LMS/SHP/S05575

Annual Performance Report April 2008 through March 2009 for the Shiprock, New Mexico, Site

December 2009

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

cfs	cubic feet per second
COCs	contaminants of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GCAP	Groundwater Compliance Action Plan
gpm	gallons per minute
kg	kilogram
lb	pounds
MCL	maximum concentration limit
mg/L	milligrams per liter
SDWA	Safe Drinking Water Act
SOWP	Site Observational Work Plan
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U.S. Geological Survey

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1.0 Introduction

This report evaluates the performance of the groundwater remediation system at the Shiprock, New Mexico, Disposal and Processing Site for the period April 2008 through March 2009. The Shiprock site, a former uranium-ore processing facility under the Uranium Mill Tailings Radiation Control Act (UMTRCA), is currently managed by the U.S. Department of Energy (DOE) Office of Legacy Management.

The mill operated from 1954 to 1968; mill tailings were contained in an engineered disposal cell in 1986. As a result of milling operations, groundwater in the mill site area was contaminated with uranium, nitrate, sulfate, and associated constituents. In March 2003, DOE initiated active remediation of the groundwater using extraction wells and interceptor drains. At that time, a baseline performance report was developed (DOE 2003). That report established specific performance standards for the Shiprock groundwater remediation system and documented the site conditions that form the basis for comparisons drawn herein.

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, and two collection trenches (Trench 1 and Trench 2). 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 is pumped into a lined evaporation pond on the terrace. Figure 1–1 shows the site layout and the major components of the floodplain and terrace groundwater remediation systems. Figure 1–2 shows the locations of monitor wells and surface water sampling locations at the site.

A detailed description of the Shiprock 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). Since these initial reports were developed, DOE has undertaken additional evaluations, including the *Refinement of Conceptual Model and Recommendations for Improving Remediation Efficiency at the Shiprock, New Mexico, Site* (DOE 2005), and the more recent evaluation of the Trench 2 groundwater remediation system (DOE 2009). Concomitant with the development of this annual report, DOE is conducting a second reevaluation of the remediation strategy for both the floodplain and the terrace. Subsequent annual reports will be developed taking into account any revised recommendations and strategies issued as a result of this effort.

1.1 Remediation System Performance Standards

This performance assessment is based on an 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 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 (COCs) that would otherwise discharge to the San Juan River.

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Figure 1–1. Location Map and Groundwater Remediation System

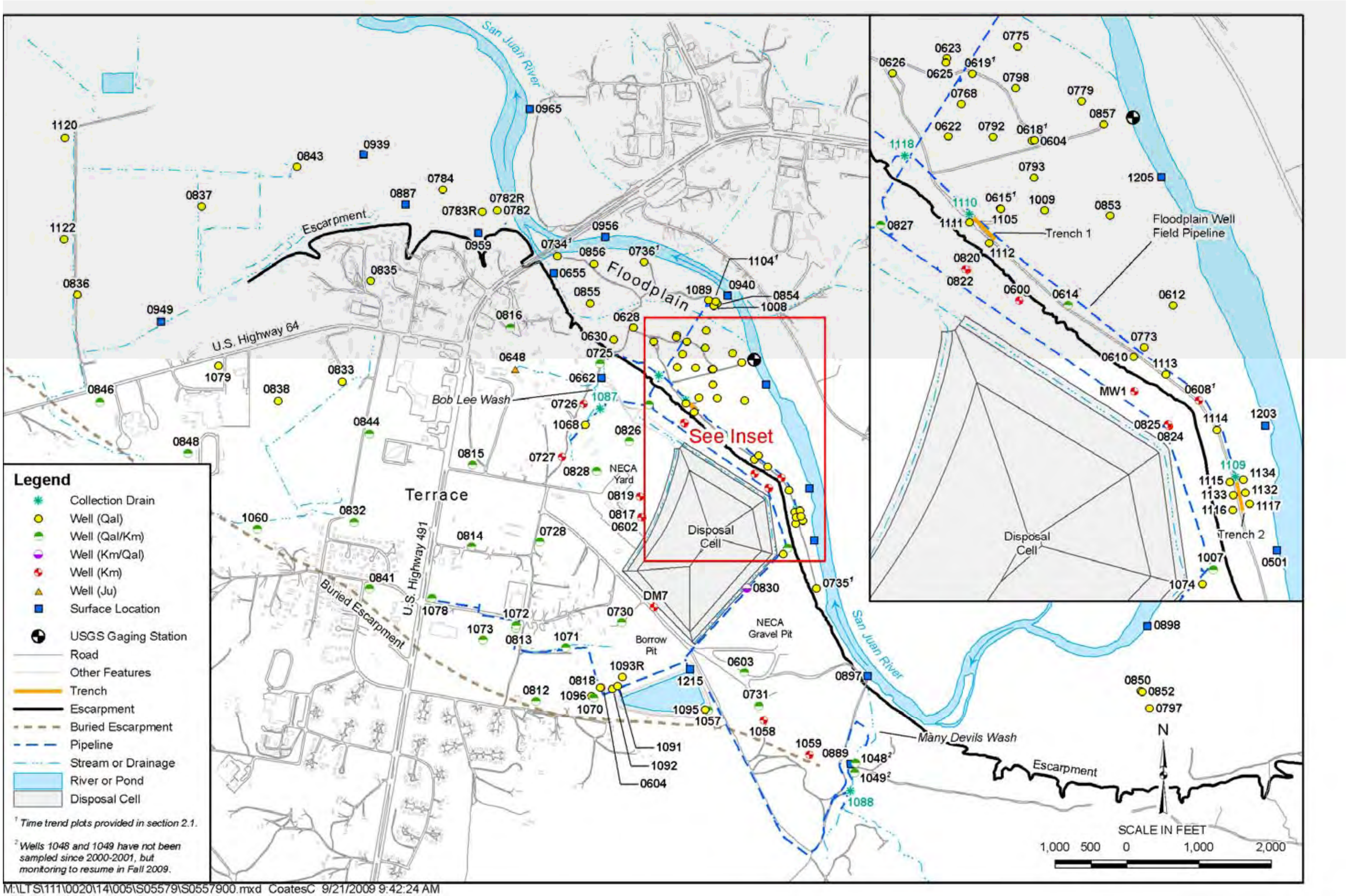

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Figure 1–2. Locations of Wells and Sampling Points at the Shiprock Site

Performance standards established for the terrace groundwater remediation system in the 2003 baseline report (DOE 2003) are:

- 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 endpoint 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 Contaminants of Concern (COCs) and Remediation Goals

The COCs for both the floodplain and terrace, defined in the GCAP (DOE 2002) are ammonia (total as nitrogen); manganese; nitrate (nitrate + nitrite as nitrogen); selenium; strontium; sulfate; and uranium. These constituents are listed in Table 1–1, along with respective UMTRCA standards and, for comparison, corresponding floodplain background data. Background data are available only for the floodplain because, even after years of investigation and reconnaissance, groundwater reflective of background conditions has not been encountered in terrace areas near the disposal cell.

Table 1–1. Groundwater COCs for the Shiprock Site

Contaminant	40 CFR 192 MCL	Historical Range in Floodplain[a] Background (Mean)	SOWP Floodplain Background Value (mg/L)	Comment
Ammonia, as N (mg/L)	NA	Not detected (≤ 0.1)	0.045	
Manganese (mg/L)	NA	0.001–7.2 (1.3)	1.24	Maximum background level measured in March 2006 (0797).
Nitrate[b] (mg/L)	10 mg/L	0.004–3.3 (0.16)	0.12	
Selenium (mg/L)	0.01 mg/L	0.0001–0.018 (0.001)	<0.001	EPA Safe Drinking Water Act (SDWA) MCL standard is 0.05 mg/L.
Strontium (mg/L)	NA	1.0–10 (3.0)	2.26	Background maximum (10 mg/L) measured in September 2008 (0797).
Sulfate (mg/L)	NA	427–5,200 (1,960)	1,432	Sulfate is also elevated in terrace artesian well 0648 (historical range: 1,870–2,340 mg/L).
Uranium[c] (mg/L)	0.044 mg/L	0.007–0.12 (0.03)	0.007	Levels in background well 0850 have been increasing since 2005 (see Figure 2–10).

[a] Floodplain background wells 0797 and 0850 (locations shown in Figure 1–2; also see Figure 2–10)
[b] Nitrate + Nitrite as Nitrogen (N)
[c] Equivalent to 30 picocuries per liter (pCi/L) U-234 + U-238, assuming secular equilibrium
EPA = U.S. Environmental Protection Agency
MCL = Maximum concentration limit (applies to 40 CFR 192), or maximum contaminant level (EPA SDWA)
mg/L = milligrams per liter
NA = Not applicable (contaminant does not have an MCL in 40 CFR 192)

The compliance standards for uranium and nitrate in the floodplain are their respective UMTRCA standards of 0.044 milligram per liter (mg/L) and 10 mg/L. A secondary standard of 250 mg/L for sulfate has been established under the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act (SDWA).[1] However, high sulfate concentrations (relative to the SDWA standard) have been detected in floodplain background wells (only 0797 and 0850 are currently monitored; see Figure 1–2). In fact, a historical background maximum concentration of 5,200 mg/L was measured in well 0797 this reporting period (in September 2008). Sulfate levels have also been elevated in groundwater entering the floodplain from flowing artesian well 0648 (up to 2,340 mg/L). Therefore, DOE will propose an alternate cleanup goal for floodplain sulfate that takes into account these elevated background concentrations.

Similar observations apply to uranium—0.12 mg/L was measured in background well 0850 in September 2008. Although seasonal fluctuations are apparent, corresponding directly with changes in groundwater elevations (see Section 2.1.2), an increasing uranium concentration trend (although less pronounced in 0797) is apparent in both floodplain background wells. These findings have bearing on the feasibility of achieving the 0.044 mg/L UMTRCA standard.

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 water from the terrace is still providing a source. Therefore, DOE has proposed an interim alternate concentration limit for selenium of 0.05 mg/L (DOE 2003), which is the EPA maximum contaminant level for drinking water.

Previous reports (e.g., DOE 2008) have cited a cleanup objective for manganese based on the maximum background concentration for the floodplain. This level is currently 7.2 mg/L, the historical maximum measurement in well 0797 in March 2006.[2] The maximum background concentration of strontium was also detected in well 0797: 10 mg/L in September 2008. A cleanup standard has not been established for ammonia (EPA has not developed any toxicity values upon which to base an associated risk-based standard), and levels measured in background wells have been low ($\leq$0.1 mg/L).

1.3 Hydrogeological Setting

This section presents a brief summary of the floodplain and terrace groundwater systems. More detailed descriptions are provided in the SOWP (DOE 2000), the refinement of the site conceptual model (DOE 2005), and the recent Trench 2 evaluation (DOE 2009).

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.

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[1] 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 or no adverse effect on humans and animals.

[2] The 2007–2008 annual report cited a maximum of 2.74 mg/L; however, that level had not been updated.

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.

As discussed in the following section, most groundwater contamination in the floodplain lies close to the escarpment east and north of the disposal cell. 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 is defined by monitor wells installed in the floodplain approximately 1 mile upriver from the site (wells 0797 and 0850).

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 about 1 mile, where it is 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, in some areas, appears to flow through deeper portions of the shale that might be fractured, and along bedding surfaces.

1.4 Contaminant Distributions

The concentrations of COCs in terrace and floodplain groundwater, based on results of the most recent sampling event, are shown in Figure 1–3 through Figure 1–9. Figure 1–10 through Figure 1–16 plot changes in the extent of the floodplain and terrace contaminant plumes, presenting interpolated data[3] for wells sampled in March 2001 (comparable to baseline conditions) and March 2009.

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[3] Interpolation is the procedure of predicting contaminant concentrations at unsampled sites based on measurements made at point locations within the same area or region.

While interpreting these figures, the reviewer should be aware of the following. The data in Figures1–3 through Figure 1–9 are plotted using graduated symbols (symbols of varying size and color) to facilitate identification of site areas with higher levels of COCs. In these figures, interval classes are established based on UMTRCA (40 CFR 192) maximum concentration limits (MCLs, when available), the floodplain background data listed in Table 1–1, and/or the sitewide contaminant distribution. However, in some cases, distinctions between groupings are subtle and not significant. For example, in Figure 1–7, the red symbols denote any strontium measurement exceeding the historical background maximum of 10 mg/L. However, in some areas (e.g., the area between the evaporation pond and Many Devils Wash), there is very little variability in the data despite differences in symbols (<10 mg/L vs. >10 mg/L), and no indication of contaminant levels significantly above the historical background range.

The contaminant plume maps presented in Figure 1–10 through Figure 1–16 warrant a different explanation. In previous annual performance reports, March 2003 data (corresponding to the onset of active groundwater remediation) were used to generate contaminant plume maps representing baseline conditions. However, because fewer alluvial wells were sampled in 2003 (42) than in 2009 (64), the data are not sufficient to draw solid conclusions regarding comparative trends (e.g., changes in plume extent) for some areas of the site. Because the number and location of sampled wells in 2001 was comparable to the 2009 data set, and because contaminant concentrations did not change significantly between 2001 and 2003, data from 2001 were used to generate the baseline contaminant plume maps in Figure 1−10 through Figure 1−16.

As shown in these figures, 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 approaches the San Juan River near the floodplain extraction wells (Figure 1–3 through Figure 1–16). 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. Additional discussion of floodplain contaminant trends is provided in Section 2.1.2, which presents time-concentration plots of COCs for a representative subset of floodplain wells.

Contamination trends on the terrace receive less focus in this annual report because the compliance strategy is based on hydrologic control—i.e., active remediation to reduce groundwater elevations, with the ultimate goal of eliminating potential exposure pathways (e.g., in seeps and washes). Therefore, concentration-driven performance standards for the terrace system have not been developed. However, as a best management practice, selected contaminant concentrations are measured at each extraction well, drain, and seep. Estimates of mass contaminant removal from the terrace system, compiled during this performance period, are presented in Section 3.2.3 of this report.

