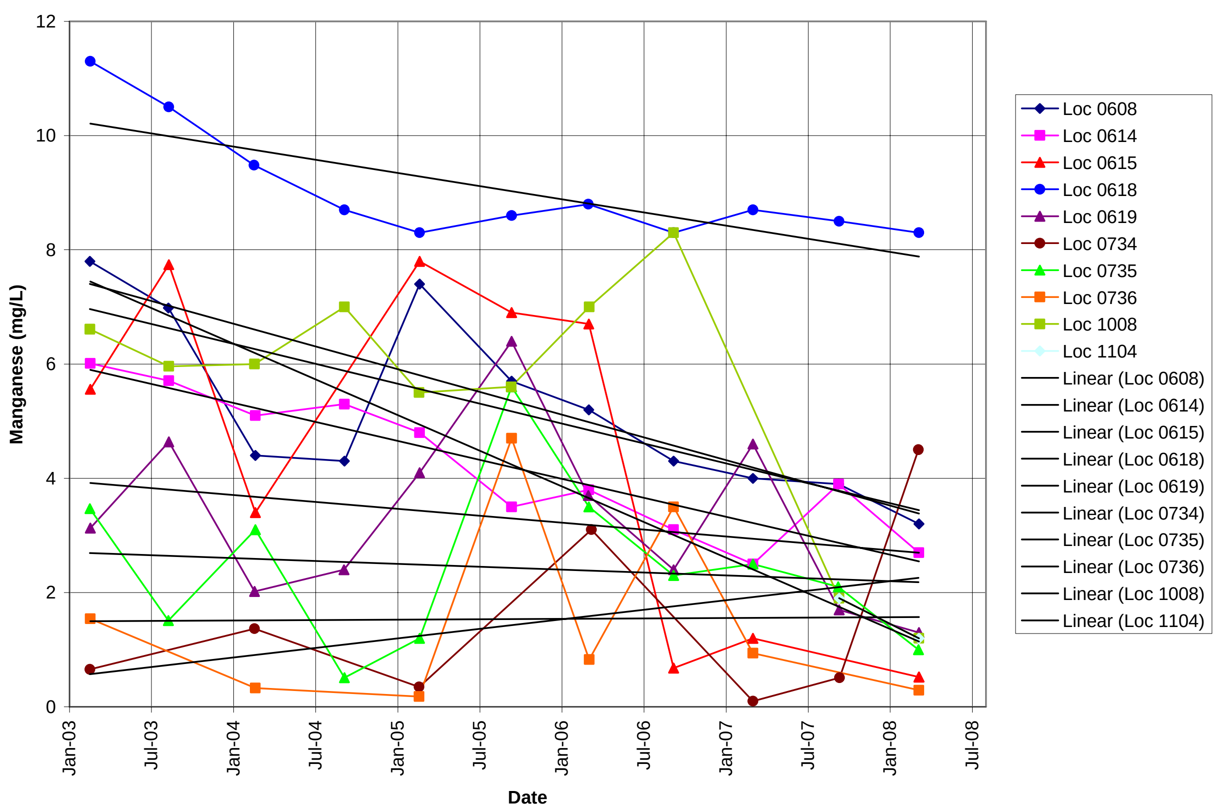

Figure 2–5. Floodplain Manganese Groundwater Concentrations Versus Time

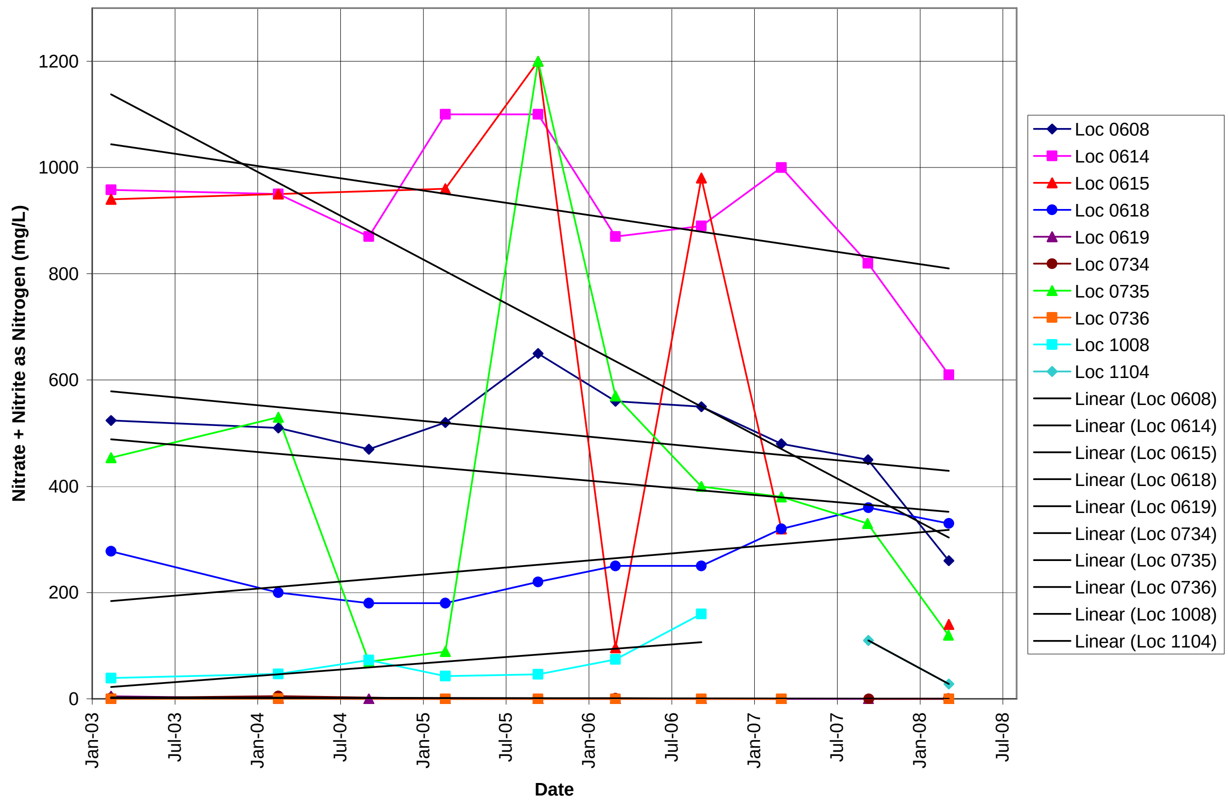

Figure 2–6. Floodplain Nitrate + Nitrite (as Nitrogen) Groundwater Concentrations Versus Time