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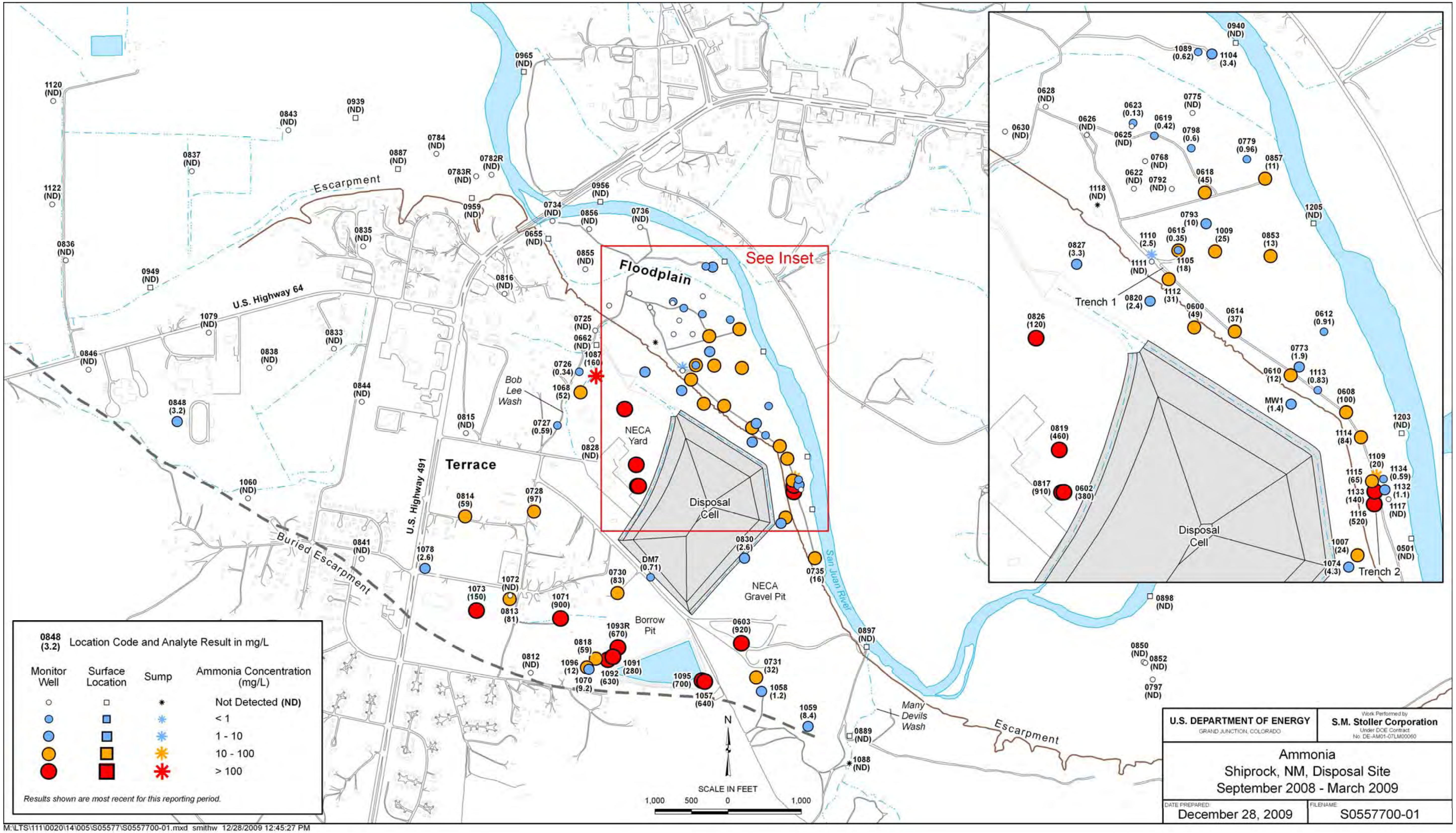

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Figure 1–3. Concentrations of Ammonia (NH3) Un-ionized as N in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

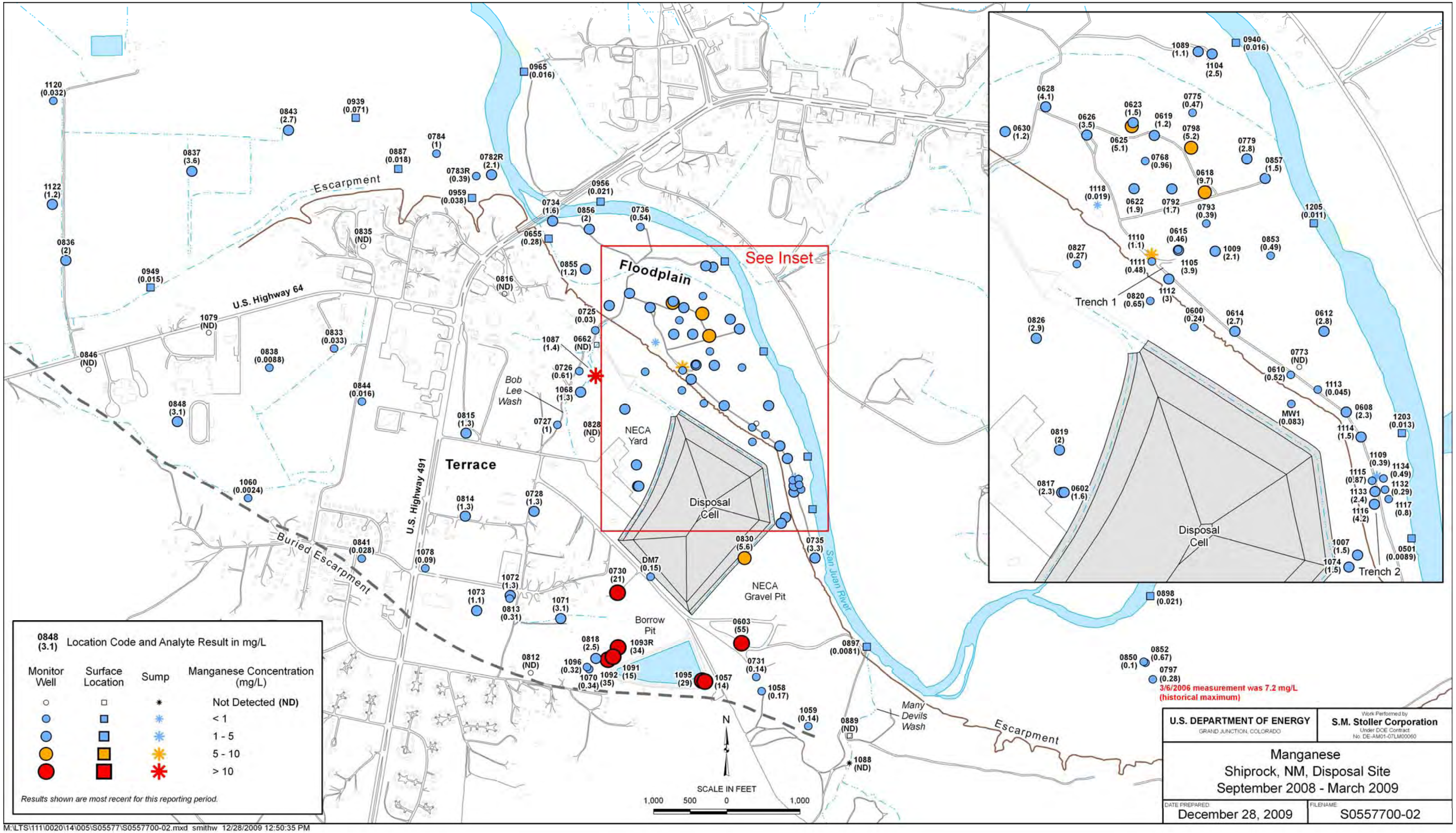

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Figure 1–4. Concentrations of Manganese in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

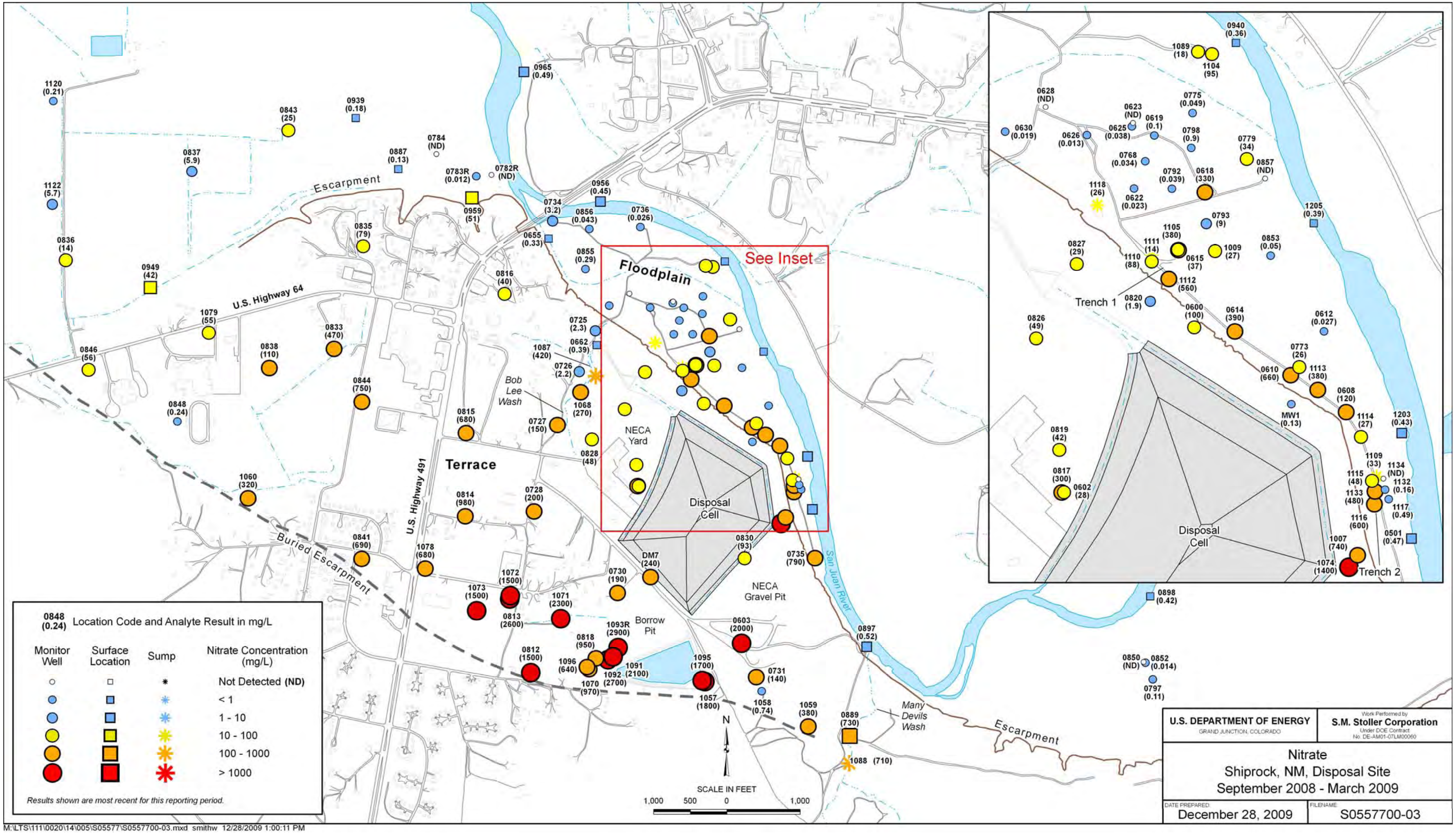

Figure 1–5. Concentrations of Nitrate + Nitrite as Nitrogen in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

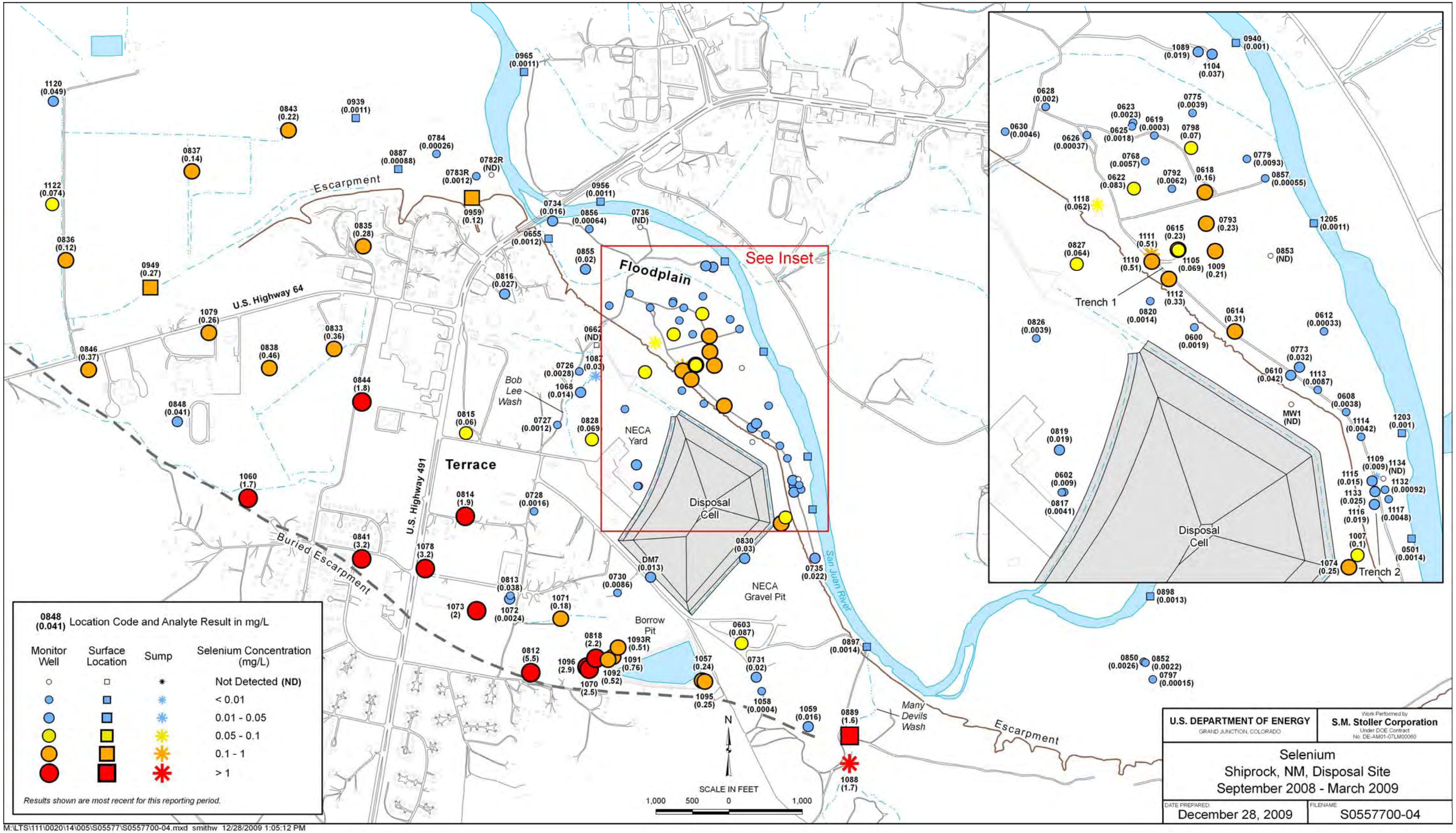

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Figure 1–6. Concentrations of Selenium in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