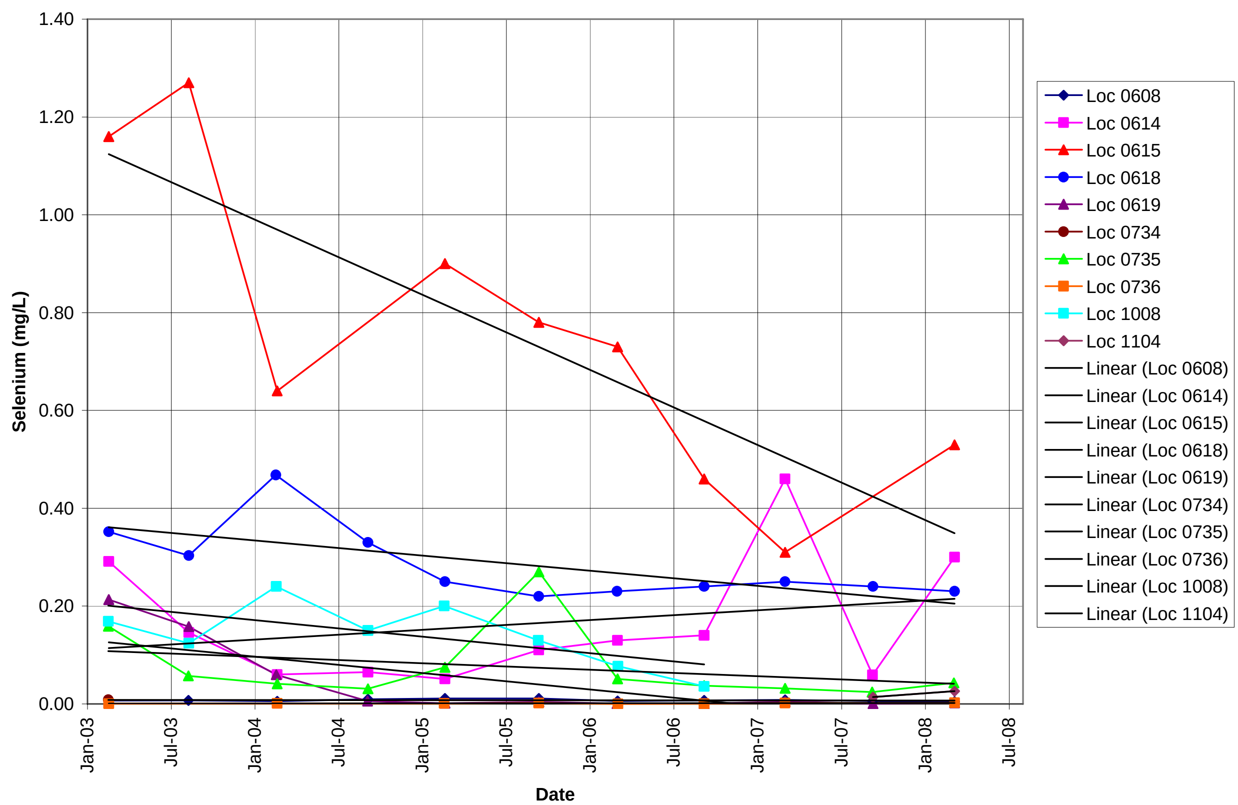

Figure 2–7. Floodplain Selenium Groundwater Concentrations Versus Time

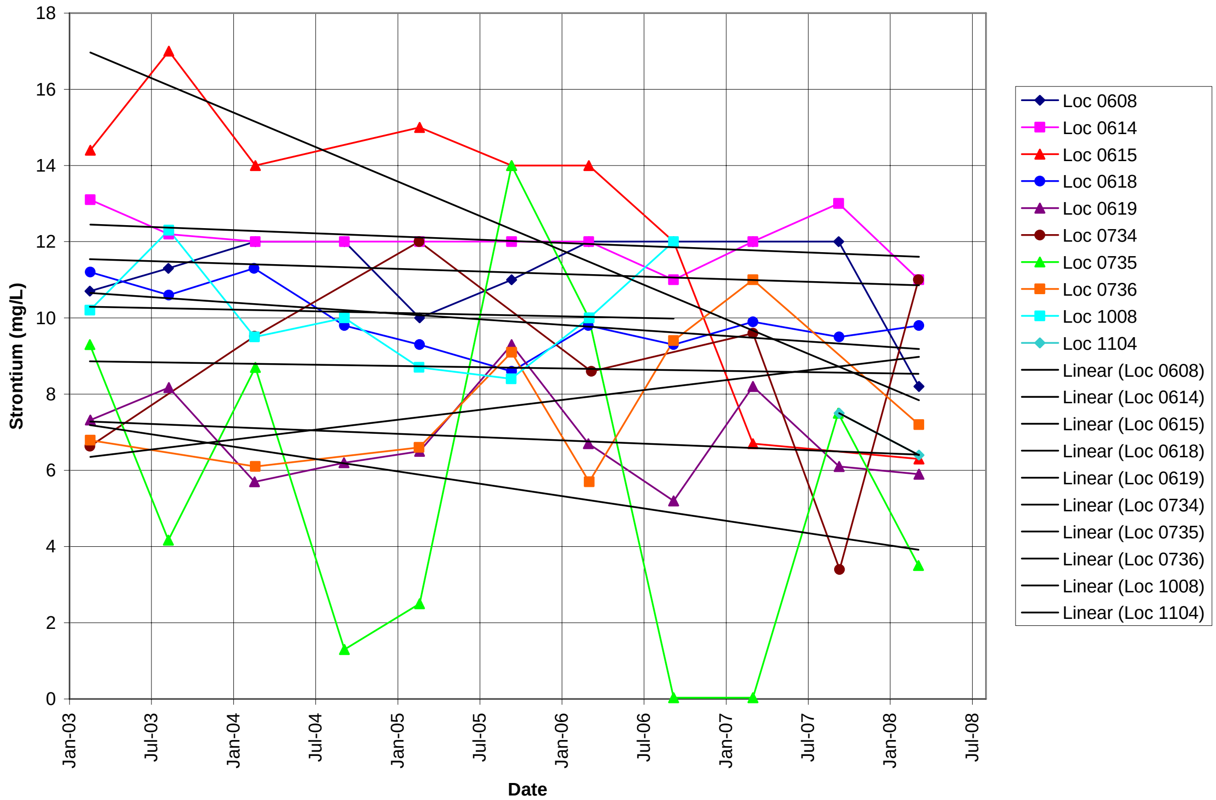

Figure 2–8. Floodplain Strontium Groundwater Concentrations Versus Time

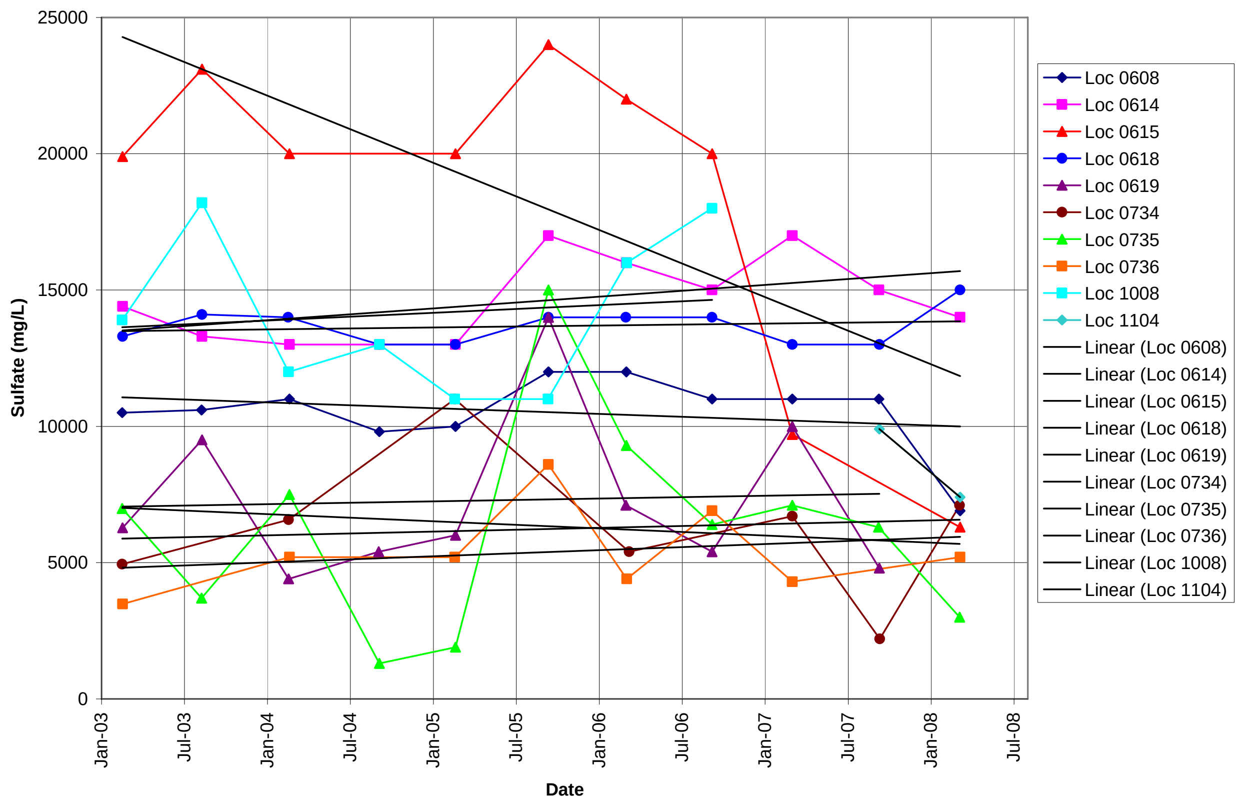

Figure 2–9. Floodplain Sulfate Groundwater Concentrations Versus Time

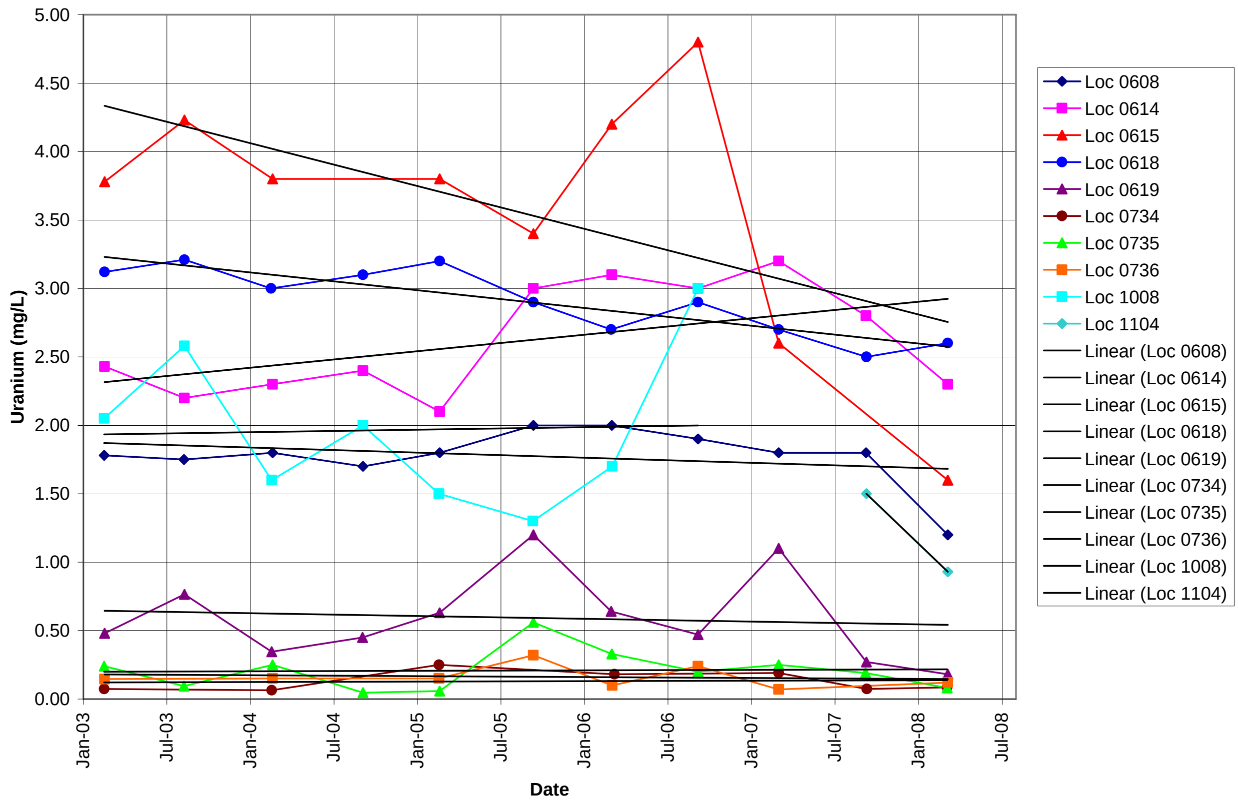

Figure 2–10. Floodplain Uranium Groundwater Concentrations Versus Time

Concentrations of selenium in groundwater have generally been decreasing over the past 5 years (Figure 2–7). The maximum concentration during the March 2008 sampling event was 0.53 mg/L; levels were greater than 0.05 mg/L in only three of the nine monitor wells.

Concentrations of strontium have generally decreased over the past 5 years (Figure 2–8). Concentrations decreased or were stable in all but one of the nine monitor wells and ranged from 3 mg/L to 11 mg/L during the March 2008 sampling event.

Sulfate concentrations in groundwater have generally increased slightly over the past 5 years (Figure 2–9). Again, variability is noted in some wells with recent decreases but overall upward trends, which may be the effect of seasonal variation and interaction with surface water from the San Juan River. The maximum sulfate concentration was 15,000 mg/L in well 618.

Uranium concentrations in groundwater ranged from 0.081 mg/L to 2.6 mg/L during the March 2008 sampling event (Figure 2–10). Trends over the past 5 years have been variable; concentrations increased in some wells and decreased in others. Again, seasonal variations may be contrary to longer-term trends.

During the remediation system's first 5 years of operation at the Shiprock site, the extraction wells and trenches have removed a significant mass of contaminants from the alluvial groundwater system (see Section 3.2.3). Additionally, natural flushing is having an effect, as the floodplain system is dynamic with the interaction of recharge and discharge of surface water from the San Juan River, precipitation, and the influx of groundwater from the artesian well discharging into Bob Lee Wash. The spring 2006 addition of two drainage trenches at the base of the escarpment (Figure 1–1) has enhanced the amount of groundwater and mass of constituents removed from the alluvial system.

Another indication that pumping groundwater from the floodplain system is having an effect is the fact that concentrations of nitrate and uranium in surface water in the San Juan River (location 0940) have remained below the upgradient background benchmark values (statistically derived), even during low-flow periods, since 2004 (Figure 2–11 and Figure 2–12).

2.2 Terrace System Subsurface Conditions

The discussion of current subsurface conditions of the terrace is based on collection and analysis of groundwater-level data through March 2008. Analyses of groundwater-level trends and flow directions, drain flow rates, and seep flow rates associated with the terrace are discussed below. Results are compared to baseline conditions established in March 2003 in the *Baseline Performance Report* (DOE 2003) to evaluate the effectiveness of the terrace treatment system.

There are no concentration-driven performance standards for the terrace system because compliance is based on hydrologic control. However, as a best management practice, selected contaminant concentrations are measured at each extraction well, drain, and seep. Estimates of mass removal from the terrace system, compiled during this performance period, are presented in Section 3.2.3 of this report.

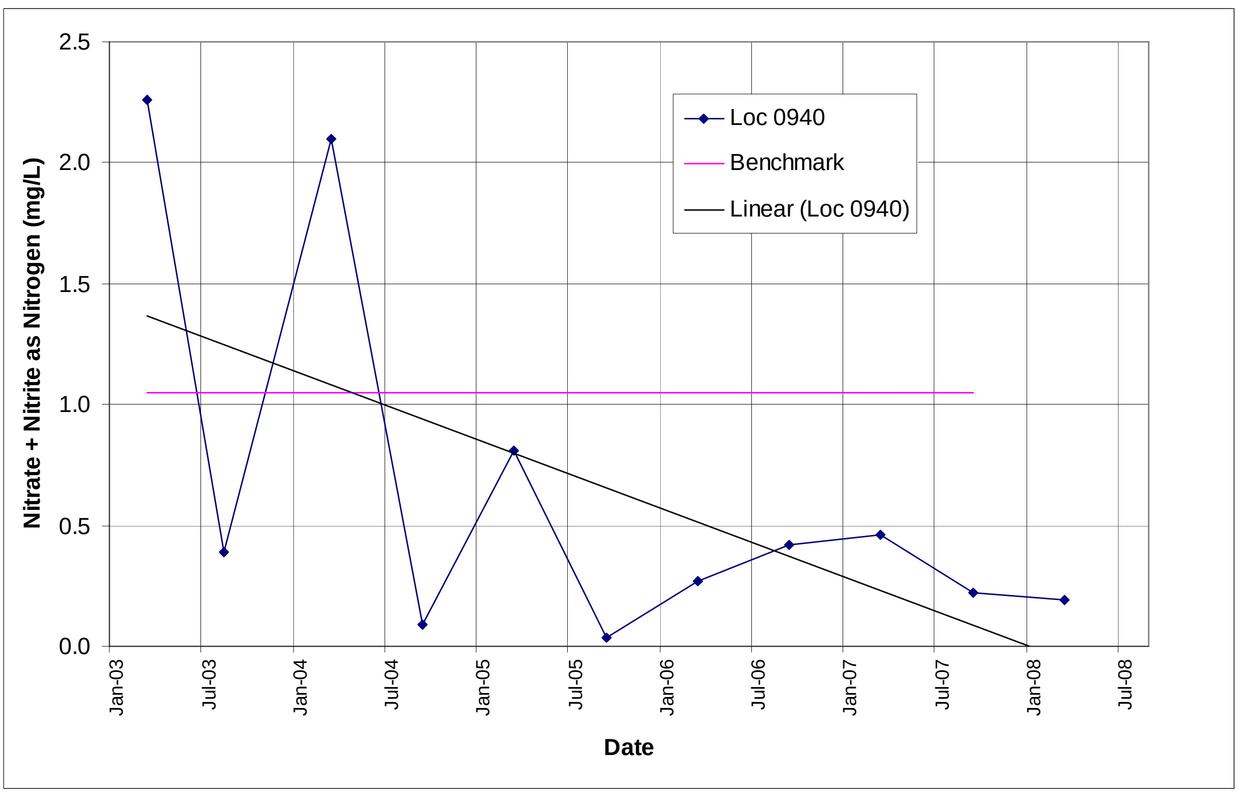

Figure 2–11. Nitrate + Nitrite (as Nitrogen) Concentrations in the San Juan River

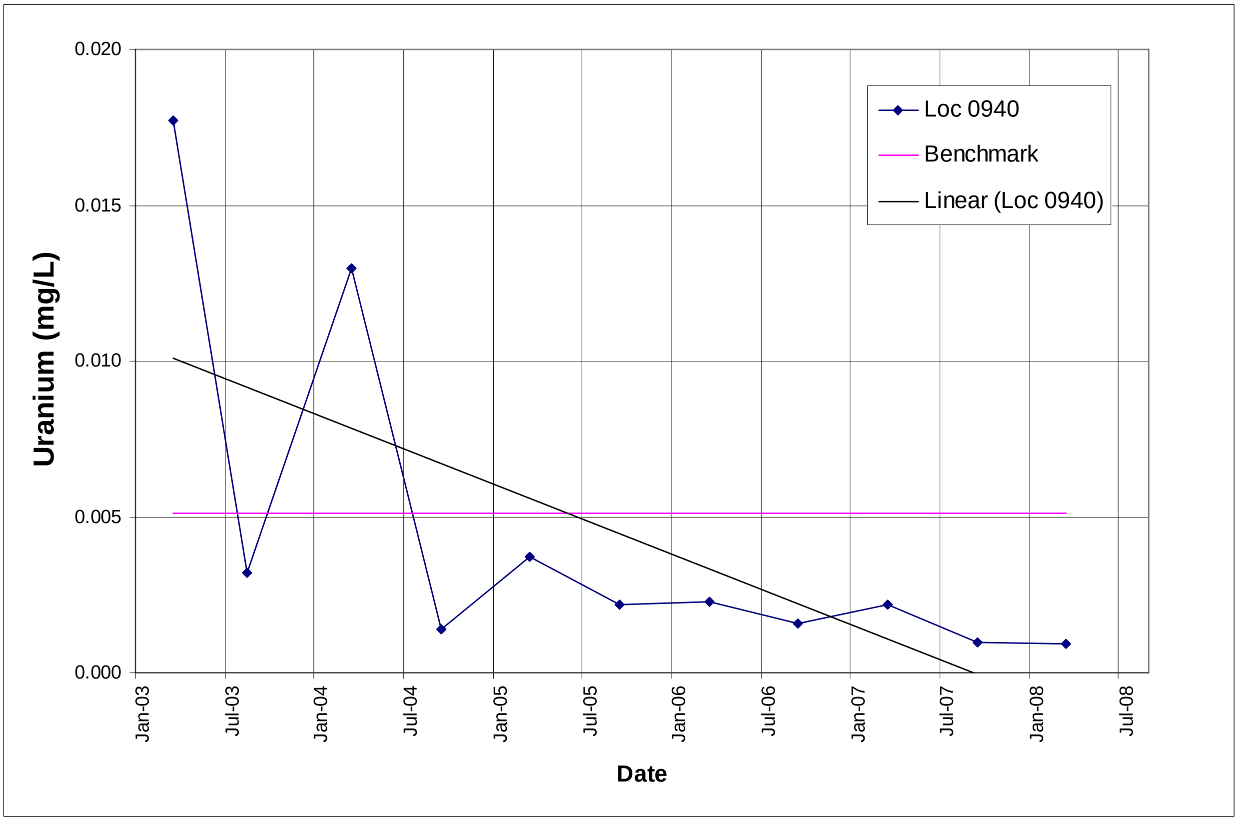

Figure 2–12. Uranium Concentrations in the San Juan River

2.2.1 Groundwater-Level Trends and Flow Directions

Three-point analyses of groundwater-level data were initiated using March 2003 information, which were subsequently compared to March 2004 and March 2005 data, to determine horizontal gradients and flow directions across the terrace system and to demonstrate that the flow of groundwater was predominantly toward the extraction wells. Results of the three-point analyses over the 2-year period showed very little change in groundwater flow directions and demonstrated that the flow system beneath the terrace was operating as expected. At the scale of the three-point vector plots, the pumping rates on the terrace over the period of observation had a negligible impact on groundwater flow directions near the extraction wells.

Groundwater-level data from the terrace collected during the March 2008 sampling event were compared to baseline groundwater elevations from March 2003 as presented in the *Baseline Performance Report* (DOE 2003). Figure 2–13 presents a qualitative map view of some of the changes in groundwater elevation during this period. Groundwater elevations appear to be declining across the entire terrace groundwater system. Of the 18 measurements of groundwater levels taken in March 2008, all showed declines relative to the baseline period of March 2003. The observation wells nearest the extraction well field are 0730 and 1057. The greatest decrease in groundwater level was 4.74 ft at well 0730, which is located southwest of the disposal cell. As of March 2008, the cumulative volume of water removed from the terrace extraction system

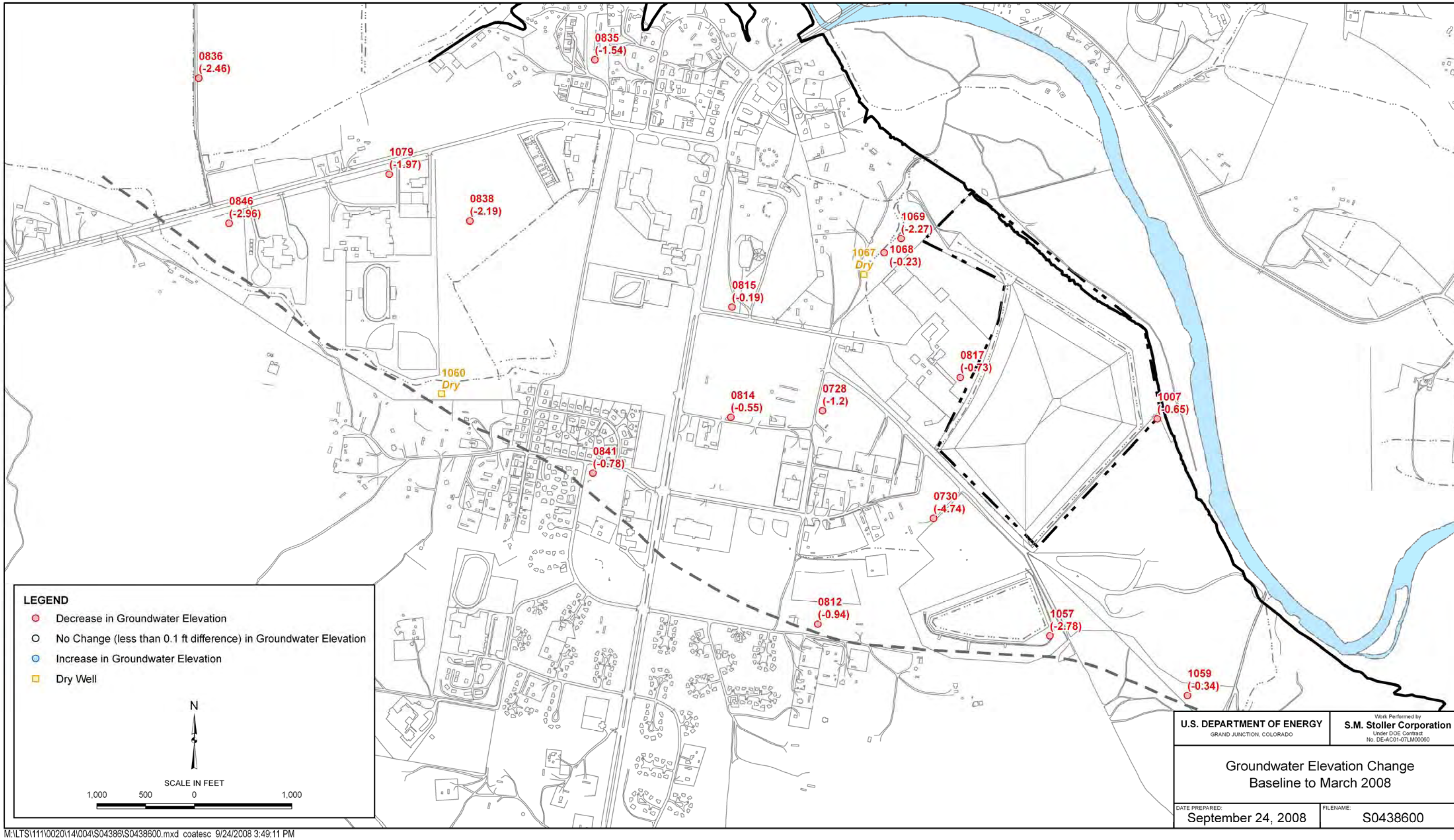

Figure 2–13. Terrace Groundwater Elevation Changes From Baseline (March 2003) to Current (March 2008) Conditions

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since pumping began was approximately 17,800,000 gallons, and pumping records showed that approximately 2,780,000 gallons were removed from April 2007 through March 2008. In 2008, the water levels in each of these wells had declined both relative to baseline conditions and relative to water level measurements made in 2007. Thus, it can generally be concluded that the extraction well field is beginning to have the desired effect on groundwater levels in the east portion of the terrace.

Water levels have also been monitored using pressure transducers that have been installed in selected wells on the terrace. Plots of groundwater elevation data versus time collected from pressure transducers connected to dataloggers in terrace east wells 0602, 0604, 0725, 0726, 0813, 0819, 0826, 0827, 0828, 0830, and 1073 are shown in Figure 2–14. Linear trend lines on these data show a decrease in water levels during the time of observation in 9 of the 11 wells. Decreases range from approximately 3.4 ft in well 0604 to 0.7 ft in well 1073. Increases range from 0.2 ft in well 0725 to 0.4 ft in well 0726. Although they are screened in a deeper zone, some wells in this area may be influenced by outflow from artesian well 0648, which adds surface water to Bob Lee Wash. The trend line for the datalogger in well 0604 (Figure 2–14) indicates how the pumping at nearby wells 0818 and 1096 has lowered the groundwater elevation during 2007 and 2008. The average pumping rates for these wells for the period were 0.76 and 1.02 gpm, respectively.

Plots of groundwater elevation data versus time collected by dataloggers in western terrace wells 0836, 0841, 0846, 0848, and 1060 are shown in Figure 2–15. Groundwater levels have generally decreased during the past 4 years.

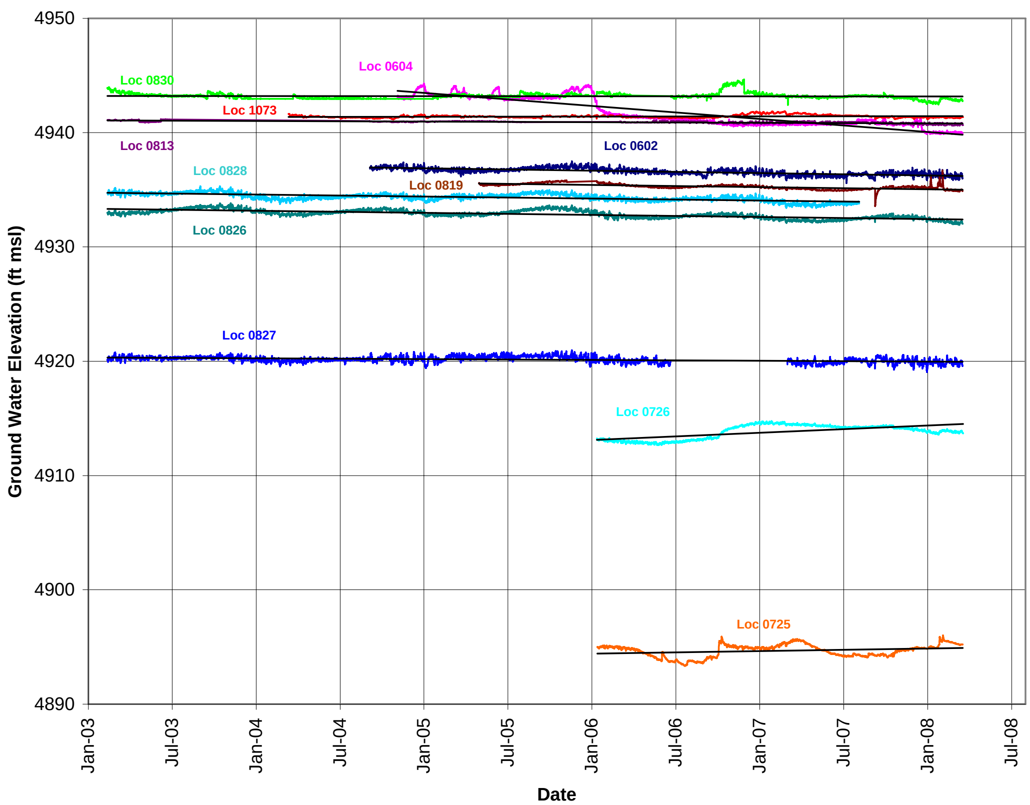

Figure 2–14. Terrace East Datalogger Groundwater Elevations

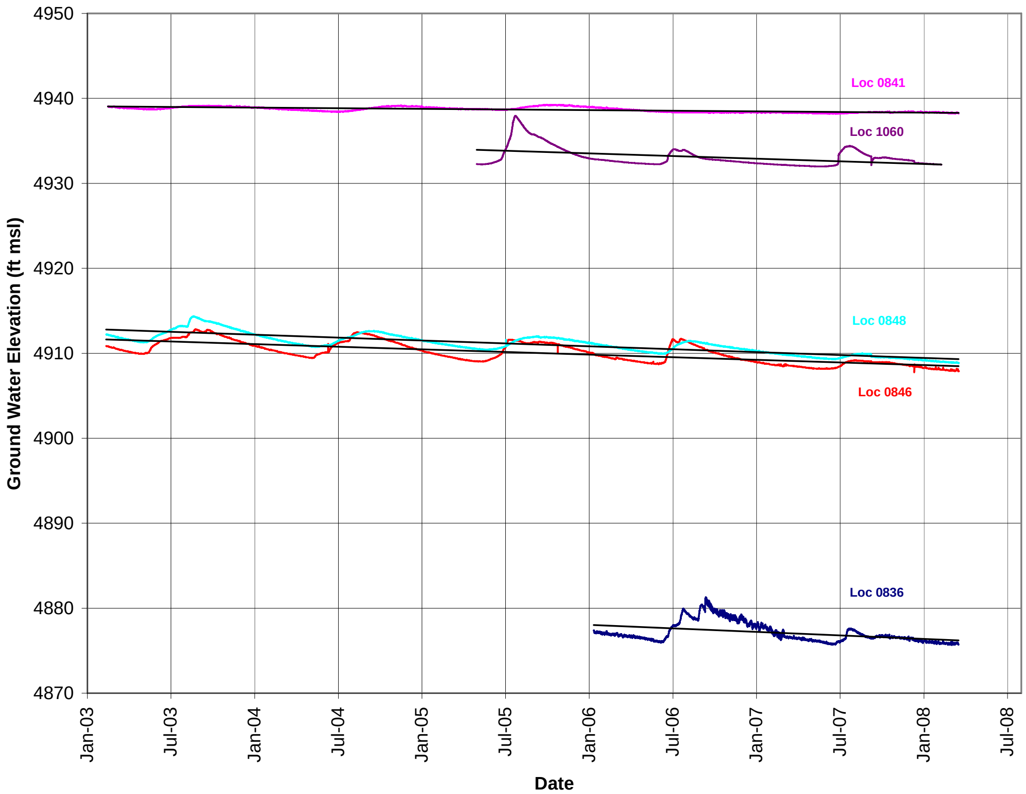

Figure 2–15. Terrace West Datalogger Groundwater Elevations

2.2.2 Drain Flow Rates

As discussed in the *Baseline Performance Report* (DOE 2003), the flow rates of the pumps removing water from the drains installed in Bob Lee Wash and Many Devils Wash were expected to decrease as groundwater levels in the terrace declined. The average pumping rate from Bob Lee Wash during the performance period was 2.04 gpm. The average pumping rate from Many Devils Wash during the performance period was 0.71 gpm. Average pumping rates decreased at both locations during this period; by 10 percent at Bob Lee Wash and 35 percent at Many Devils Wash. Much of the decrease at Many Devils Wash may be attributed to the declining effectiveness of the collection drain.

3.0 Remediation System Performance

The following sections provide a brief description of the components of the floodplain and terrace groundwater remediation systems and summarize their performance during the current reporting period.

3.1 Floodplain Remediation System

The objective of the floodplain groundwater extraction system is to reduce the mass of COCs in alluvial groundwater near the San Juan River. Pumping is focused at this location to lessen exposure risk to aquatic life. All groundwater collected from the floodplain extraction wells and trenches is piped south to the terrace where it feeds into the evaporation pond.

3.1.1 Extraction Well Performance

During the current period, the floodplain remediation extraction system consisted of wells 1089 and 1104 (Figure 1–1). These wells were constructed using slotted culverts placed in trenches excavated to bedrock. The cumulative volume of extracted groundwater and measured pumping rates at wells 1089 and 1104, from April 2006 to March 2008, are shown in Figure 3–1 and Figure 3–2. During this performance period, approximately 3,314,000 gallons of water were removed from well 1089 at an average pumping rate of 6.3 gpm, and approximately 1,077,000 gallons of water were removed from well 1104 at an average pumping rate of 2.0 gpm. During the 5-year period since the start of operations in March 2003 through the end of March 2008, a total of just under 13,500,000 gallons of water have been removed from well 1089 and just under 2,300,00 gallons of water have been removed from well 1104.

3.1.2 Floodplain Drain System Performance

Two drainage trenches were installed in the floodplain just below the escarpment to enhance the extraction of groundwater from the alluvial system (Figure 1–1). The pumping of groundwater from Trench 1 (1110) and Trench 2 (1109) began in April 2006. The cumulative volume of extracted groundwater and measured pumping rates at Trench 1 and Trench 2, from April 2006 to March 2008, are shown in Figure 3–3 and Figure 3–4. During this performance period, approximately 1,440,000 gallons of water were removed from Trench 1 at an average pumping rate of 2.7 gpm, and approximately 8,930,000 gallons of water were removed from Trench 2 at an average pumping rate of 17 gpm.