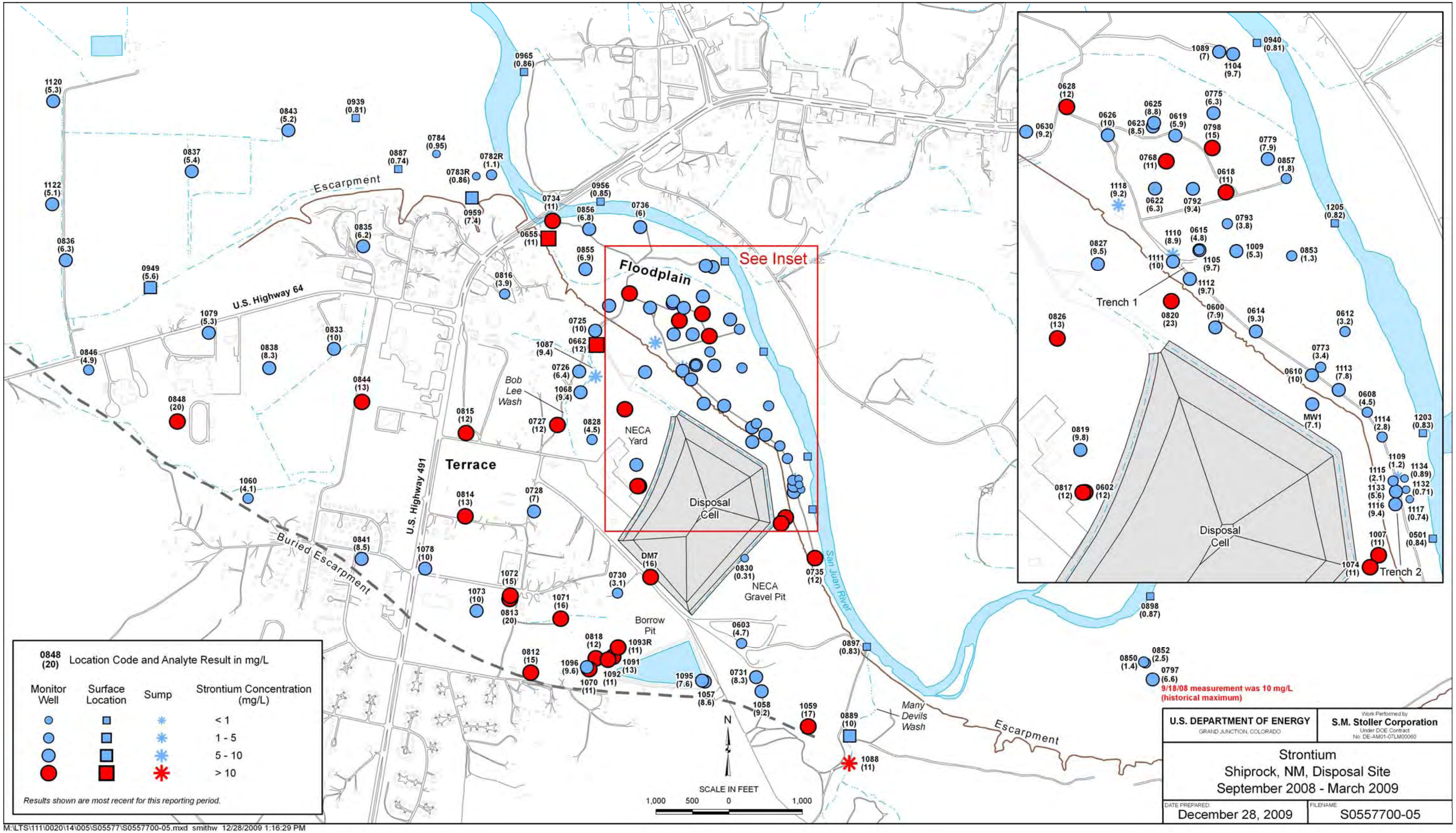

Figure 1–7. Concentrations of Strontium in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

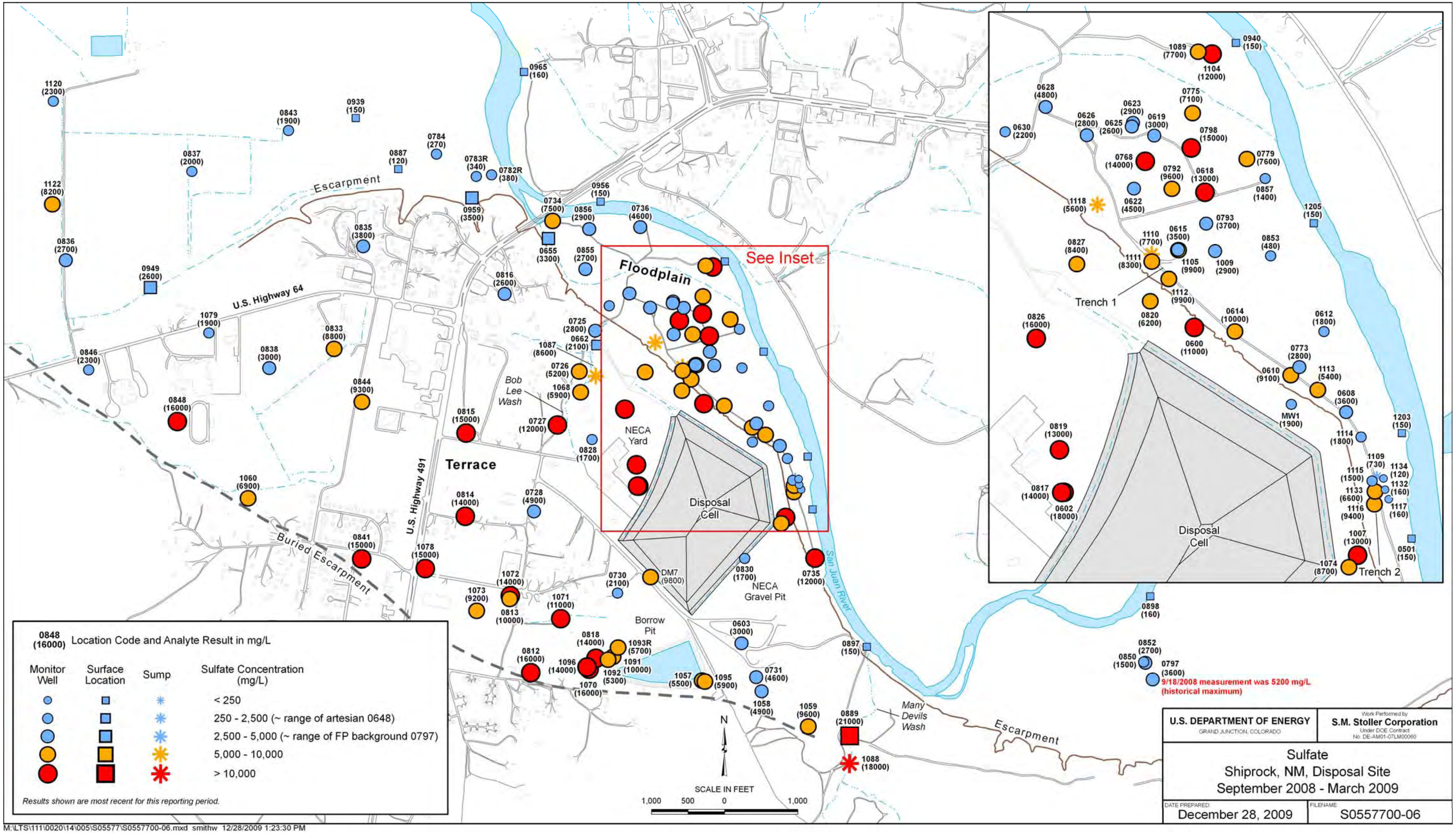

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Figure 1–8. Concentrations of Sulfate in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

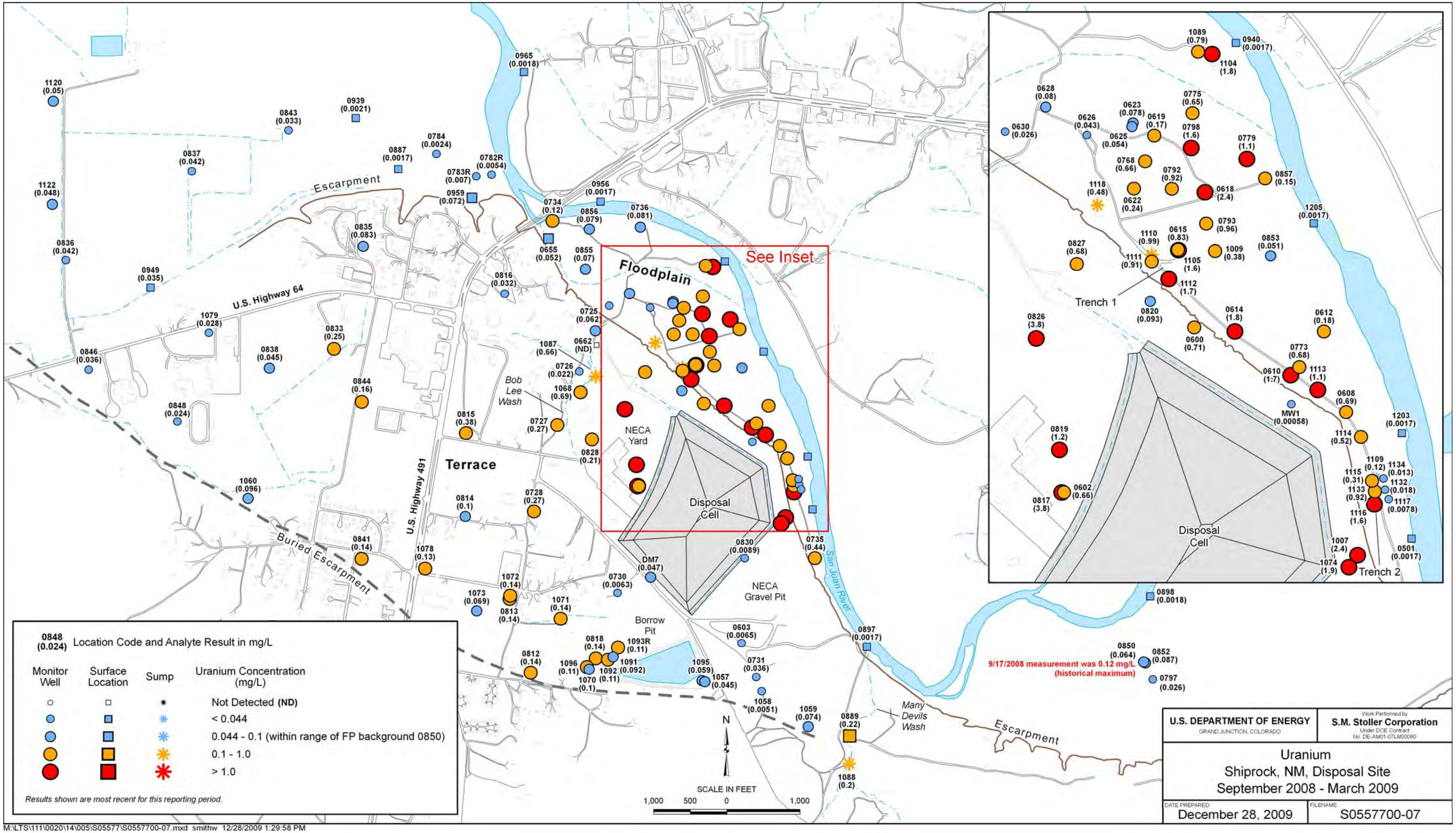

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Figure 1–9. Concentrations of Uranium in Terrace and Floodplain Groundwater and Surface Water, September 2008–March 2009

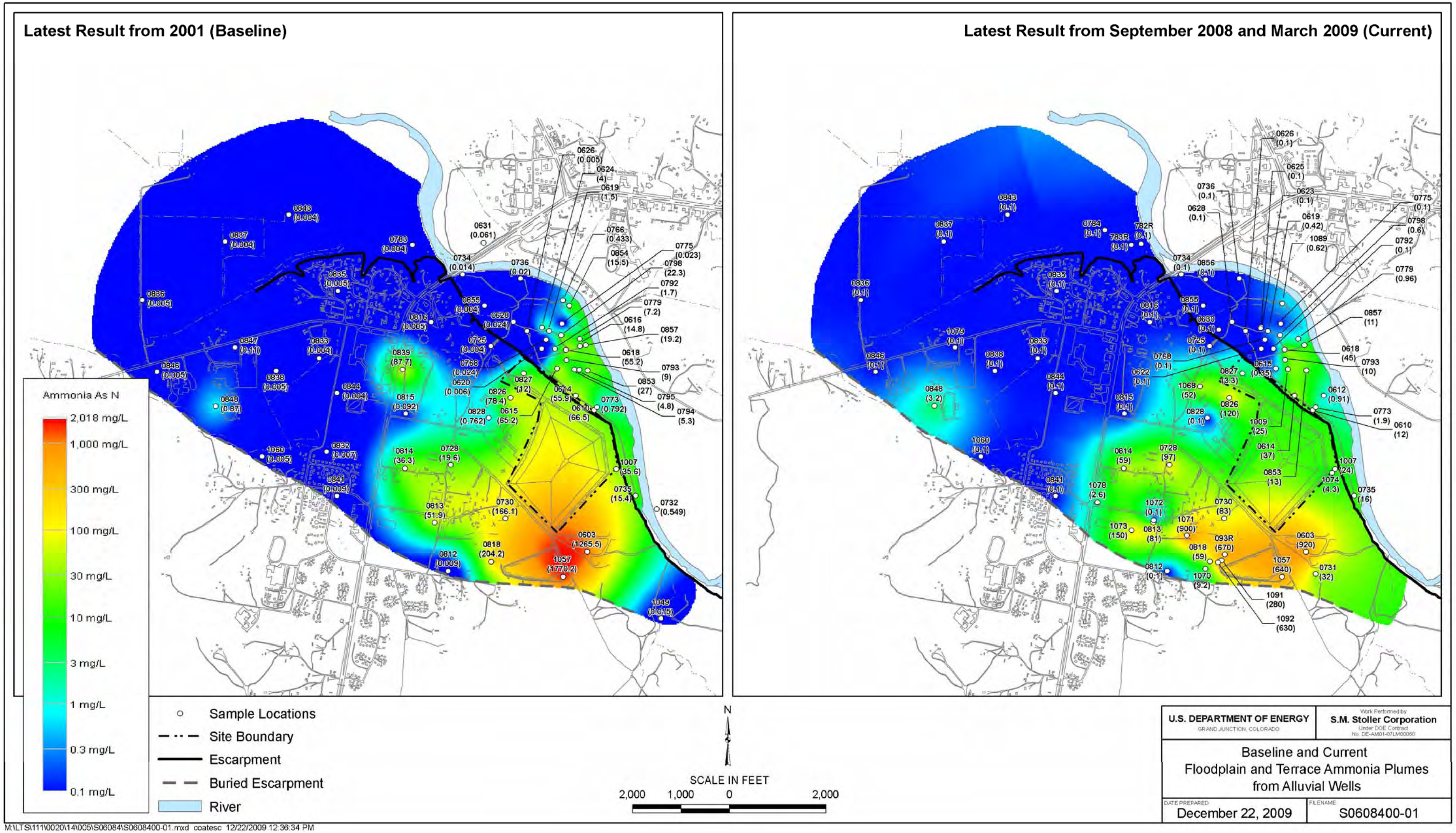

Figure 1–10. March 2001 (Baseline) and March 2009 Floodplain and Terrace Ammonia Plumes

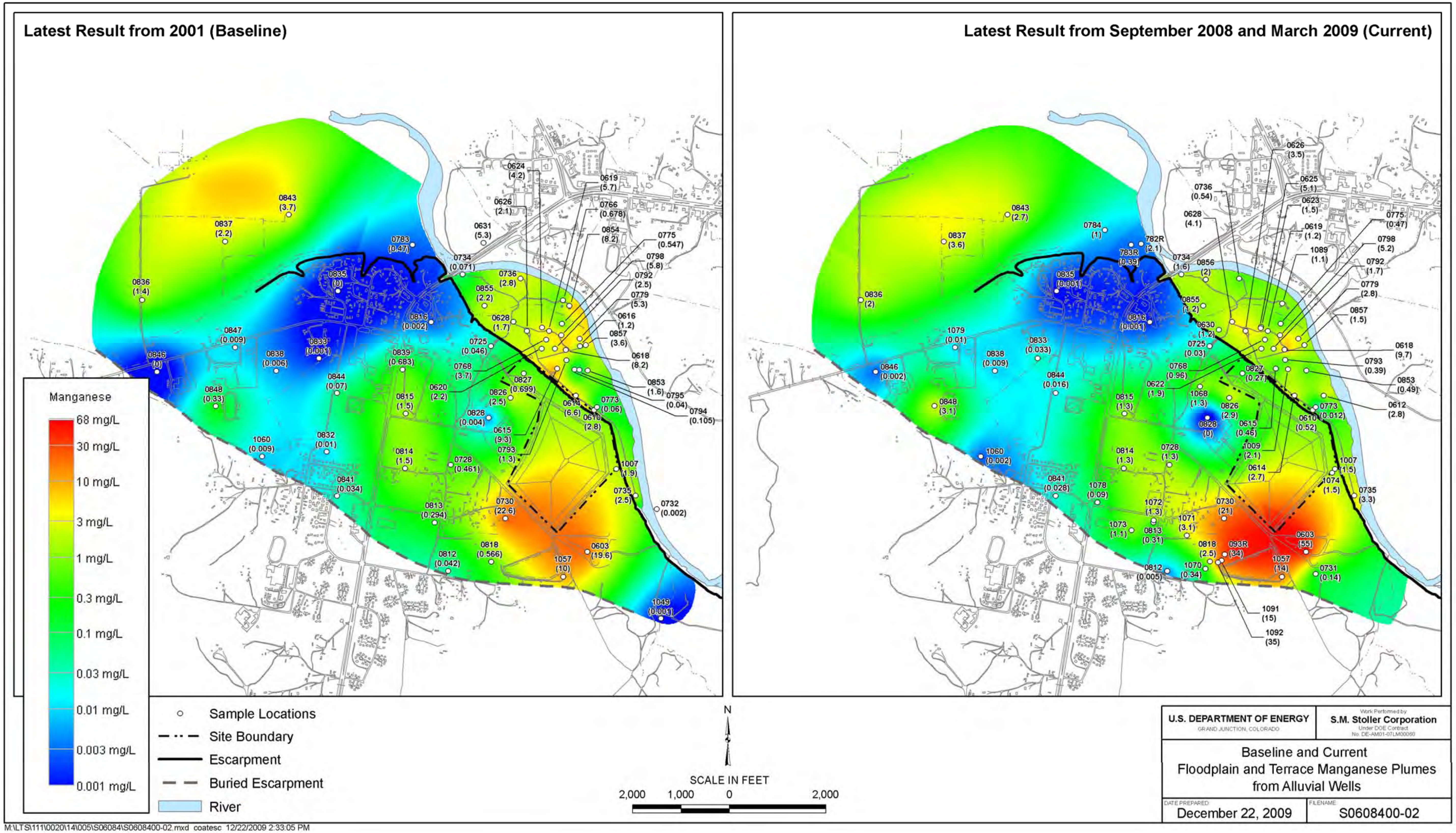

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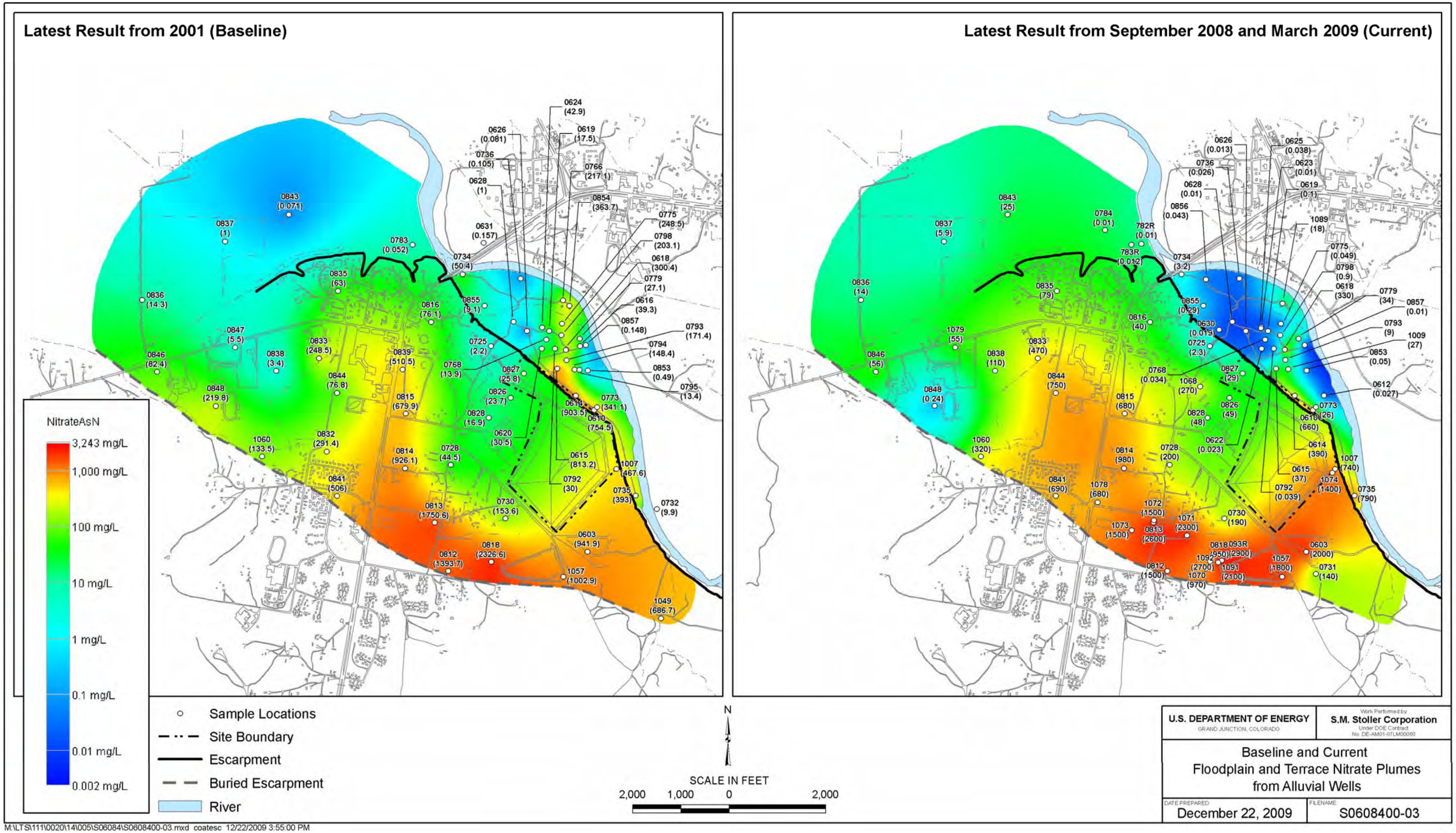
Figure 1–11. March 2001 (Baseline) and March 2009 Floodplain and Terrace Manganese Plumes



Latest Result from 2001 (Baseline)

Latest Result from September 2008 and March 2009 (Current)

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Figure 1–12. March 2001 (Baseline) and March 2009 Floodplain and Terrace Nitrate Plumes

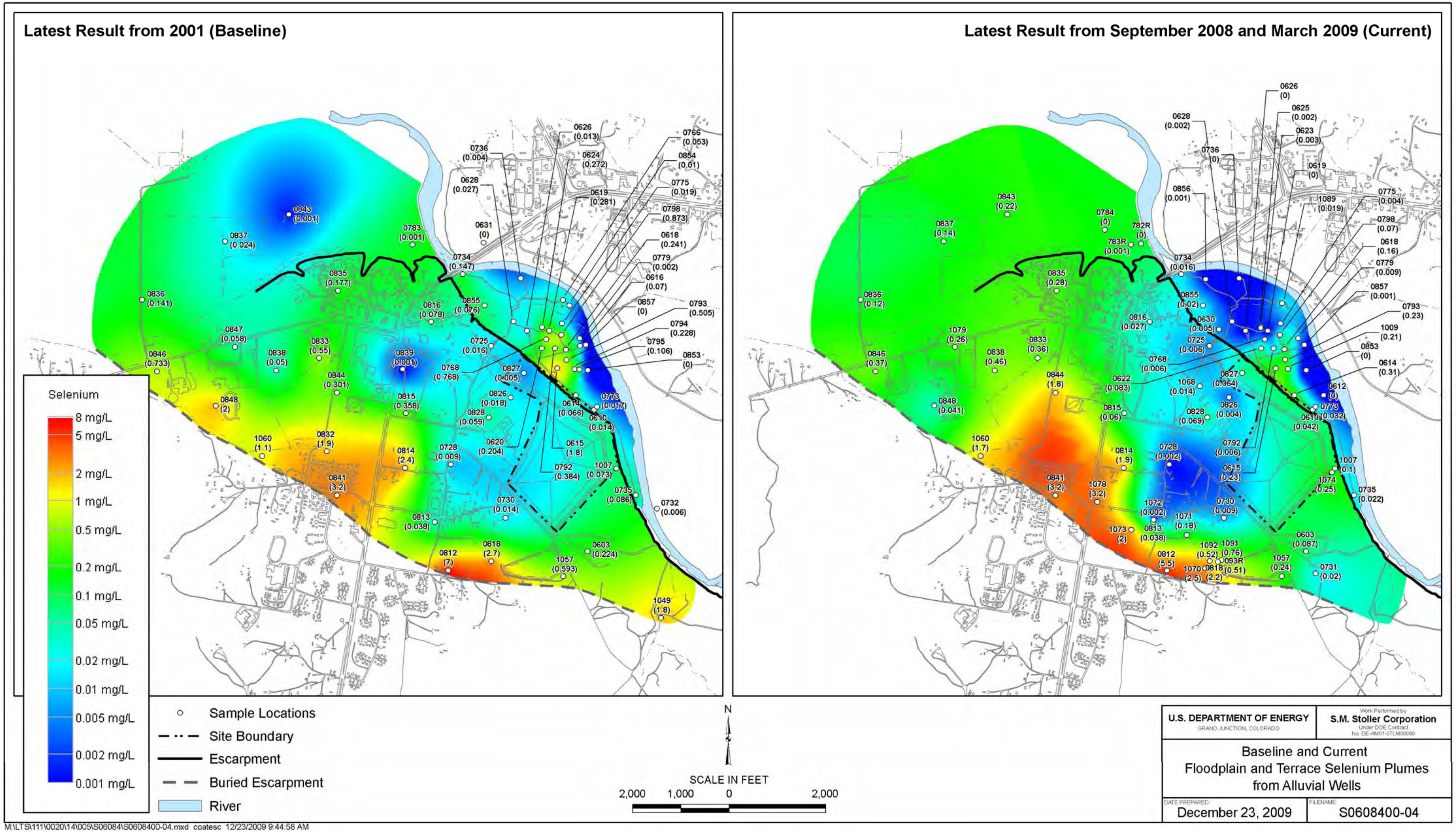

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Figure 1–13. March 2001 (Baseline) and March 2009 Floodplain and Terrace Selenium Plumes

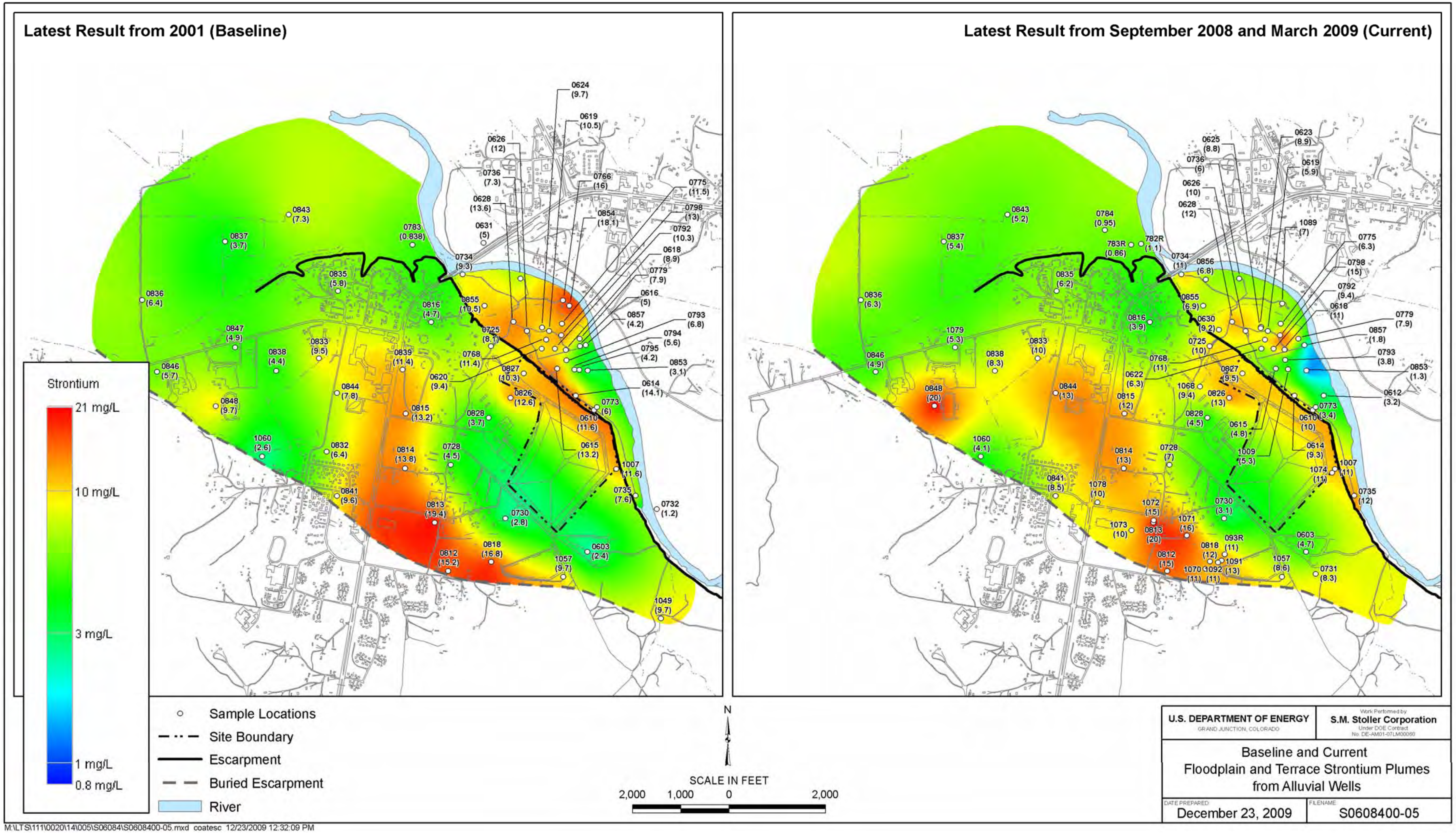

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Figure 1–14. March 2001 (Baseline) and March 2009 Floodplain and Terrace Strontium Plumes