3.1.3 Floodplain Seep Sump Performance

Rates of groundwater discharge at seeps 0425 and 0426 have decreased since March 2003. During August 2006 the seeps were incorporated into the remediation system, with discharge from the two seeps piped into a sump and then transported to the evaporation pond. The average discharge rate from the seep sump during this performance period is 0.87 gpm. There were approximately 459,000 gallons pumped during this period, and the total volume of water produced since pumping began is approximately 822,000 gallons.

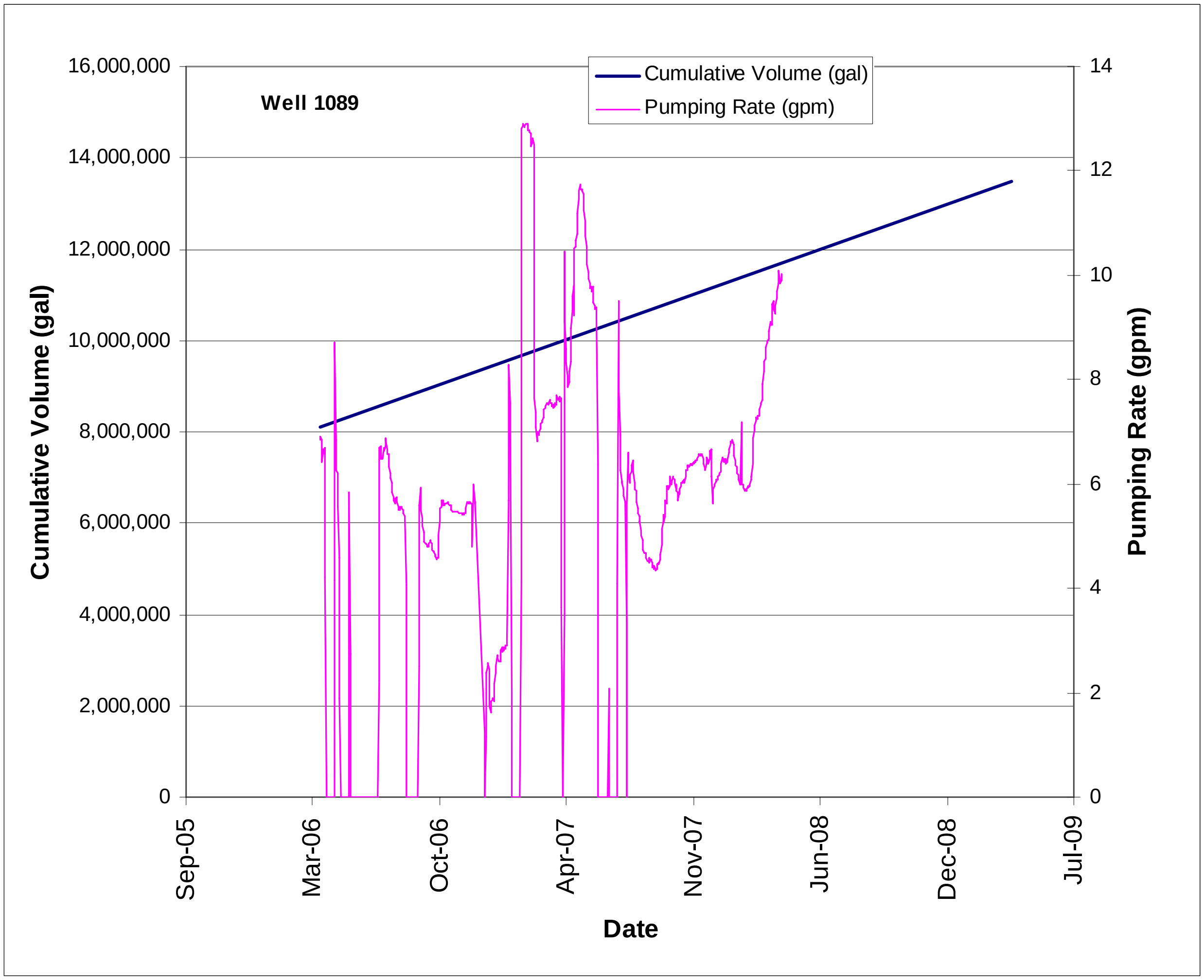

Figure 3–1. Well 1089 Pumping Rate and Cumulative Groundwater Volume Extracted

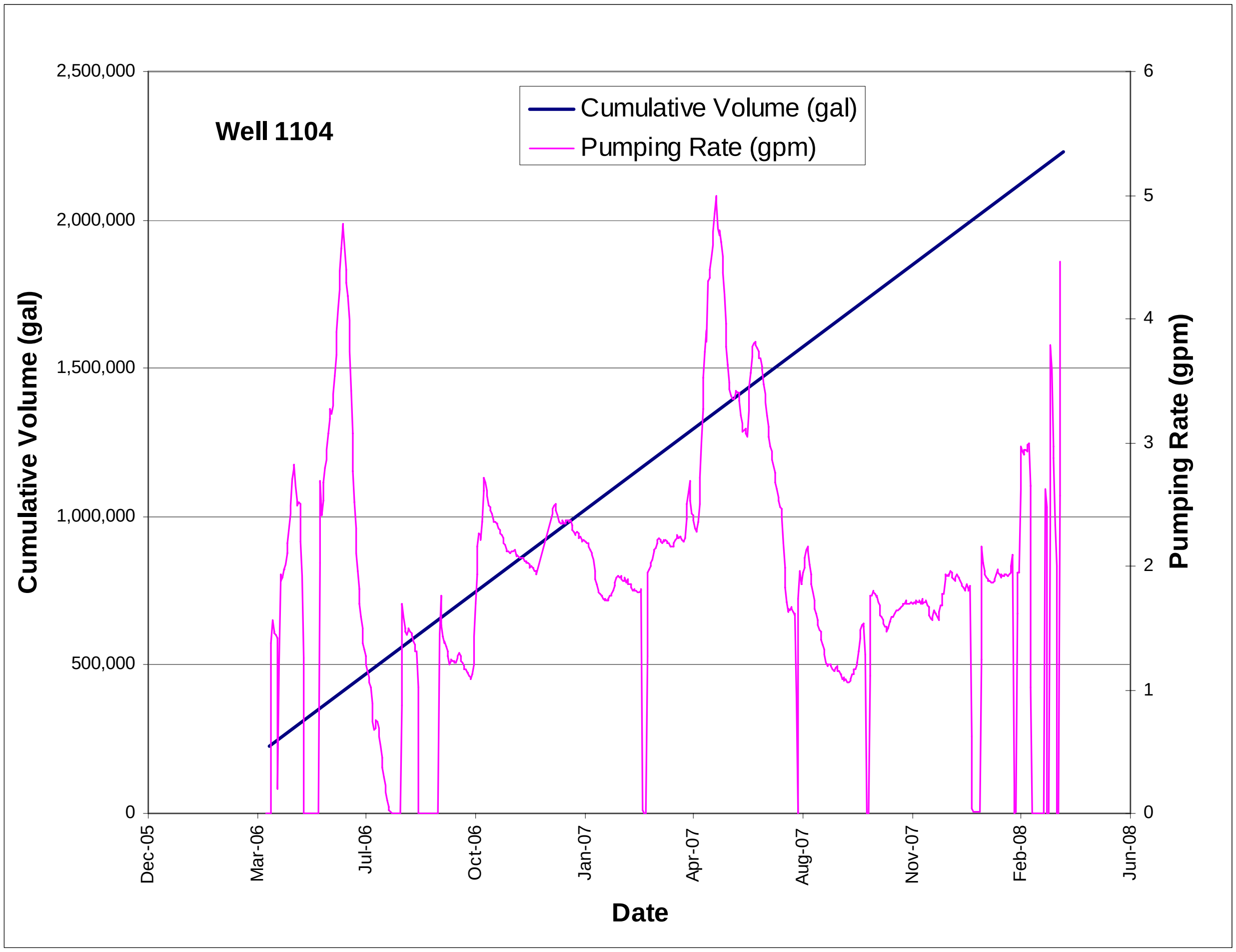

Figure 3–2. Well 1104 Pumping Rate and Cumulative Groundwater Volume Extracted

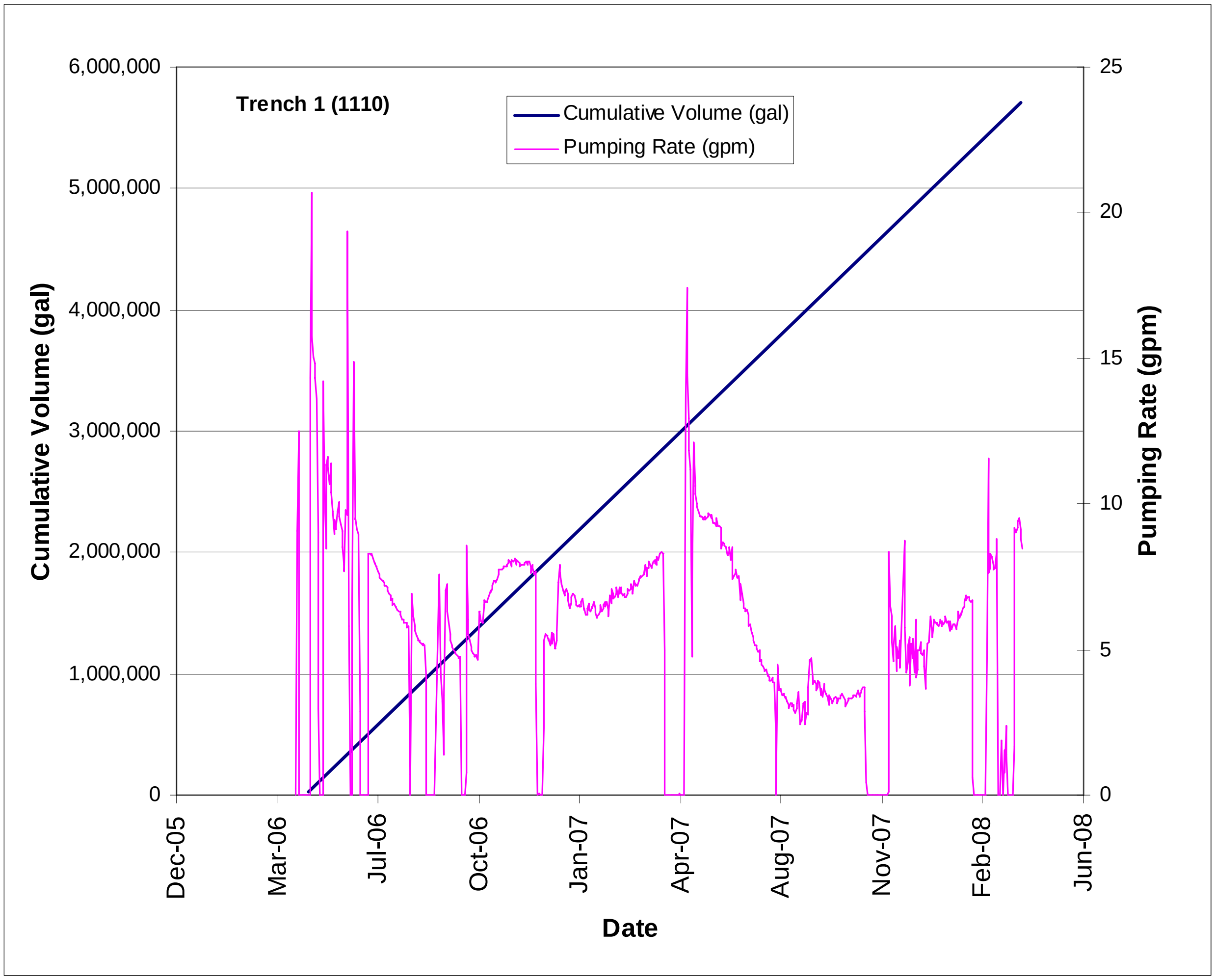

Figure 3–3. Trench 1 Pumping Rate and Cumulative Groundwater Volume Extracted

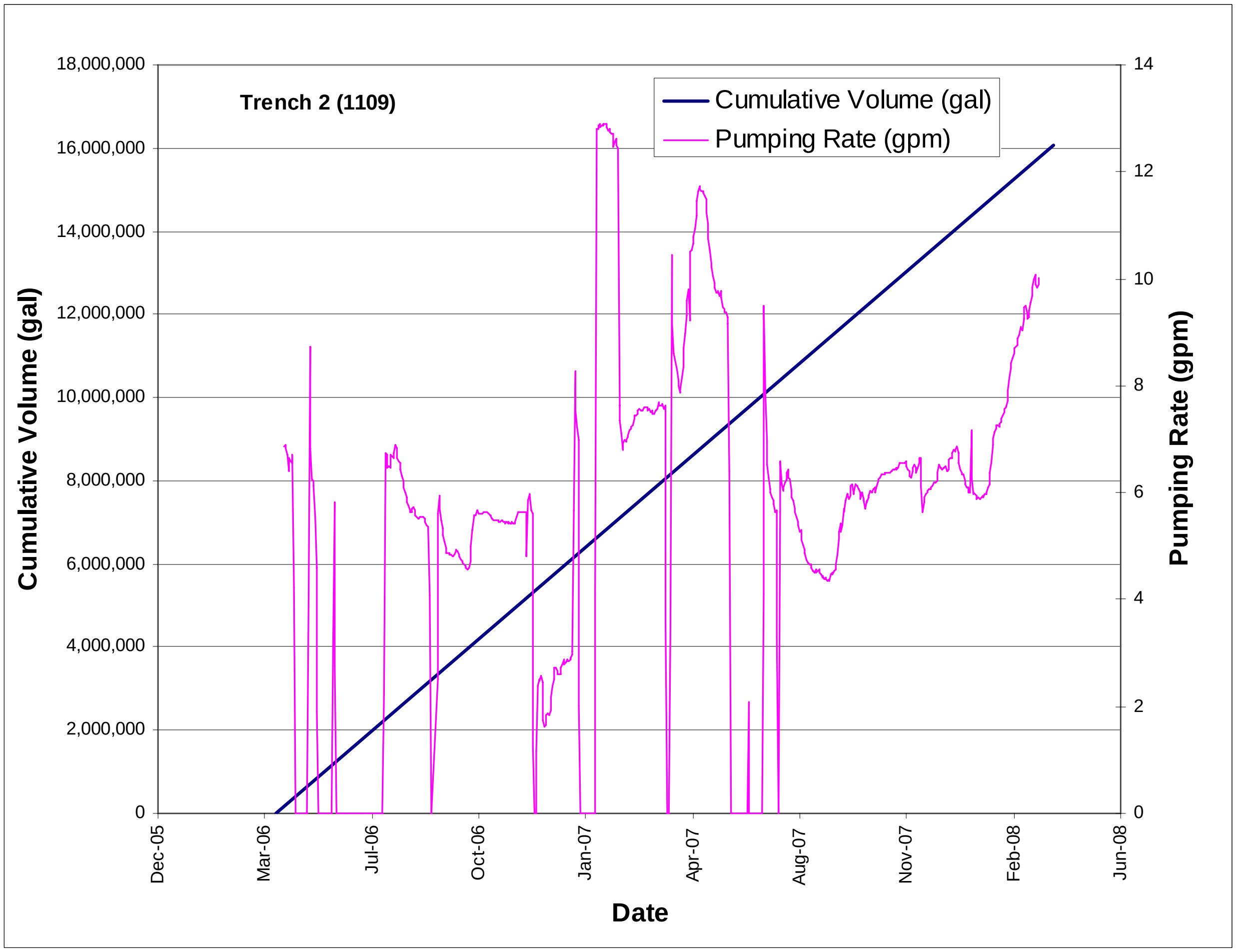

Figure 3–4. Trench 2 Pumping Rate and Cumulative Groundwater Volume Extracted

3.2 Terrace Remediation System

The objective of the terrace remediation system is to remove groundwater from the south part of the area so that current exposure pathways at seeps and at Bob Lee Wash and Many Devils Wash are eventually eliminated and the flow of groundwater from the terrace to the floodplain is reduced. Since groundwater compliance for the terrace is based on hydrologic control, concentration standards for COCs do not apply. The terrace remediation system consists of four components: the extraction wells, the terrace drains (Bob Lee Wash and Many Devils Wash), the evaporation pond, and the terrace outfall drainage channel diversion (Figure 1–1).

3.2.1 Extraction Well Performance

During the current period, the terrace remediation well field consisted of wells 0818, 1070, 1071, 1078, 1091, 1092, 1093, 1095, and 1096 (Figure 1–1). The average pumping rates and corresponding cumulative groundwater volumes removed from these wells from April 2006 through March 2008 are presented in Figure 3–5 through Figure 3–13. Measured pumping rates and corresponding volumes of groundwater removed from the terrace groundwater extraction wells during the recent performance period are available in the database at the DOE Office in Grand Junction, Colorado. Table 3–1 compares the current-period and previous-period average pumping rate and total groundwater volume removed from each of the extraction wells. The current-period average pumping rates ranged from 0.005 (well 1071) to 0.83 gpm (well 1093), and the total groundwater volume removed from each well during this period ranged from 2,702 (well 1071) to 433,945 gallons (well 1093). The cumulative total volume removed during the current period was approximately 16 percent less than during the previous reporting period. This decrease is expected as more water is removed from the aquifer.

Table 3–1. Terrace Extraction Well Average Pumping Rate and Total Groundwater Volume Removed

Well	Previous Period (April 1, 2006, through March 31, 2007)		Current Period (April 1, 2007, through March 31, 2008)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
0818	0.76	372,754	0.41	218,088
1070	0.05	21,314	0.015	8,125
1071	0.01	6,715	0.005	2,702
1078	0.53	237,046	0.43	209,963
1091	0.15	30,976	0.027	14,093
1092	0.06	29,037	0.031	16,502
1093	0.38	206,248	0.83	433,945
1095	0.88	439,154	0.65	339,435
1096	1.02	516,370	0.59	311,345
Total	**3.84**	**1,859,614**	**2.99**	**1,554,198**