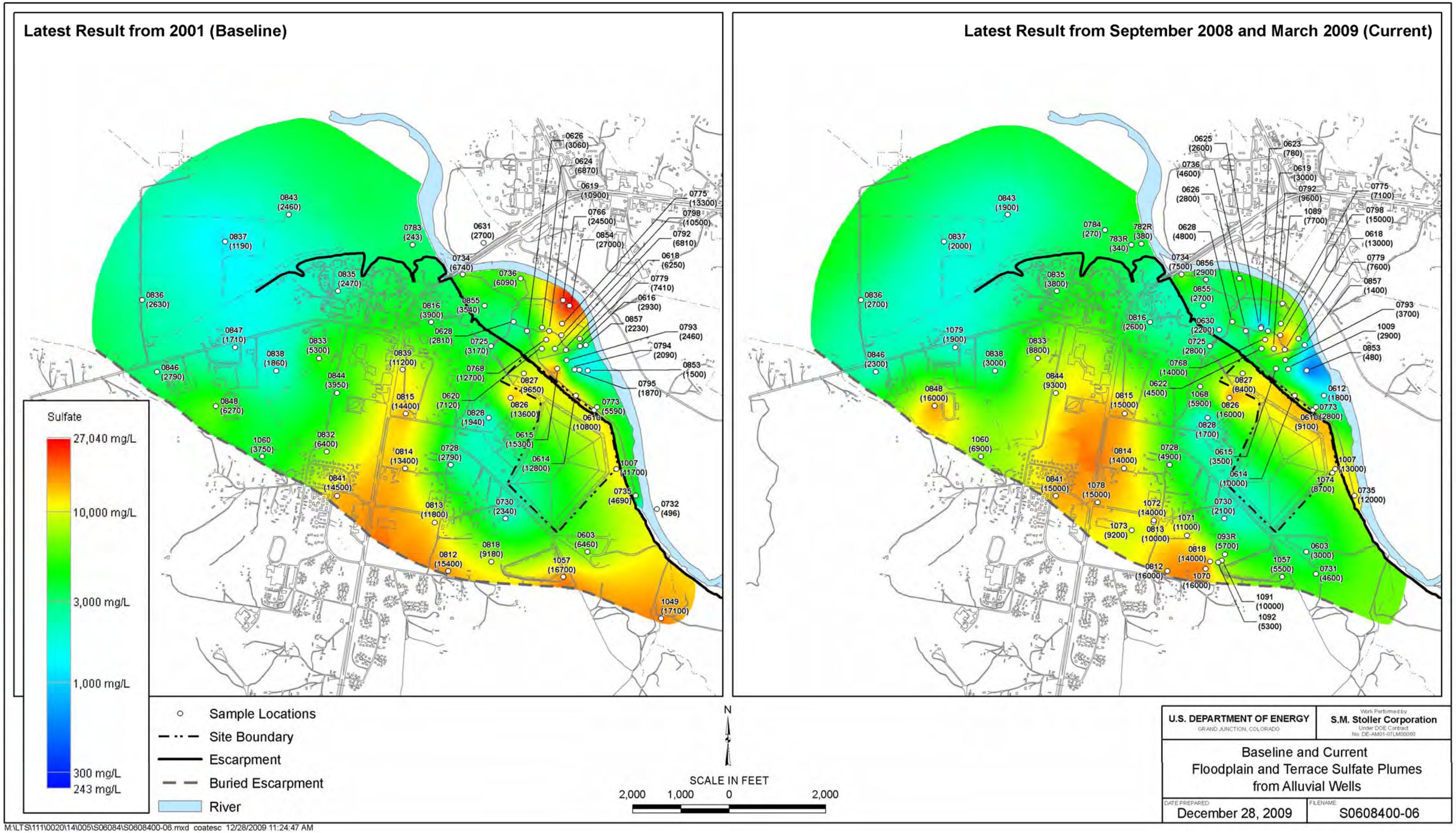

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Figure 1–15. March 2001 (Baseline) and March 2009 Floodplain and Terrace Sulfate Plumes

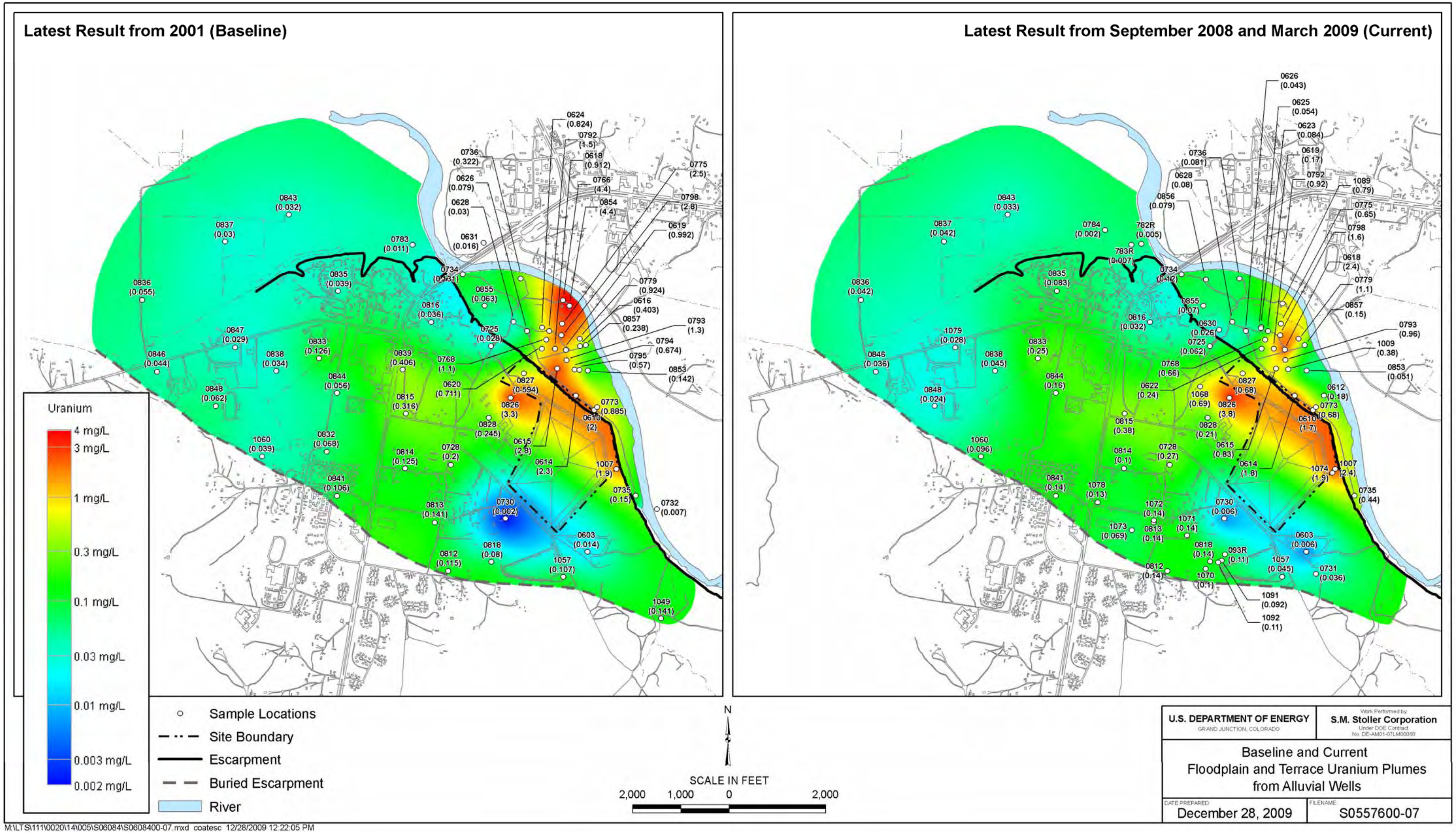

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Figure 1–16. March 2001 (Baseline) and March 2009 Floodplain and Terrace Uranium Plumes

2.0 Subsurface Conditions

This section summarizes hydraulic and water-quality characteristics of the floodplain and terrace groundwater systems for the April 2008 through March 2009 reporting period, approximately 6 years after the startup of the treatment system.

2.1 Floodplain Subsurface Conditions

The following discussion of current subsurface conditions in the floodplain is based on the collection and analysis of groundwater samples and groundwater level data through March 2009. 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 the Baseline Performance Report (DOE 2003) to evaluate the effectiveness of the floodplain treatment system.

2.1.1 Floodplain Groundwater Level Trends and Flow Directions

Analysis of groundwater level (horizontal gradients) and flow data is important in evaluating 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 previous three-point analyses showed very little change in groundwater flow directions and demonstrated that the flow system in the floodplain was operating as expected—that is, the flow of groundwater is predominantly toward the extraction wells (DOE 2008). The recent evaluation of the Trench 2 remediation system corroborates this conclusion (DOE 2009).

Groundwater levels in the floodplain aquifer are manually recorded during routine groundwater sampling events. Figure 2–1, which plots groundwater levels for a representative subset of these wells, indicates that groundwater level fluctuations over the past 6 years have been on the order of 2 ft. As expected, higher groundwater levels generally coincide with elevated flows in the San Juan River.

In addition to manual measurements, groundwater elevations in the floodplain aquifer are also measured every 4 hours by pressure transducers connected to dataloggers that are installed in five monitor wells—0617, 0736, 0854, 0857, and 1008. These data are plotted in Figure 2–2, along with stream flow in the San Juan River, for comparison.

Flow data were obtained from U.S. Geological Survey (USGS) Gauging Station 09368000 (San Juan River at Shiprock), located just east of well 0857 (Figure 1–1). The river flow in March 2003 was 649 cubic feet per second (cfs), while the flow in March 2009 was 814 cfs.[1] In terms of stage, or water surface elevation, the San Juan River flow measured in 2009 was of the same general magnitude as that measured in 2003.

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[1] River flow measurements cited above correspond to the days manual water level measurements were taken at the Shiprock site.

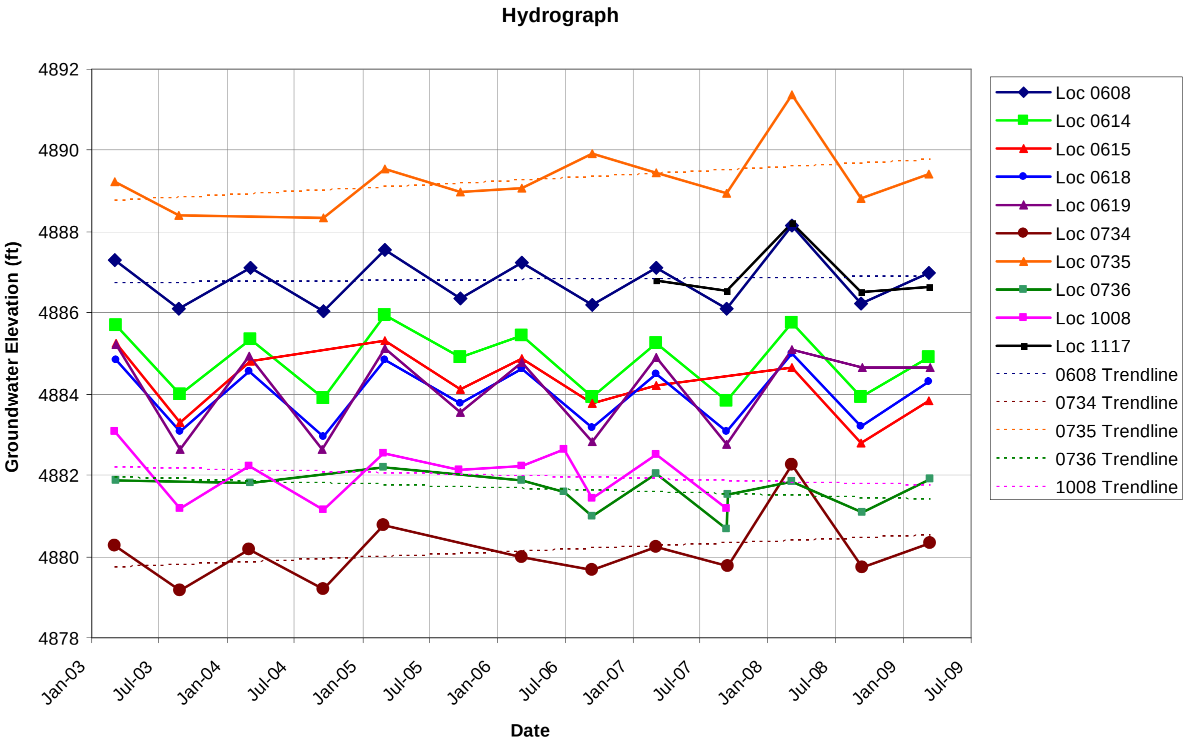

Figure 2–1. Floodplain Groundwater Elevations from Manual Measurements

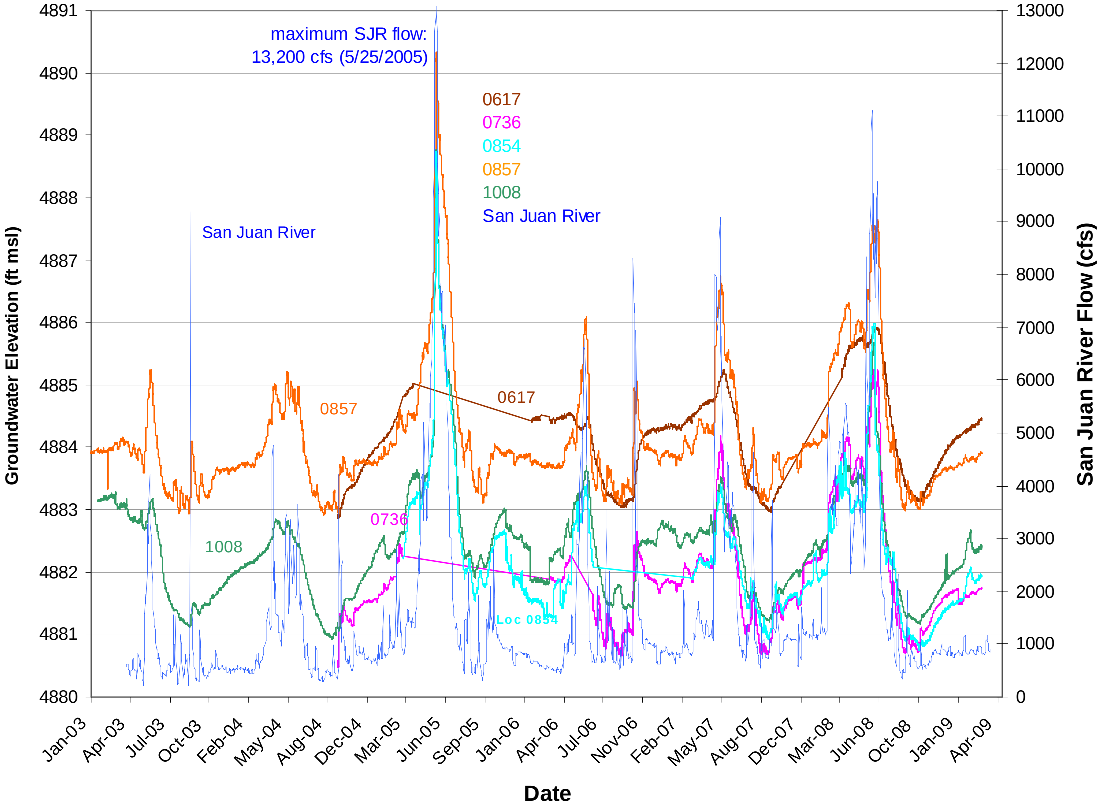

Figure 2–2. Floodplain Groundwater Elevations From Datalogger Measurements

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 2–2). It is well established that much 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 former milling site would likely increase under such circumstances. A more detailed evaluation of floodplain groundwater flow and chemistry is provided in the recent evaluation of the Trench 2 groundwater remediation system (DOE 2009).