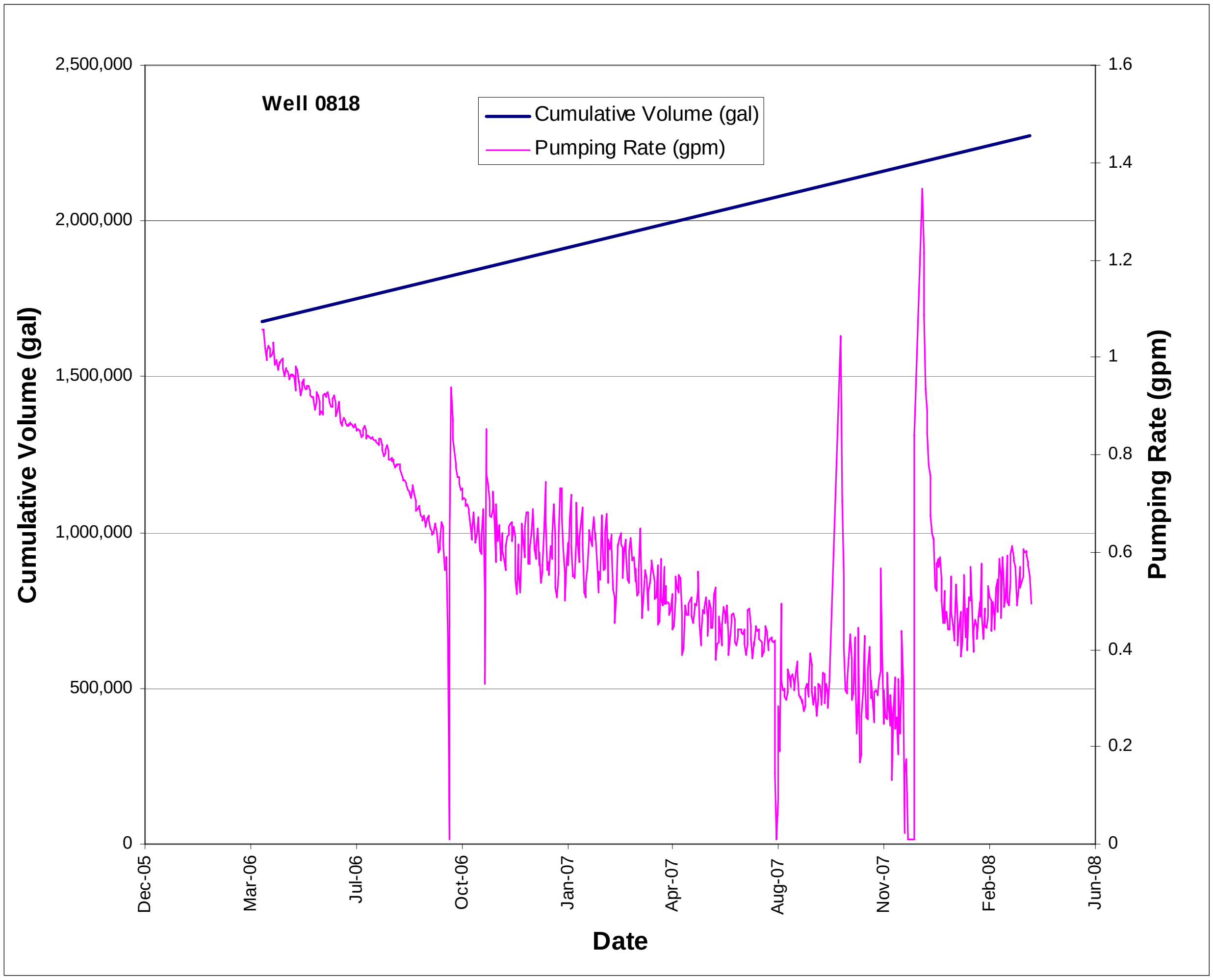

Figure 3–5. Well 0818 Pumping Rate and Cumulative Groundwater Volume Extracted

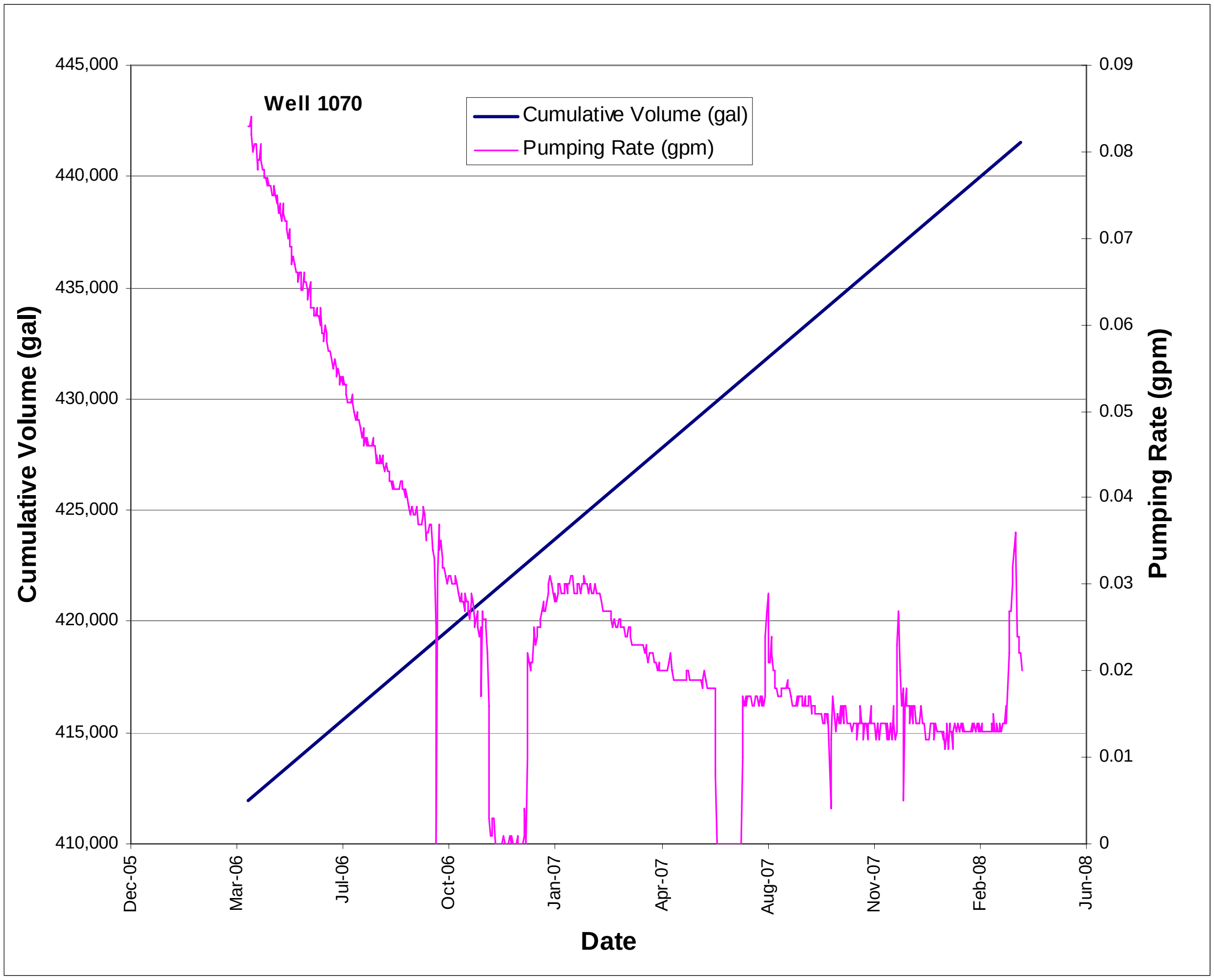

Figure 3–6. Well 1070 Pumping Rate and Cumulative Groundwater Volume Extracted

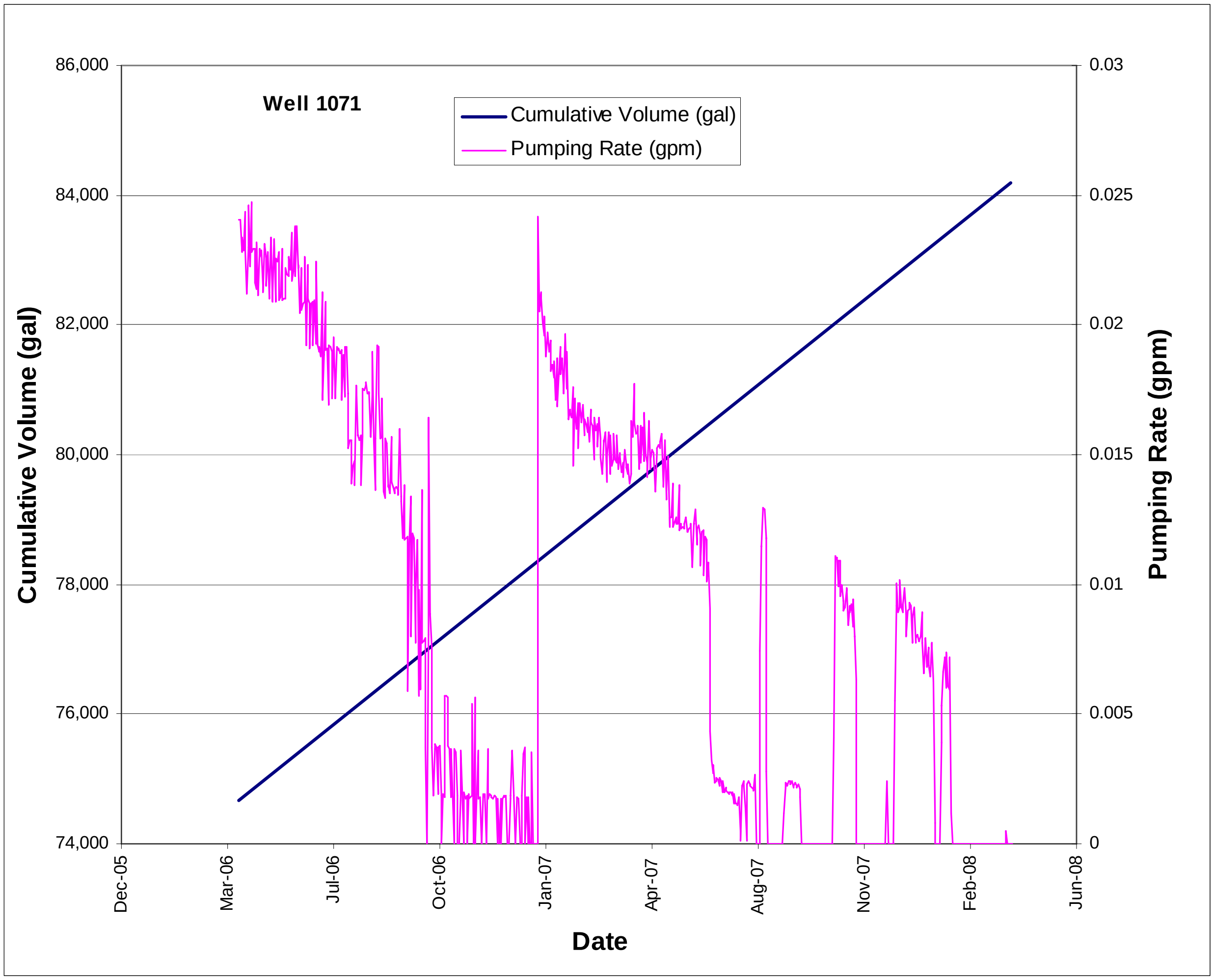

Figure 3–7. Well 1071 Pumping Rate and Cumulative Groundwater Volume Extracted

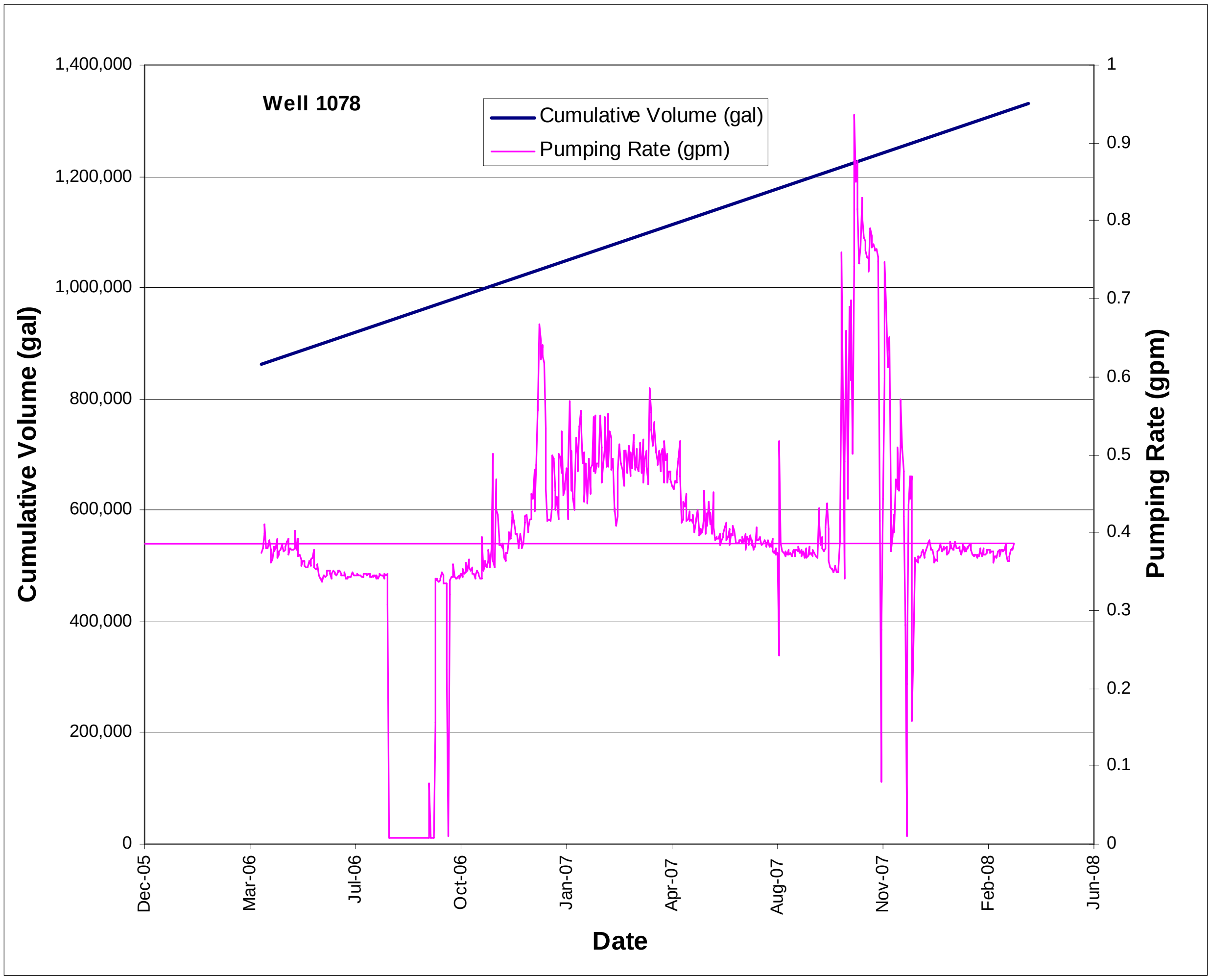

Figure 3–8. Well 1078 Pumping Rate and Cumulative Groundwater Volume Extracted

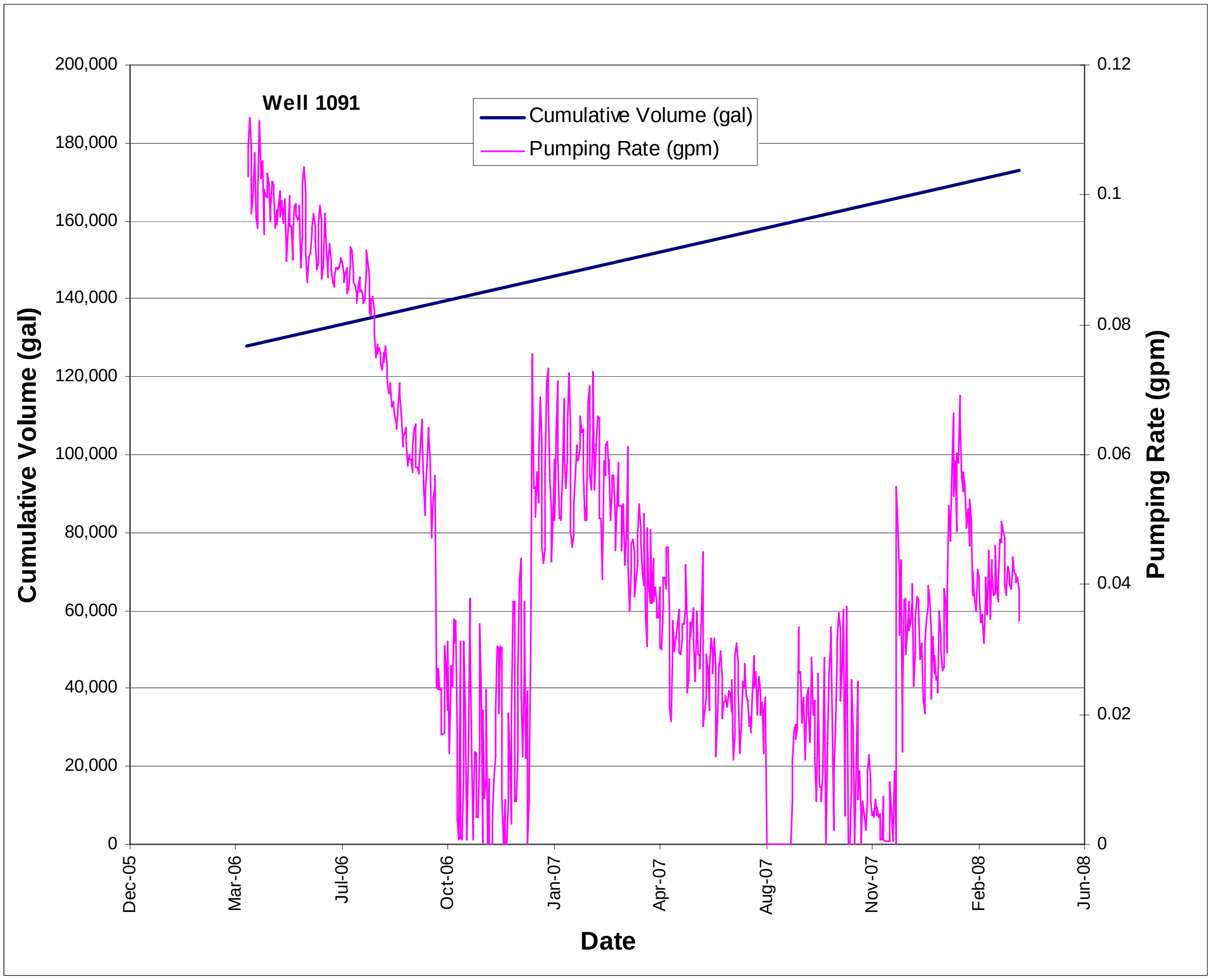

Figure 3–9. Well 1091 Pumping Rate and Cumulative Groundwater Volume Extracted

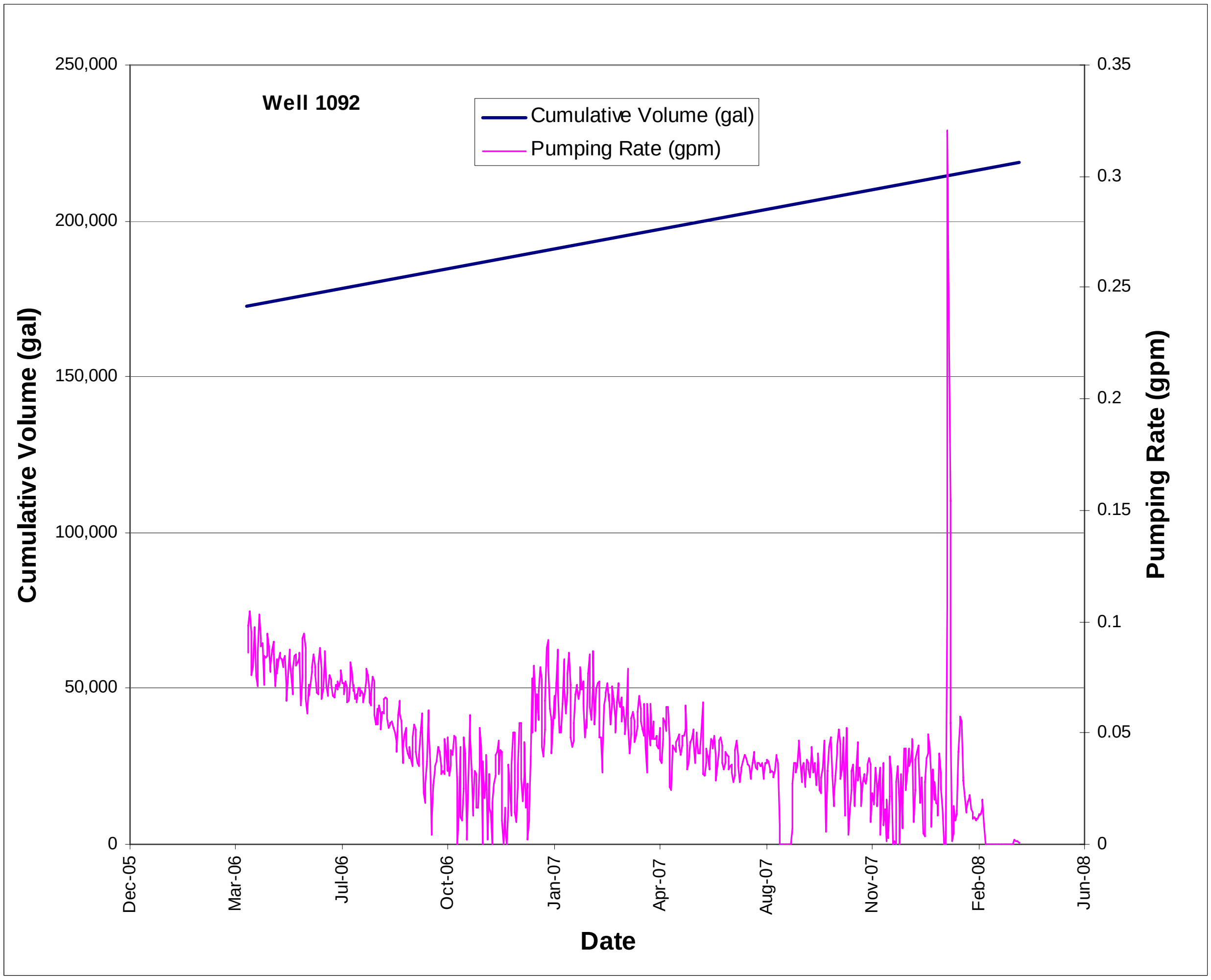

Figure 3–10. Well 1092 Pumping Rate and Cumulative Groundwater Volume Extracted

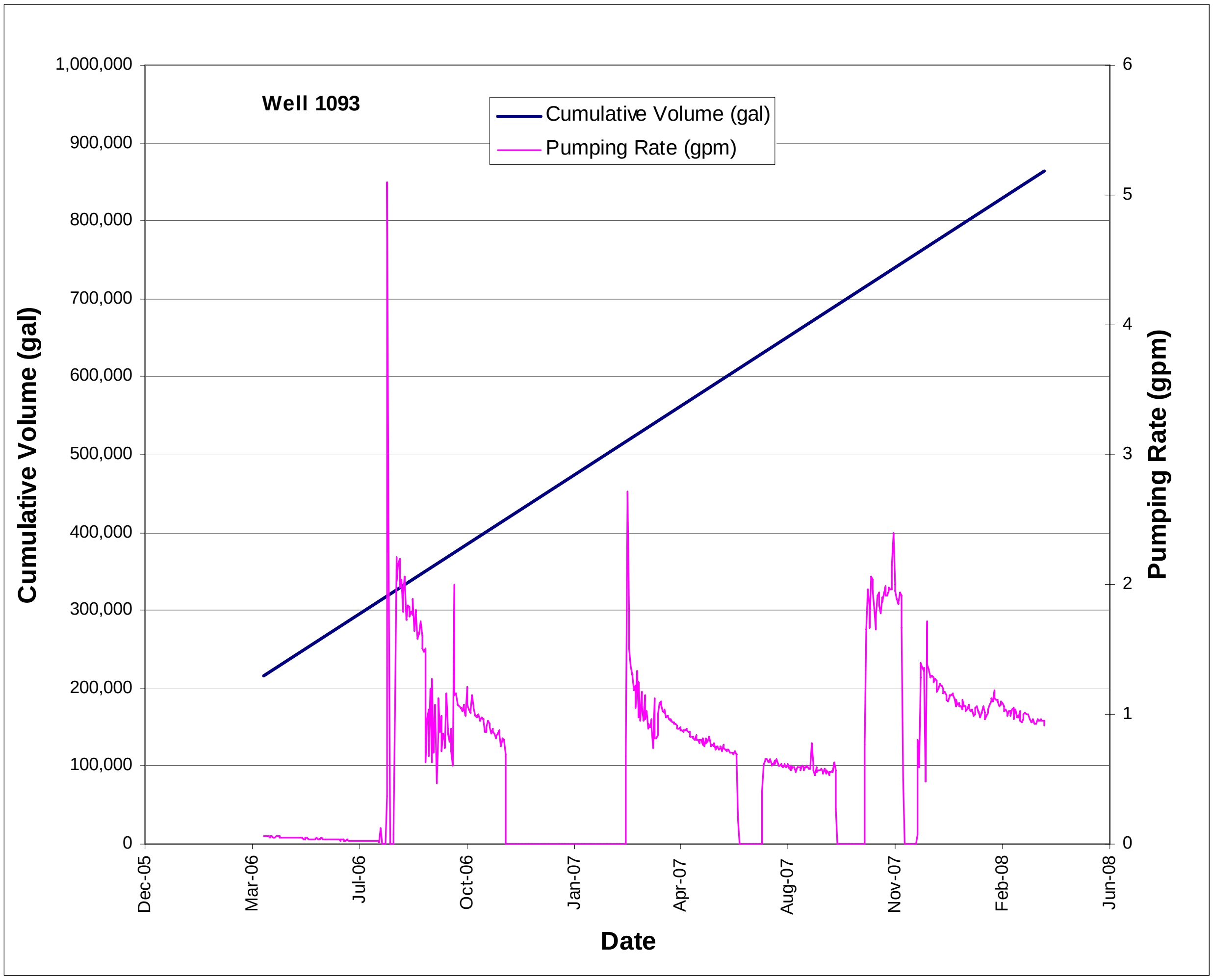

Figure 3–11. Well 1093 Pumping Rate and Cumulative Groundwater Volume Extracted

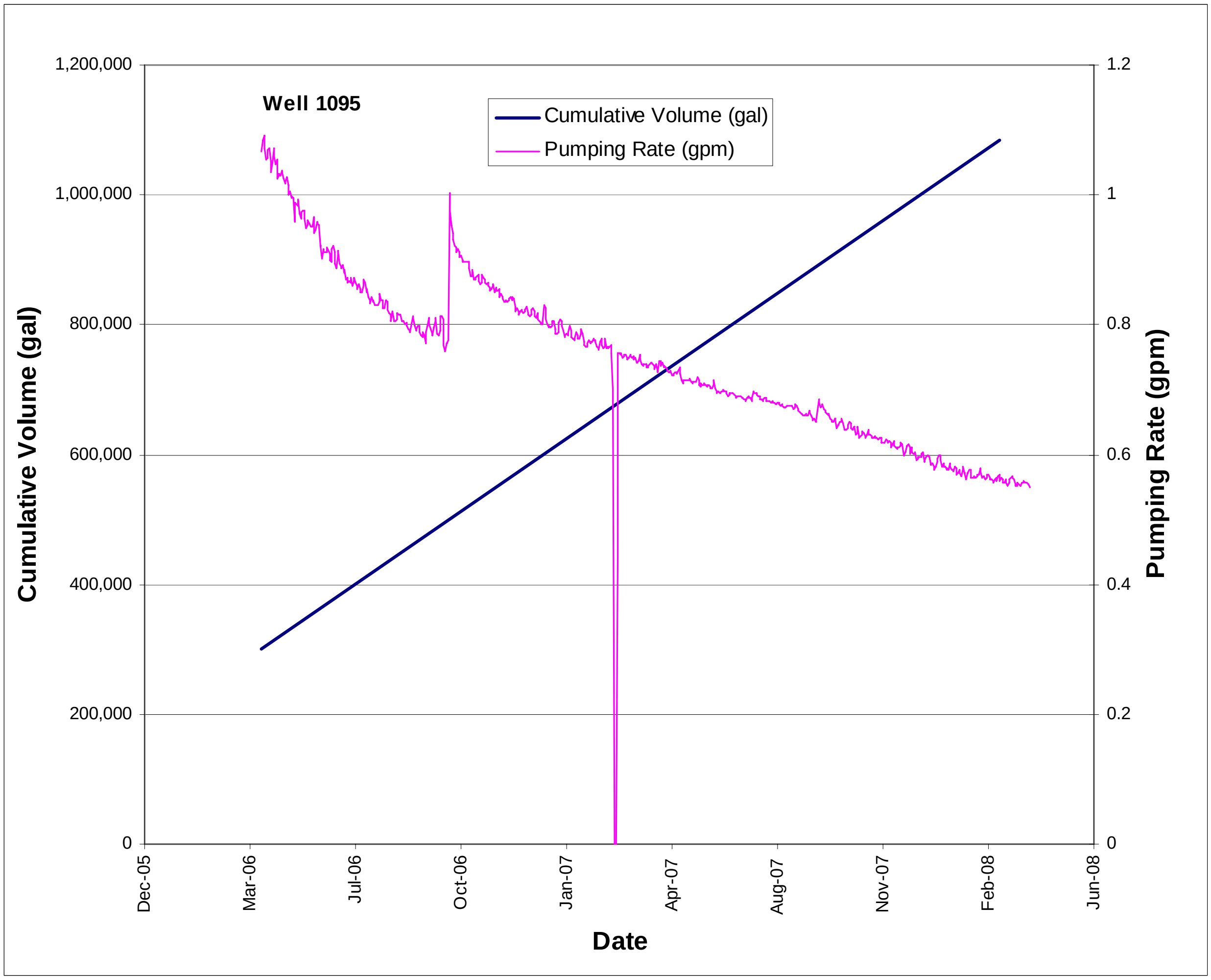

Figure 3–12. Well 1095 Pumping Rate and Cumulative Groundwater Volume Extracted

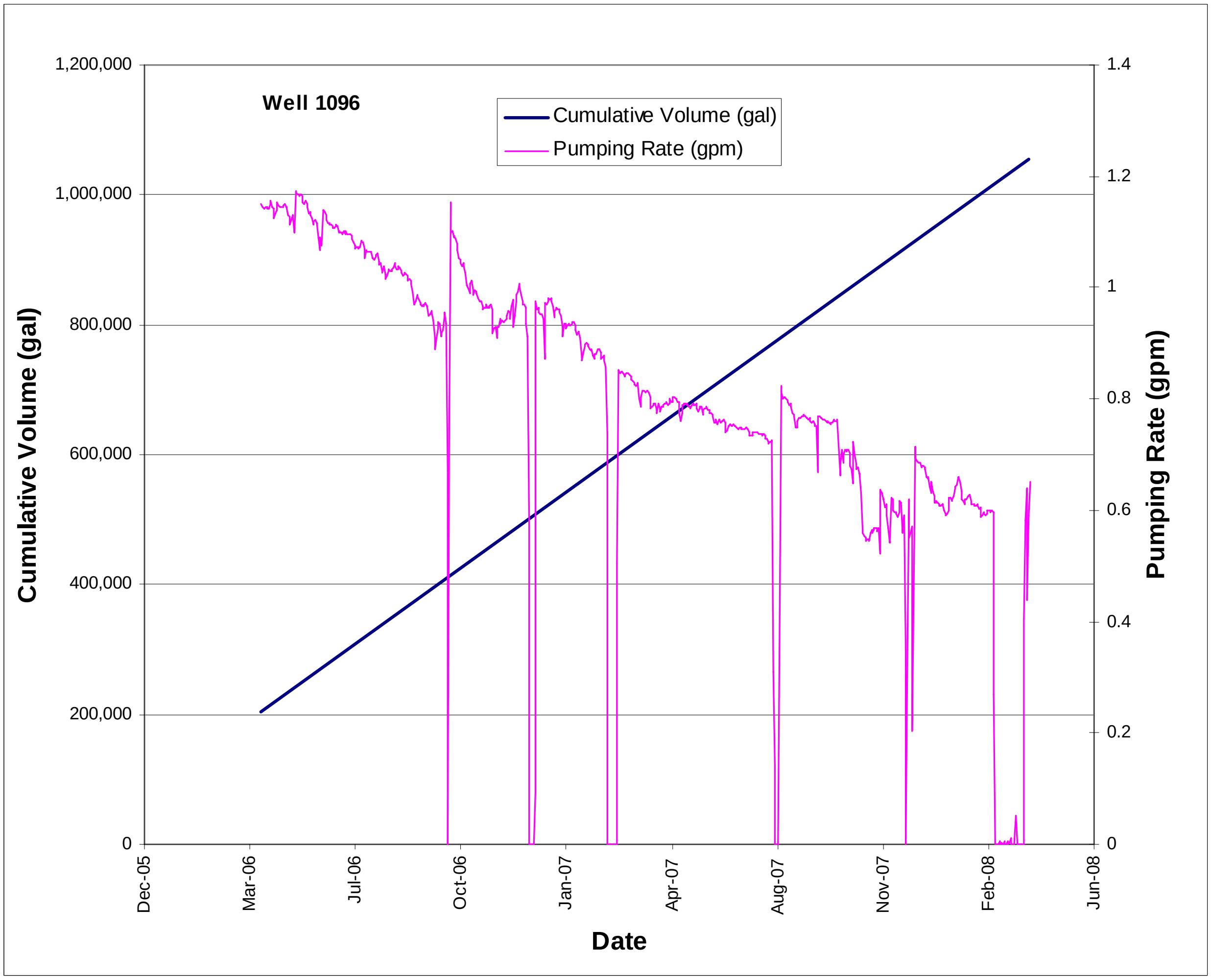

Figure 3–13. Well 1096 Pumping Rate and Cumulative Groundwater Volume Extracted

3.2.2 Terrace Drain System Performance

The terrace extraction system collects seepage from Bob Lee Wash and Many Devils Wash using subsurface interceptor drains. These drains, which consist of perforated pipe surrounded by drain rock and lined with impermeable geomembrane and geotextile filter fabric, are offset from the centerline of each wash to minimize the infiltration of surface water. All water collected by these drains is pumped through a pipeline to the evaporation pond.

Extraction rates and cumulative flow volumes for the pump installed in the Bob Lee Wash (location 1087) drain are presented in Figure 3–14. During the current performance period, the average pumping rate from Bob Lee Wash was 1.96 gpm, and the groundwater interceptor drain removed approximately 1,027,650 gallons of water.

The pumping rates and volume of water removed from the groundwater interceptor drain in Many Devils Wash (location 1088) are presented in Figure 3–15. During the current performance period, the average pumping rate from Many Devils Wash was 0.71 gpm, and the groundwater interceptor drain removed approximately 202,212 gallons of water.

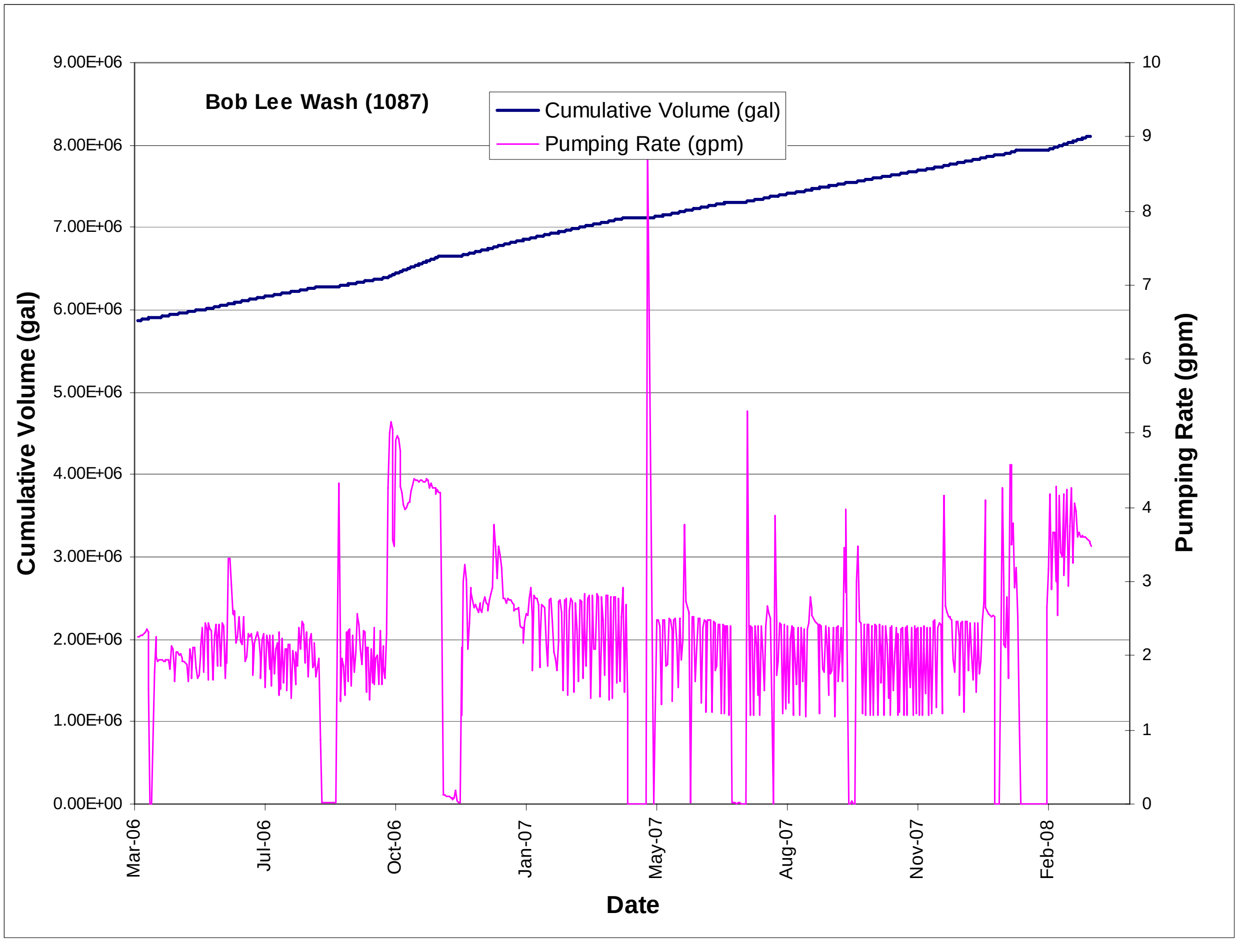

Figure 3–14. Bob Lee Wash Pumping Rate and Cumulative Groundwater Volume Extracted