2.1.2 Floodplain Contaminant Distributions

Groundwater samples were collected from selected floodplain monitor wells in September 2008 and March 2009. The locations of these wells are shown in Figure 1–2, which also identifies the zone in which the wells were completed (the term Qal denotes the alluvium, and Km denotes the Mancos Shale). Variations in constituent concentrations over time from March 2003 (baseline) through March 2009 are plotted in Figures 2–3 through 2–9 for a representative subset of these wells. These wells, marked with an asterisk in Figure 1–2, are:

- 0608—Km, near the disposal cell at the base of the escarpment;
- 0614—Qal/Km, base of escarpment between 0608 and Trench 1;
- 0615—Qal, Trench 1 area;
- 0618—Qal, northeast of Trench 1;
- 0619—Qal, northwest of well 0618;
- 0734—Qal, western floodplain near highway (farthest downgradient of well subset);
- 0735—Qal, upgradient of disposal cell, adjacent to river (farthest upgradient of subset);
- 0736—Qal, western floodplain;
- 1008—Qal, monitoring discontinued in 2006 and replaced by well 1104; and
- 1104—Qal, well 1089 area (no samples collected until March 2008).

In the time trend plots, trend lines are shown only for those wells exhibiting apparent trends. Also, for those wells with the highest COC concentrations, data values are plotted to facilitate review. Periodic variation attributable to seasonal influences is apparent in most wells, as expected. Concentrations of constituents in groundwater in the floodplain alluvium are affected by seasonal changes in climate, changes in river stage, 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 collection trenches.

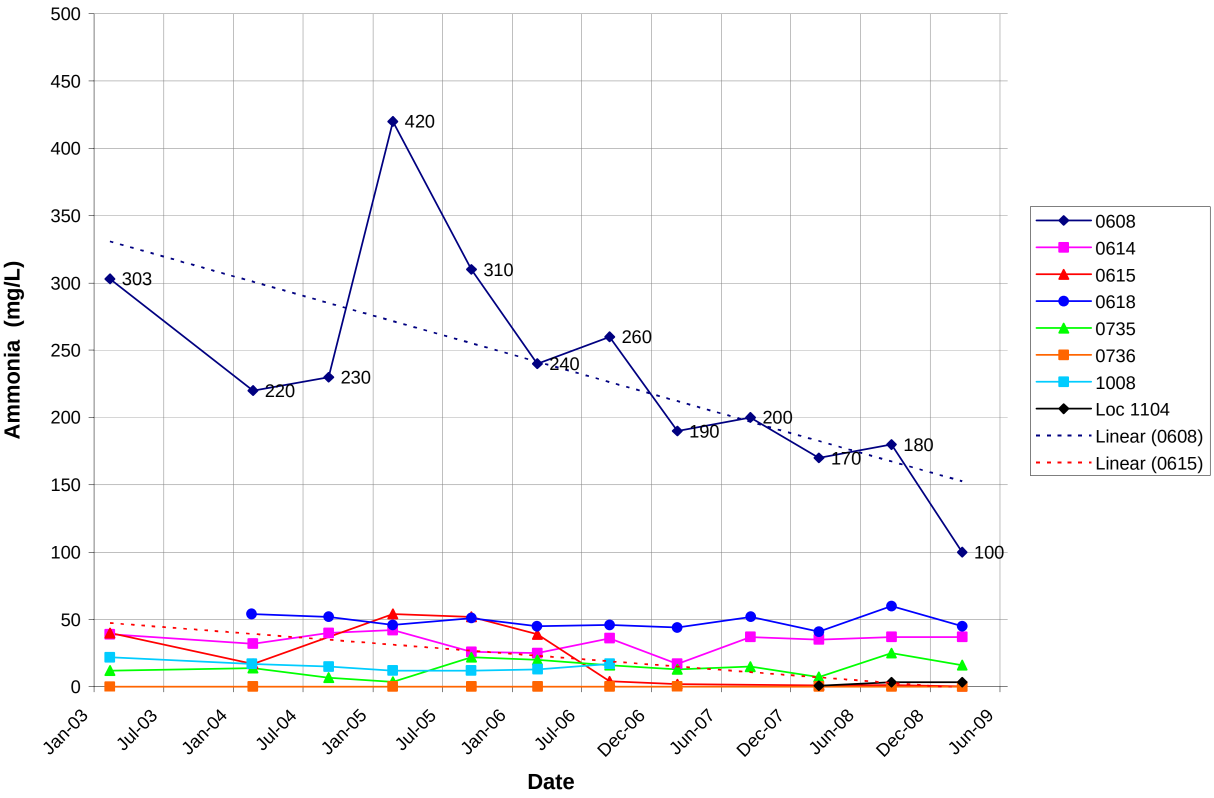

Figure 2–3. Floodplain Ammonia (Total as Nitrogen) Groundwater Concentrations Versus Time

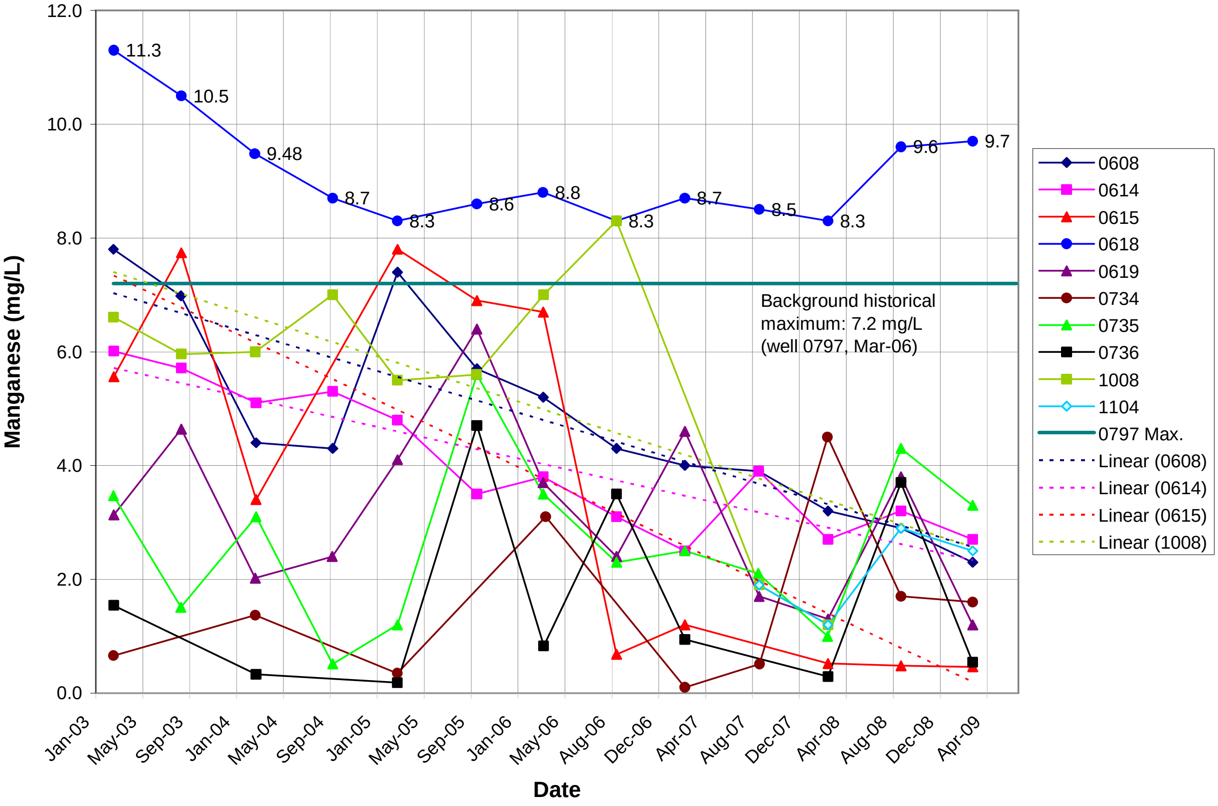

Figure 2–4. Floodplain Manganese Groundwater Concentrations Versus Time

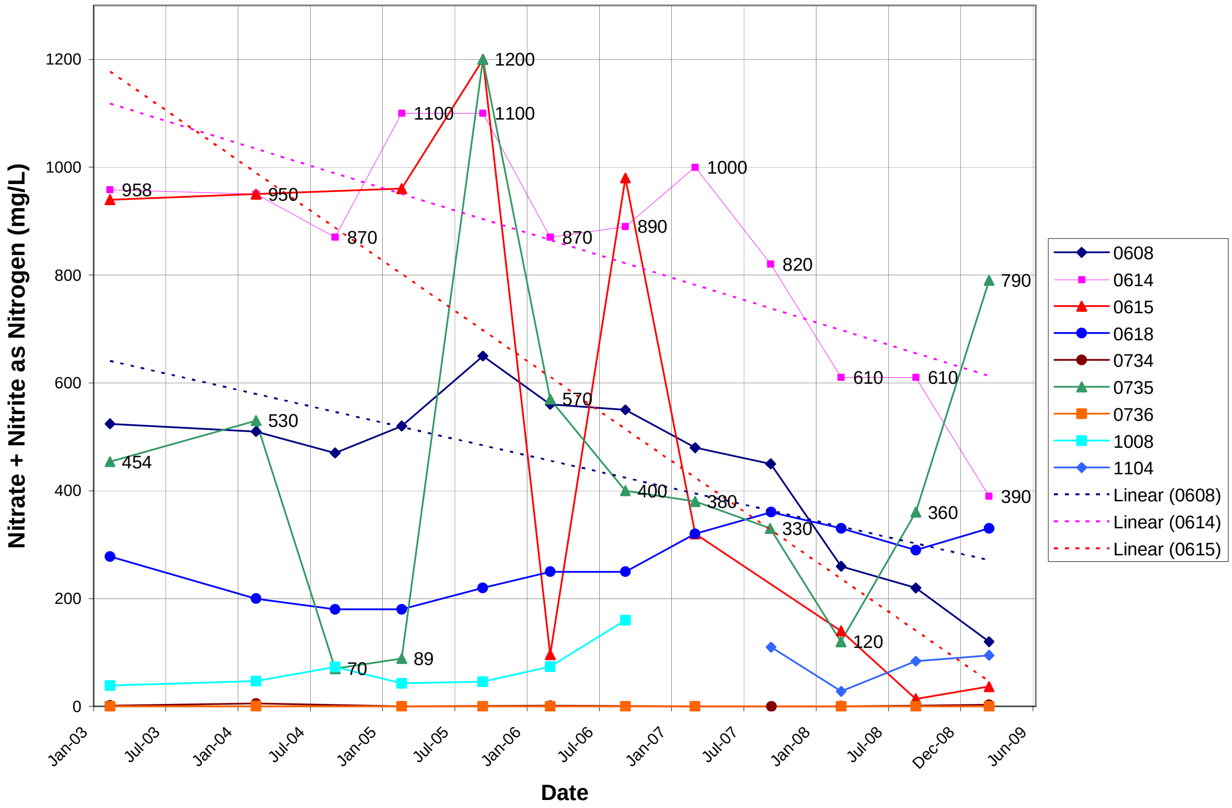

Figure 2–5. Floodplain Nitrate + Nitrite (as Nitrogen) Groundwater Concentrations Versus Time

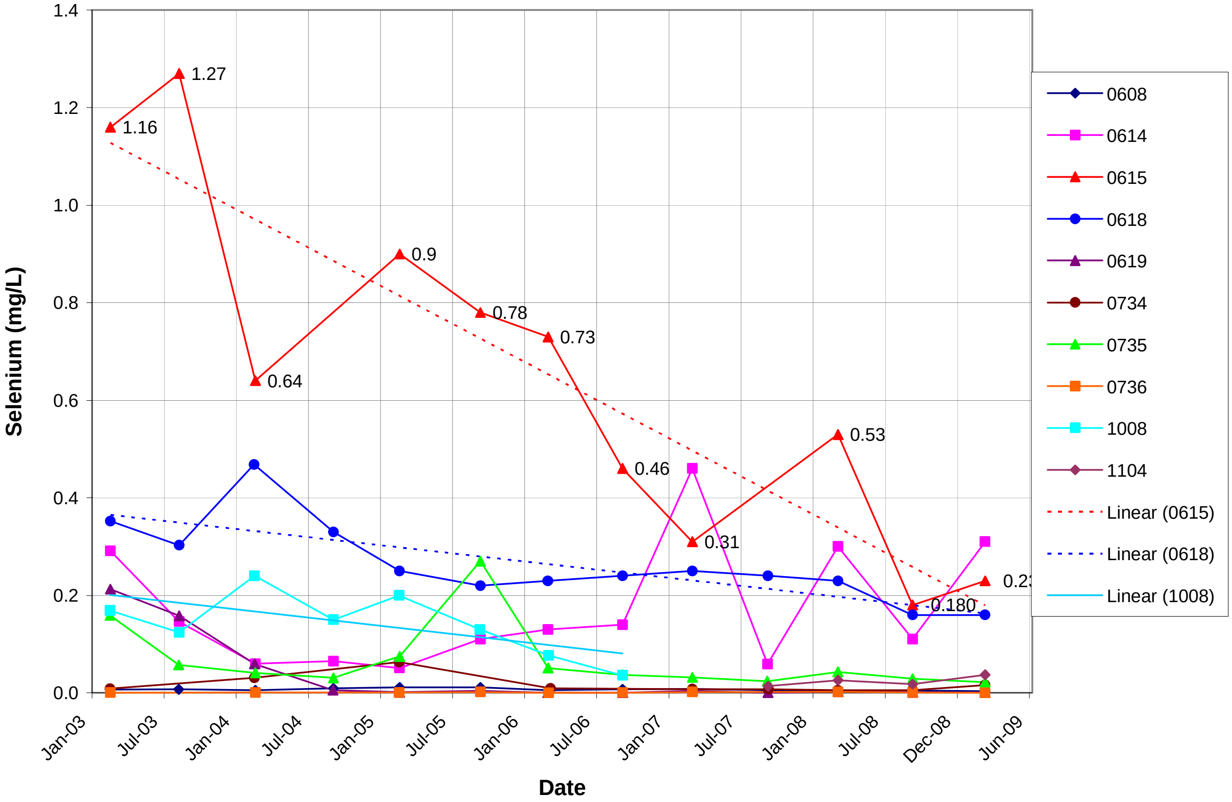

Figure 2–6. Floodplain Selenium Groundwater Concentrations Versus Time

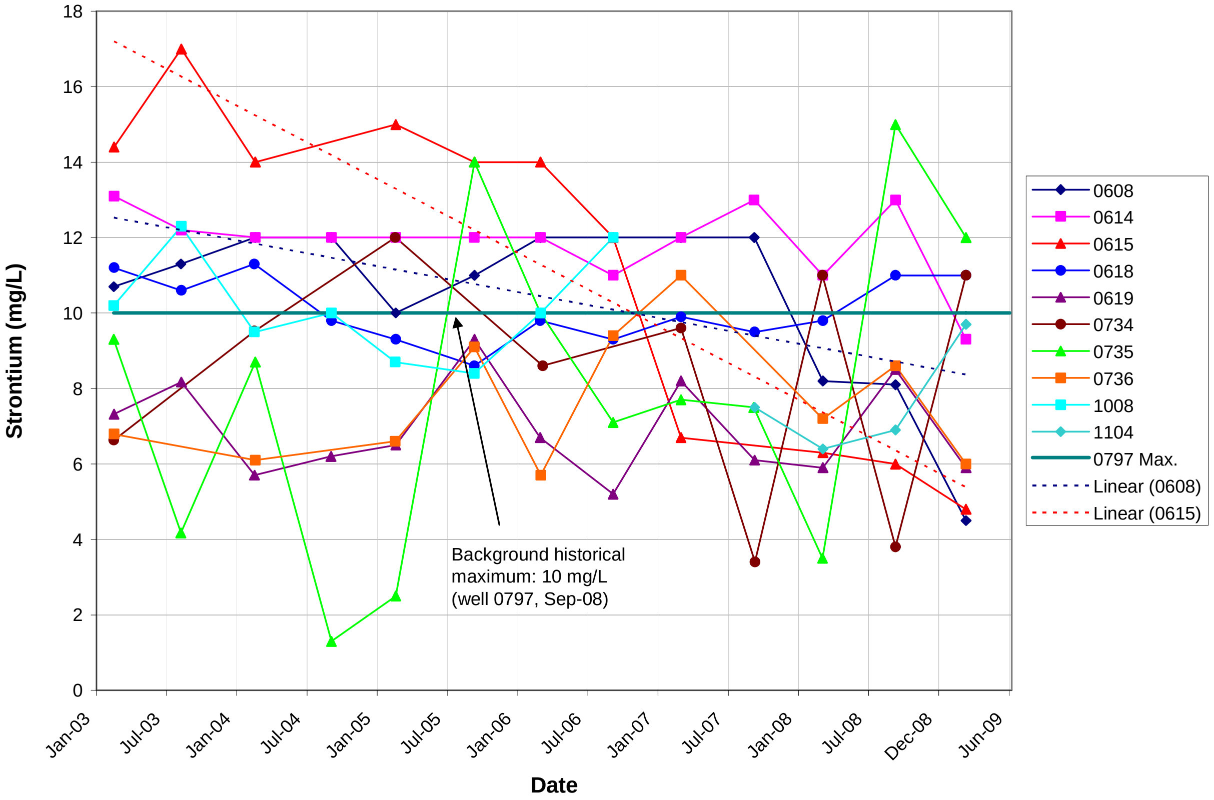

Figure 2–7. Floodplain Strontium Groundwater Concentrations Versus Time

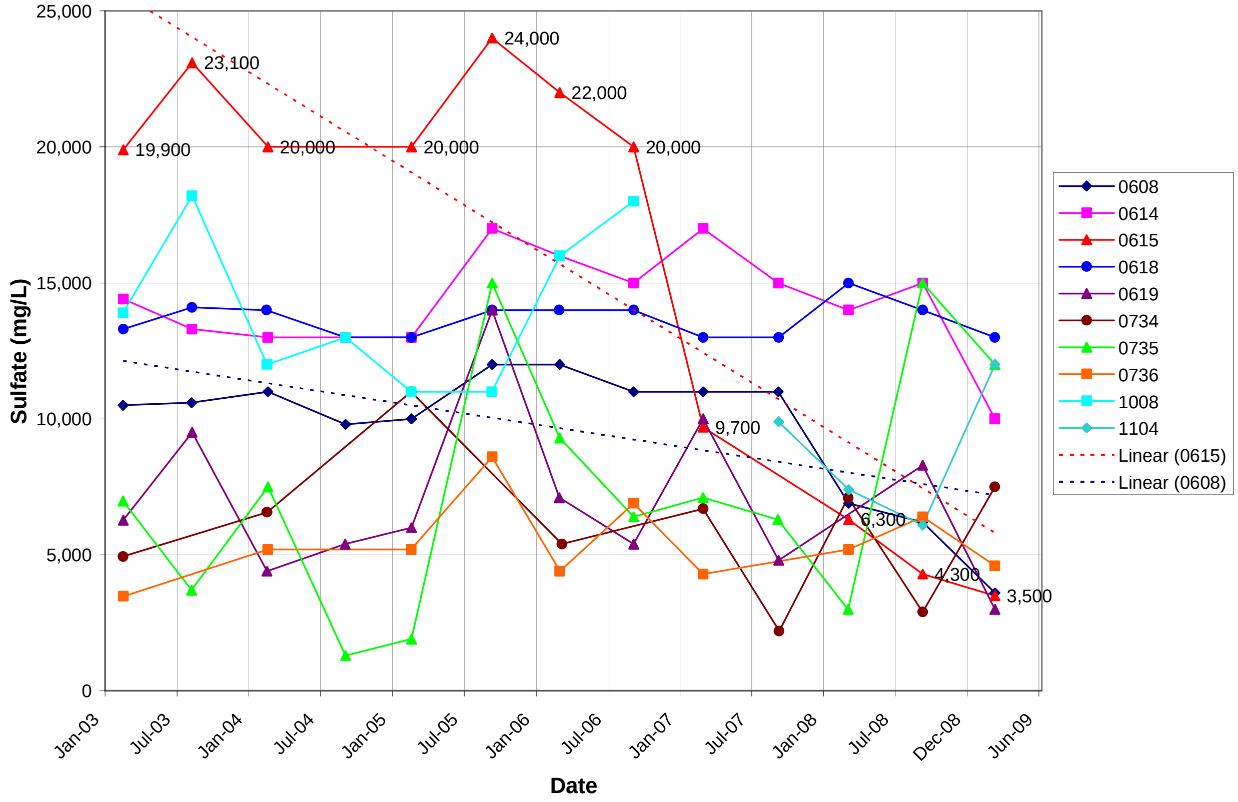

Figure 2–8. Floodplain Sulfate Groundwater Concentrations Versus Time

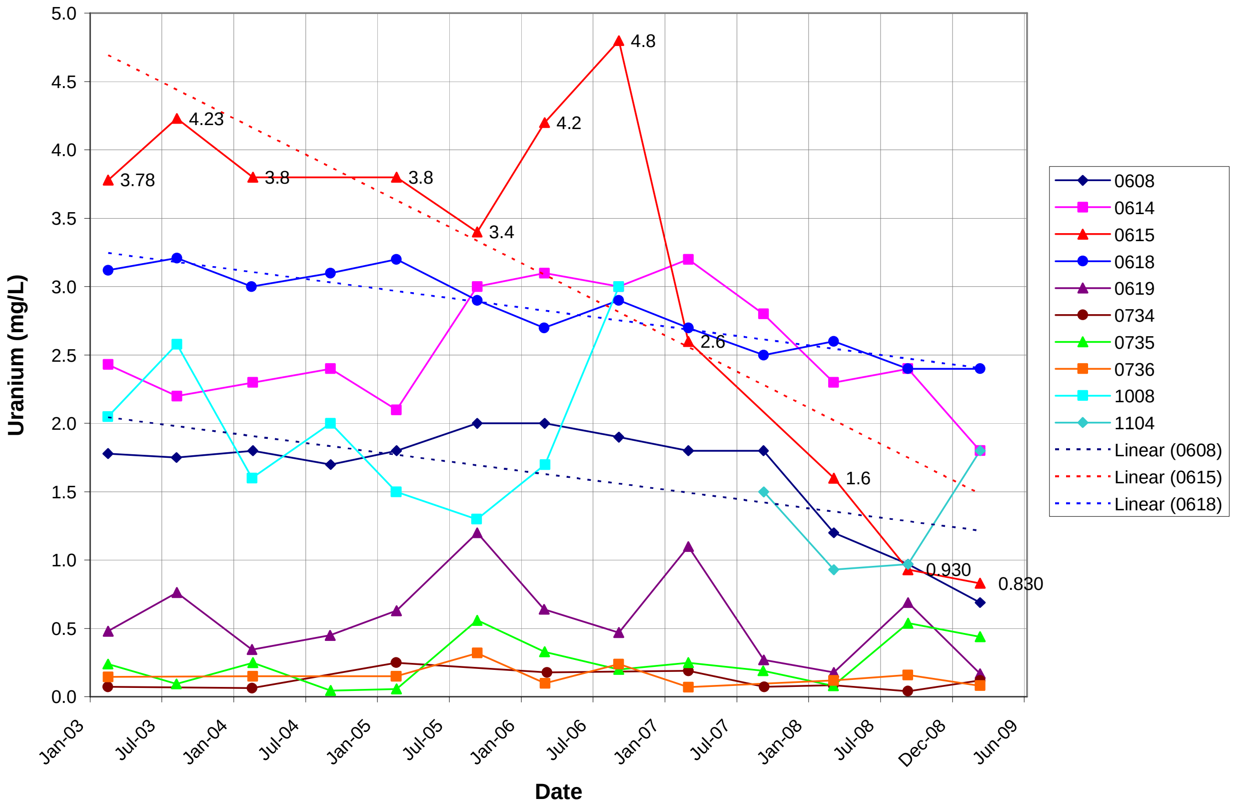

Figure 2–9. Floodplain Uranium Groundwater Concentrations Versus Time

Ammonia

With the exception of wells 0608 and 0615, ammonia concentrations in groundwater (in the subset of wells plotted) have not varied significantly over the past 6 years (Figure 2–3). However, ammonia concentrations in monitor well 0608, located adjacent to the disposal cell and completed in the Mancos Shale bedrock, continue to decrease—from 170 mg/L to 100 mg/L in the past year, compared with 303 mg/L in March 2003. Ammonia concentrations in well 0615, located in the Trench 1 area, have also decreased significantly—from a peak of 54 mg/L in March 2005 to 0.35 mg/L in March 2009. Floodplain-wide, ammonia concentrations ranged from 0.1 to 520 mg/L (Figure 1–3). Concentrations are highest in the western Trench 2 area (e.g., well 1116)—the marked concentration decrease in wells located between Trench 2 and the San Juan River is evidence of the effectiveness of the remediation system in this area. Lower, but still elevated ammonia levels occur in the central floodplain; no contamination is apparent in the northwest floodplain (Figure 1–3).

Manganese

Concentration trends for manganese, although decreasing for some wells, are not noteworthy. A decreasing trend—on the order of about 2 to 4 mg/L—is apparent in wells 0608, 0614, 0615, and 1008. With the exception of Trench 1 area well 0618, manganese levels in the subset of wells plotted in Figure 2–4 are below the maximum floodplain background concentration (7.2 mg/L). This is also the case floodplain-wide, where manganese concentrations range from 0.01 to 9.7 mg/L (well 0618; Figure 1–4, Figure 2–4), and the average concentration is 2.3 mg/L, well below the maximum background concentration.

Nitrate

As observed for ammonia, nitrate concentrations in well 0608 (completed in the Mancos near the escarpment) and Trench 1 area well 0615 have decreased notably since the baseline period—from 524 to 120 mg/L and from 940 to 37 mg/L, respectively (Figure 2–5). A similar decrease is apparent for well 0614, located between well 0608 and Trench 1 (decreased from 958 to 390 mg/L). Nitrate concentrations in well 0735, upgradient of the disposal cell, increased since the last reporting period—from 120 to 790 mg/L. Nitrate has fluctuated widely in this well historically; the cause for the recent increase is not known, nor are there any correlations with trends observed for other COCs.

Floodplain-wide, nitrate concentrations ranged from 0.01 mg/L in the northwest floodplain to 790 mg/L at well 0735. As shown in Figure 1–5 and Figure 1–12, the highest concentrations of nitrate occur in wells near the escarpment. As is the case for other parameters (e.g., uranium and sulfate), nitrate concentrations are generally lower in the northwest portion of the floodplain that is influenced by influx from the artesian well feeding Bob Lee Wash. The plume maps shown in Figure 1–12 demonstrate the reduction in nitrate concentrations in the central floodplain and Trench 2 area.

Selenium

In general, selenium concentrations in floodplain groundwater have not varied significantly over the past 6 years. (This conclusion is based primarily on data from the subset of wells plotted in Figure 2–6.) However, selenium concentrations in Trench 1 area well 0615 have decreased from a peak of 1.3 mg/L in August 2003 to 0.2 mg/L in September 2008 and March 2009. Decreases are also apparent in well 0618, located northeast of Trench 1, and, from 2003 through 2006, in well 1008 (which has since been replaced by well 1104). Floodplain-wide, selenium concentrations ranged from 0.0001 to 0.51 mg/L (Trench 1 well 1111), and the average concentration is 0.05 mg/L (equivalent to the EPA MCL; Table 1−1).

Strontium

Like manganese, concentration trends for strontium, although decreasing for some wells, are not noteworthy. A slight decreasing trend is apparent in wells 0608 and 0615. However, strontium levels in all wells plotted in Figure 2–7 are not significantly higher than the maximum floodplain background concentration (10 mg/L). This is also the case floodplain-wide, where strontium concentrations range from 0.7 to 12 mg/L (well 0735) in March 2009, and the average concentration is 6.9 mg/L (also see Figure 1–7).

Sulfate

As observed for all other COCs, sulfate concentrations in Trench 1 area well 0615 have decreased notably since the baseline period—from nearly 20,000 mg/L to 3,500 mg/L in March 2009 (Figure 2–8). Between March 2003 and September 2007, sulfate concentrations in well 0608, completed in the Mancos, were stable at about 10,000 mg/L (the Mancos Shale contains gypsum, which is a source of sulfate). However, sulfate concentrations in this well have since declined to 3,600 mg/L.

Sulfate concentration trends in remaining wells plotted in Figure 2–8 reflect seasonal variability but otherwise have been relatively stable. Alternatively, sulfate levels have been increasing in upgradient background well 0797, to a recent maximum of 5,200 mg/L (see Figure 2–10). Floodplain-wide, sulfate concentrations ranged from 120 to 14,000 mg/L in March 2009 (maximum in well 0768). (The maximum for this reporting period, 27,000 mg/L, was detected in well 0792 in September 2008.) Sulfate concentrations are generally highest between Trench 1 and well 1089; this area is also characterized by high variability (Figure 1–8).

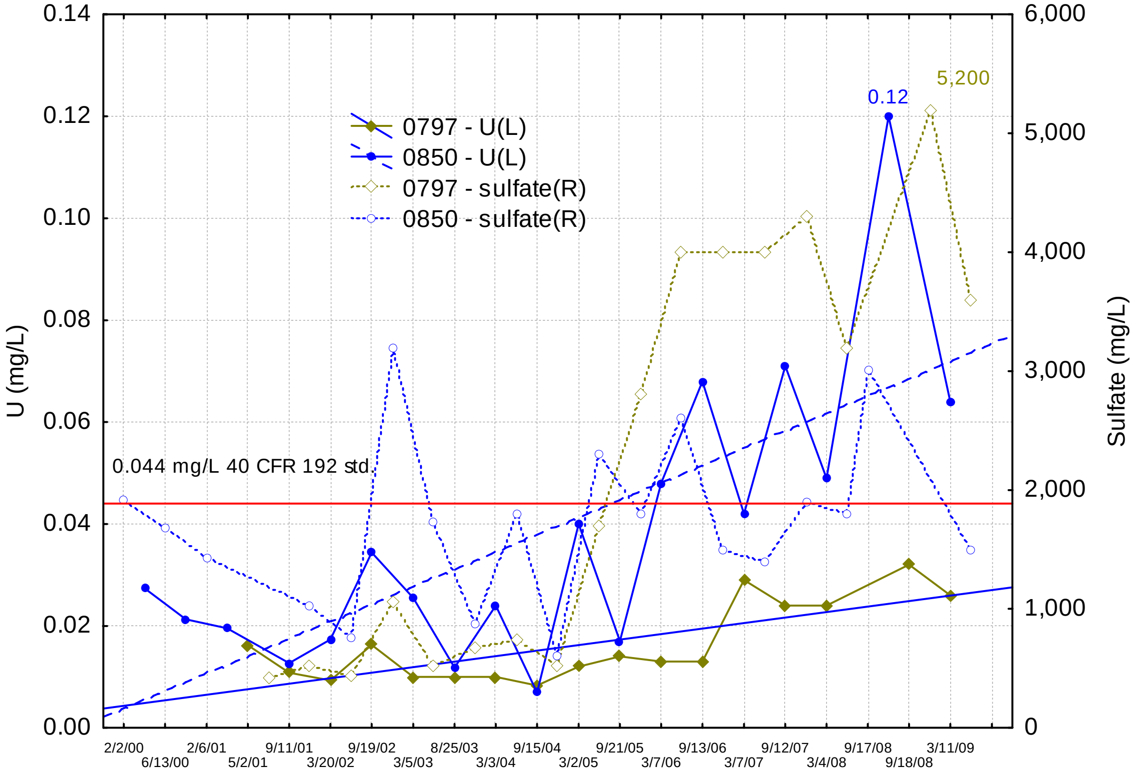

Figure 2–10. Time Trend Plots of Uranium and Sulfate in Floodplain Background Wells 0797 and 0850

Again, the water entering the northwest portion of the floodplain from artesian well 0648 has sulfate concentrations ranging between about 2,000 and 3,000 mg/L (the March 2009 measurement was 2,200 mg/L). As shown in Figure 1–8, sulfate concentrations in groundwater in the northwest portion of the floodplain are generally consistent with this artesian groundwater component.