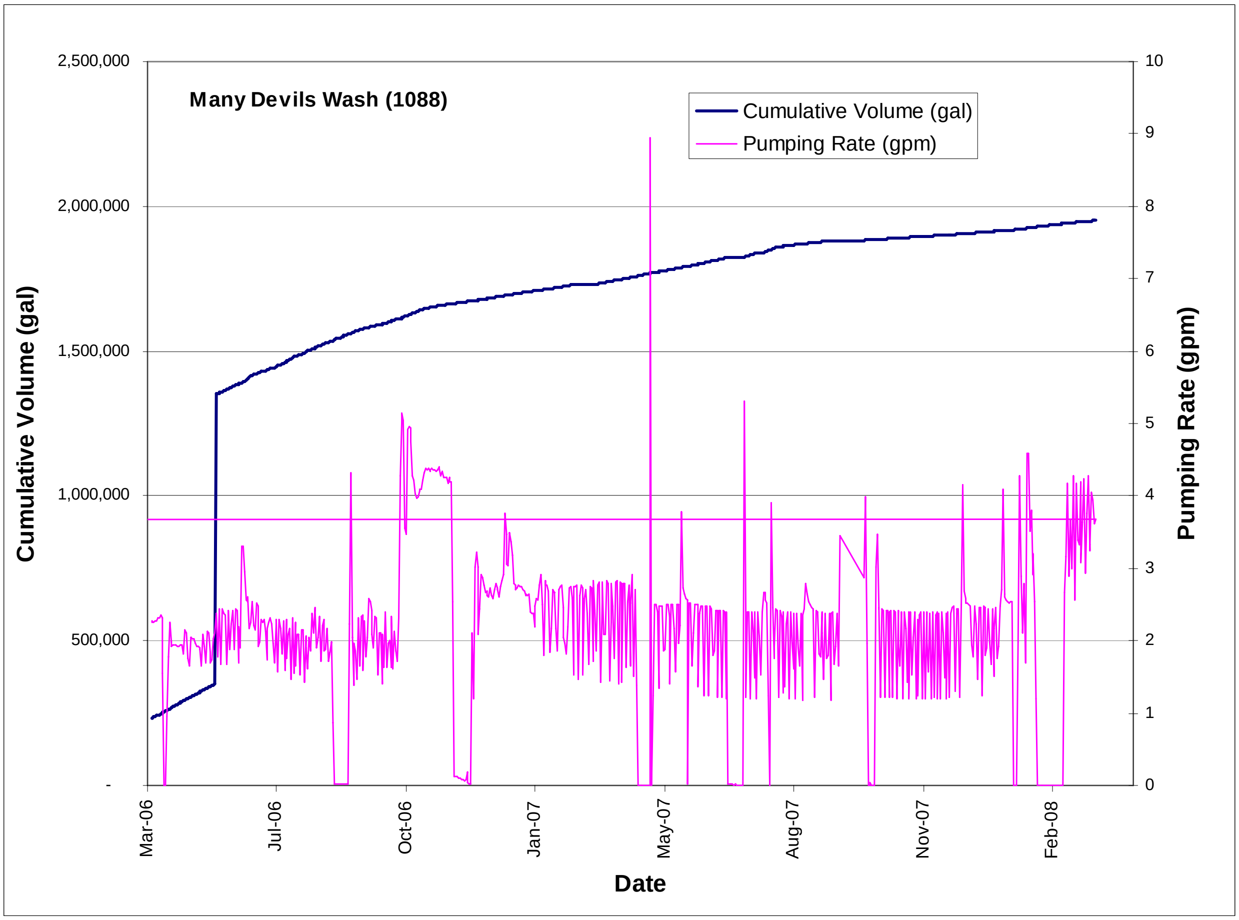

Figure 3–15. Many Devils Wash Pumping Rate and Cumulative Groundwater Volume Extracted

3.2.3 Evaporation Pond

The selected method for treating groundwater from the interceptor drains and extraction wells is solar evaporation. The contaminated groundwater is pumped to a lined evaporation pond in the south part of the radon cover borrow pit area (Figure 1–1). The water in this 11-acre pond was approximately 2.2 ft deep in March 2008, leaving approximately 5.8 ft of unfilled pond capacity. The evaporation pond is expected to be filled by the winter of 2009.

During this performance period, approximately 84.5 percent of the influent liquids entering the evaporation pond come from the floodplain aquifer, leaving approximately 15.5 percent of the inflow to come from the terrace groundwater system. At the end of this reporting period, approximately 54,000,000 gallons of water had been pumped to the evaporation pond from all sources since the start of operations in March 2003. The floodplain contribution includes two extraction wells, two trenches and the seep sump. The terrace contribution includes nine extraction wells, Bob Lee Wash, and Many Devils Wash. Figure 3–16 presents the total volume of water transported to the pond, and the relative contributions from the floodplain and terrace systems.

The estimated masses of nitrate, sulfate, and uranium entering the evaporation pond from the alluvial extraction wells, trenches, and terrace groundwater extraction system are summarized in

Table 3–2. Because of its high concentration in both the alluvial and terrace groundwater systems, sulfate is the dominant COC (in terms of mass) that enters the evaporation pond. During the current performance period, the estimated mass of selected COCs pumped to the evaporation pond was 757,620 pounds of sulfate, 33,680 pounds of nitrate, and 77.3 pounds of uranium. The estimate was computed from the average COC concentrations and the total flows at each well for the performance period.

3.2.4 Terrace Drainage Channel Diversion

Storm-water runoff from the disposal cell is designed to drain northwest to a rock-lined energy dissipation area, eventually reaching upper Bob Lee Wash. The so-called outfall drainage channel diversion conveys surface water to the lower part of Bob Lee Wash from the energy dissipation area. The extent to which the energy dissipation area functions as a point source of recharge to the terrace is unclear.

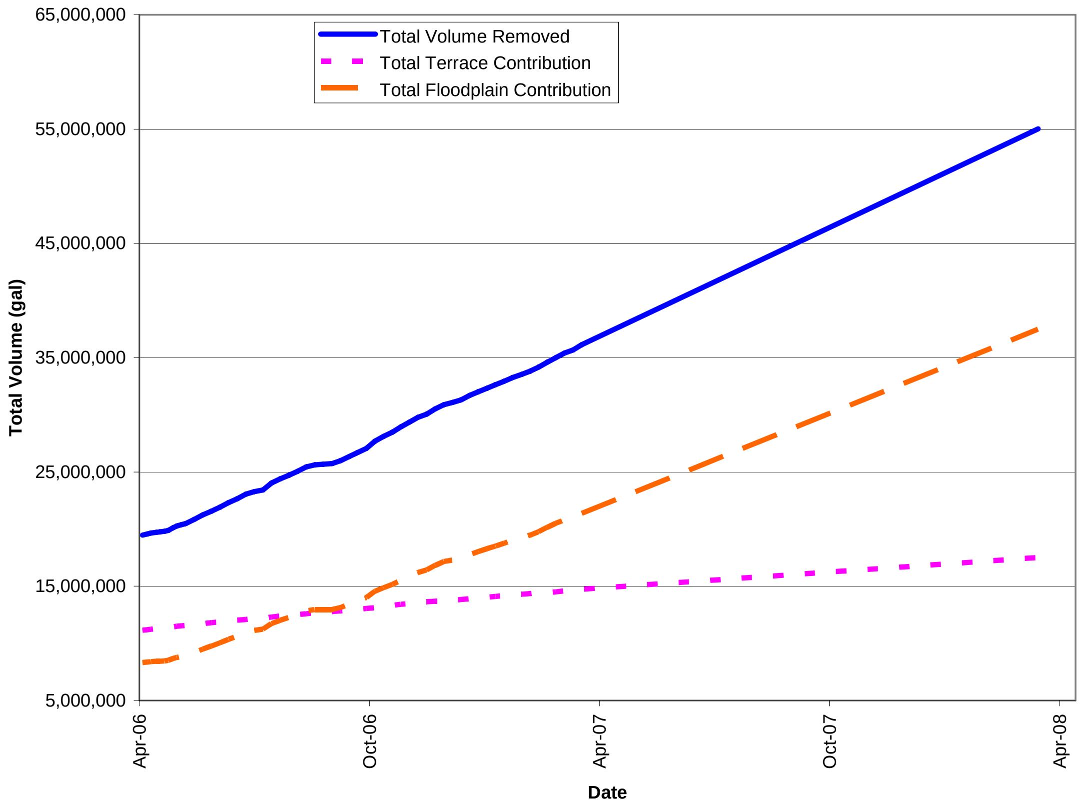

Figure 3–16. Total Groundwater Volume Transported to the Evaporation Pond

Table 3–2. Estimated Total Mass of Selected Constituents Pumped From Terrace and Floodplain

Location	Annual cumulative volume (gal)[a]	Percent contribution	Nitrate - Average Concentration (mg/L)	Nitrate Mass Contribution per Location (kg)[b]	Nitrate Mass Contribution per Location (lb)[c]	Sulfate - Average Concentration (mg/L)	Sulfate Mass Contribution per Location (kg)[b]	Sulfate Mass Contribution per Location (lb)[c]	Uranium - Average Concentration (mg/L)	Uranium Mass Contribution per Location (kg)[b]	Uranium Mass Contribution per Location (lb)[c]
Terrace											
0818	218,088	1.2	1,500	1,238	2,730	11,667	9,630	21,231	0.123	0.10	0.22
1070	8,125	0.0	815	25	55	15,000	461	1,017	0.115	0.00	0.01
1071	2,702	0.0	2,333	24	53	5,833	60	132	0.077	0.00	0.00
1078	209,963	1.2	780	620	1,367	13,667	10,861	23,944	0.153	0.12	0.27
1091	14,093	0.1	1,767	94	208	10,567	564	1,243	0.127	0.01	0.01
1092	16,502	0.1	1,297	81	179	12,267	766	1,689	0.127	0.01	0.02
1093	433,945	2.4	3,000	4,927	10,863	4,200	6,898	15,208	0.092	0.15	0.33
1095	339,435	1.9	1,410	1,812	3,994	7,000	8,993	19,827	0.066	0.08	0.19
1096	311,345	1.7	660	778	1,715	14,000	16,498	36,372	0.117	0.14	0.30
1087 (blw)	1,027,650	5.7	387	1,504	3,316	8,633	33,581	74,032	0.700	2.72	6.003
1088 (mdw)	202,212	1.1	593	454	1,001	18,000	13,777	30,372	0.167	0.13	0.281
Floodplain											
1089	3,314,000	18.4	23	285	628	7,650	95,958	211,548	0.808	10.13	22.330
1104	1,077,000	6.0	83	337	743	10,433	42,531	93,764	1.510	6.16	13.570
Trench 1 (1110)	1,440,000	8.0	280	1,526	3,364	11,333	61,771	136,181	1.667	9.08	20.027
Trench 2 (1109)	8,930,000	49.6	44	1,487	3,279	974	32,908	72,548	0.163	5.52	12.165
Seep sump (1118)	459,000	2.5	49	85	186	4,833	8,397	18,512	0.403	0.70	1.545
				15,277	33,680		343,654	757,620		35	77
Total Terrace	2,784,060	15.5									
Total Floodplain	15,220,000	84.5									
Total pond	18,004,060										

[a]Annual cumulative volumes derived from data used to generate plots in Figures 3–1 through 3–15 (data from April 1, 2007 through March 31, 2008.
[b] Mass in kg derived = annual volume × 3.785 (liters to gallons) × average concentration × (1/1000000)
[c]Conversion to pounds = kg × 2.2046

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4.0 Performance Summary

This report contains an assessment of the floodplain and terrace groundwater remediation systems at the DOE-LM site in Shiprock, New Mexico, for the performance period of April 2007 through March 2008. This performance period marks the end of the fifth year of operation of the groundwater remediation system.

- Groundwater in the floodplain system is currently being extracted from two wells adjacent to the San Juan River north of the disposal cell. Two collection trenches and the seep collection sump were added to the system in 2006 to enhance the extraction of contaminated groundwater from the alluvial system.
- Approximately 15,220,000 gallons of groundwater were extracted from the floodplain aquifer system during this performance period for a total of approximately 36,600,000 gallons extracted since March 2003.
- Relative to March 2003 baseline conditions, levels of some COCs in groundwater in the floodplain aquifer appear to be decreasing, though there is a certain amount of periodic variation in concentrations of constituents that is not necessarily indicative of the longer-term trend. Concentrations of constituents in groundwater in the floodplain alluvium are affected by seasonal climate changes, river stage influence, discharge of groundwater from the artesian well that flows into Bob Lee Wash and then onto the floodplain, and the pumping rates of the extraction wells.
- Groundwater in the terrace system is currently being extracted from two drainage trenches (in Bob Lee Wash and Many Devils Wash) and nine wells.
- Approximately 2,780,000 gallons of groundwater were extracted from the terrace system during this performance period for a total of approximately 17,800,000 gallons extracted since March 2003.
- A significant mass of COCs, which would otherwise discharge to the San Juan River, is being intercepted by the remediation system. This contaminated groundwater is being transported to the evaporation pond on the terrace just south of the disposal cell.
- Concentrations of nitrate and uranium in surface water in the San Juan River adjacent to the site have remained below background benchmark levels during this performance period.
- The estimated dissolved masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields were 757,620 pounds, 33,680 pounds, and 77.3 pounds, respectively during this performance period.
- The overall compliance strategy will be evaluated during the 2008–2009 performance period following the recommendations presented in the *Refinement of Conceptual Model and Recommendations for Improving Remediaton Efficiency at the Shiprock, New Mexico, Site, July 2005*. In particular, the cleanup goals for sulfate should be evaluated since sulfate levels in background wells have been consistently higher than the sampling values that were used to establish the current goals.

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5.0 Recommendations

The following recommendations are provided to help improve the performance and evaluation of the Shiprock remediation system:

- The floodplain extraction system appears to be functioning as anticipated. The addition of the two trenches at the base of the escarpment enhances the removal of contaminant mass from groundwater in the alluvium. No additions to the floodplain system are deemed necessary at this time.
- The terrace extraction system is operating adequately, and water levels are gradually declining. No additions to this system are recommended at this time. However, the effectiveness of the subsurface drain in Many Devils Wash has been decreasing over the last year and modifications should be made to system components to capture surface water before it flows down the wash.
- As the remediation system continues to operate, it will become more important to monitor the fluid level in the evaporation pond. The pond depth is currently monitored by the System Operation and Analysis at Remote Sites.
- The performance of the terrace remedial action is currently tied to the reduction of flow from seeps 0425 and 0426 (which are now part of the remediation system) and from other seeps on the terrace, some of which are currently dry. Discharge from these seeps will continue to be monitored and included as part of the annual performance evaluation. Given the temporal variability in hydrologic conditions at the site, long-term trends in annual combined flow rates from the seeps may be discernible.

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6.0 References

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