Uranium

Concentration trends for uranium generally parallel those reported for sulfate. Again, the most marked decreases are seen in Trench 1 area well 0615—uranium concentrations decreased from 3.8 mg/L to 0.8 mg/L in March 2009 (Figure 2–9). Decreasing trends are also apparent in well 0618 (northeast of Trench 1) and Mancos well 0608. Uranium concentrations in remaining wells plotted in Figure 2–9 are variable and exhibit no apparent trend.

Floodplain-wide, uranium concentrations ranged from 0.005 to 2.4 mg/L in March 2009 (maximum in well 0618). Uranium concentrations are generally highest near the escarpment and between Trench 1 and well 1089 (Figure 1–9 and Figure 1–16). Also, as observed for sulfate and demonstrated in Figure 2–10, uranium concentrations have been increasing in upgradient background wells, in particular well 0850. In fact, uranium concentrations in well 0850 have been above the 0.044 mg/L UMTRCA standard since September 2007.

2.1.3 Floodplain Contaminant Removal

During the remediation system's first 6 years of operation at the Shiprock site, the extraction wells and trenches have removed approximately 860,000 pounds of contaminants from the alluvial groundwater system (see Section 3.2.3). The addition of two drainage trenches at the base of the escarpment in spring 2006 (Figure 1–1) has enhanced the amount of groundwater and mass of constituents removed from the alluvial system. It is also likely that pumping of groundwater from the floodplain is preventing contaminant discharge to the San Juan River, as concentrations of nitrate and uranium in river samples (location 0940) have remained below the upgradient background benchmark values (statistically derived), including during low-flow periods, since 2004 (Figure 2–11 and Figure 2–12).

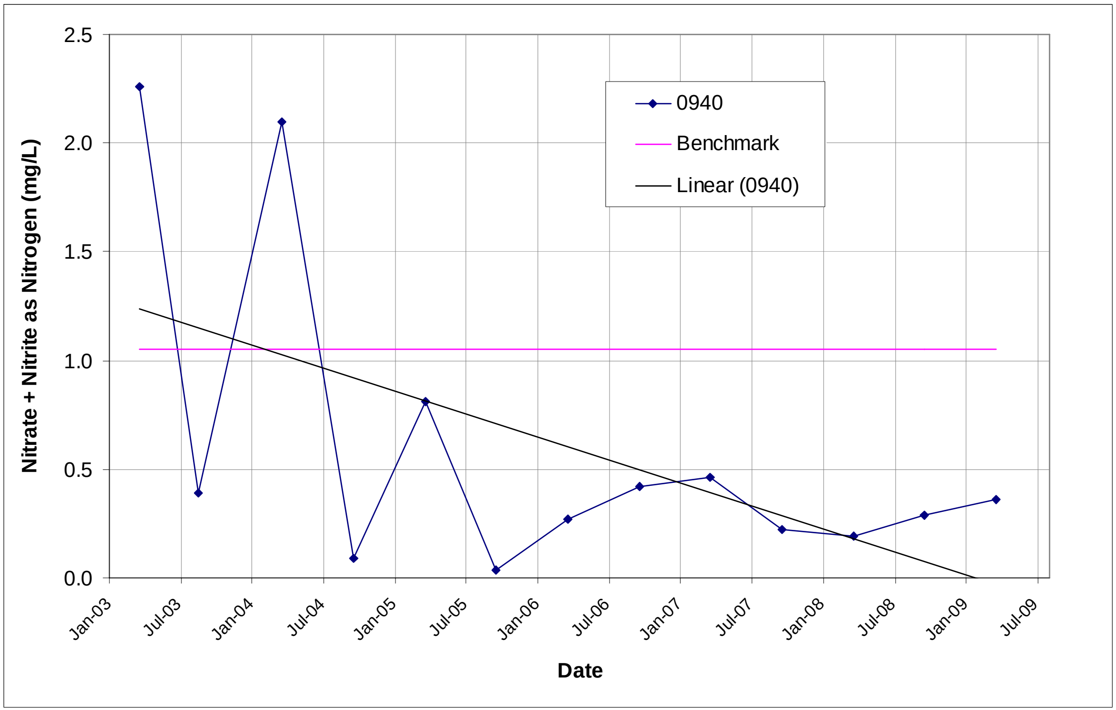

Figure 2–11. Nitrate + Nitrite (as Nitrogen) Concentrations in the San Juan River

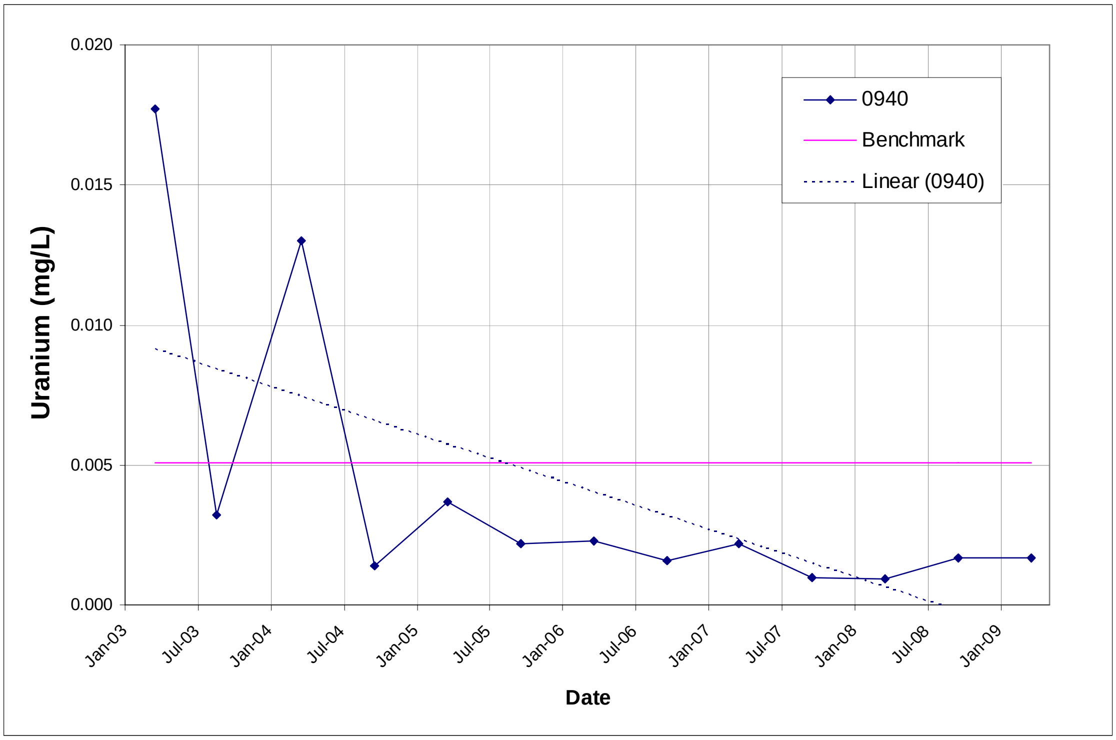

Figure 2–12. Uranium Concentrations in the San Juan River

2.2 Terrace System Subsurface Conditions

The discussion of current subsurface conditions on the terrace is based on collection and analysis of groundwater level data through March 2009. 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.

Currently, there are no concentration-driven performance standards for the terrace system because the compliance strategy is active remediation (hydrologic control) to eliminate exposure pathways at escarpment seeps and at Bob Lee and Many Devils Washes. 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.

2.2.1 Terrace Groundwater Level Trends

Groundwater level data from the terrace collected during the March 2009 sampling event were compared to baseline groundwater elevation data from March 2003 reported 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. This figure demonstrates that groundwater elevations have declined across the entire terrace groundwater system. The only groundwater level increases are in wells MW1 and 0830, both completed in the Mancos shale.

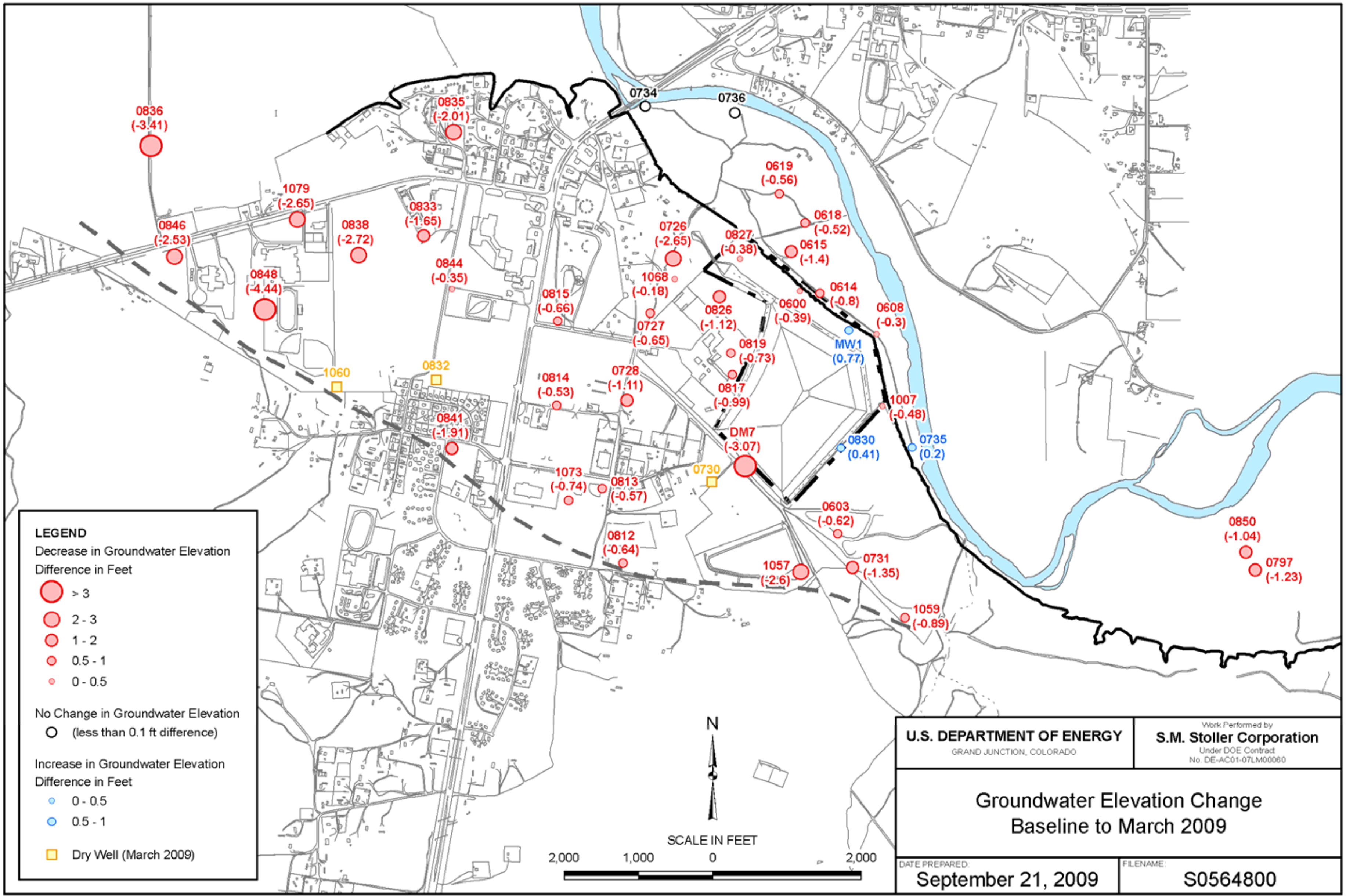

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Figure 2–13. Terrace Groundwater Elevation Changes from Baseline (March 2003) to Current (March 2009) Conditions

For wells completed in the alluvium (Qal or Qal/Km), of the 23 groundwater level measurements taken in September 2008 or March 2009, all show declines relative to the baseline period of March 2003. Declines ranged from 0.18 ft to a maximum decrease of 4.44 ft in well 0848, located in the west terrace; the average decrease was 1.4 ft. In the previous annual report (DOE 2008), a groundwater level decline of 4.7 ft was reported for well 0730, located southwest of the disposal cell. However, this well was dry at the time of the March 2009 sampling event.

As discussed in greater detail in the following section, as of March 2009, the cumulative volume of water removed from the terrace extraction system since pumping began was approximately 20,246,000 gallons. Pumping records indicate that approximately 2,460,000 gallons were removed between April 2008 and March 2009. In 2009, the water levels in each of these wells had declined both relative to baseline conditions and, at some wells, relative to water level measurements made in 2008. Thus, it can generally be concluded that the extraction well field is resulting in the desired effect on groundwater levels in 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 selected terrace wells are shown in Figure 2−14 and Figure 2–15 for wells screened in more shallow (water level elevations greater than 4,930 ft) and deeper zones, respectively. Linear trend lines shown in Figure 2–14 indicate decrease in water levels during the time of observation in most of the wells, although not of the magnitude reflected in Figure 2−13 (based on manual measurements). However, with the exception of well 0836, plots of groundwater elevation data for wells screened in deeper zones show little decrease.

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. Between April 2008 and March 2009, the average pumping rate from Bob Lee Wash was 2.1 gpm, about equal to the rate reported last year.

The average pumping rate from Many Devils Wash during the performance period was 0.31 gpm, less than half the rate reported last year (0.71 gpm). However, the decrease at Many Devils Wash is probably largely attributable to the declining effectiveness of the collection drain (rather than being a function of declining groundwater levels). Because of this declining effectiveness, and to better capture contaminated surface water in the wash, DOE installed a diversion structure in August 2009, after which the flow rate of water from the sump increased from about 0.4 gpm to 0.8 gpm.

In response to stakeholder concerns that large storm events could generate runoff from Many Devils Wash resulting in contaminant loading to the San Juan River, DOE installed an automated sampling system in the lower end of the wash in May 2009. The automated sampler, monitored via telemetry, is designed to begin collecting samples with any increase in flow resulting in a surface water elevation increase of 2 inches, and it will collect additional samples for each subsequent 2-inch increase in surface water elevation.

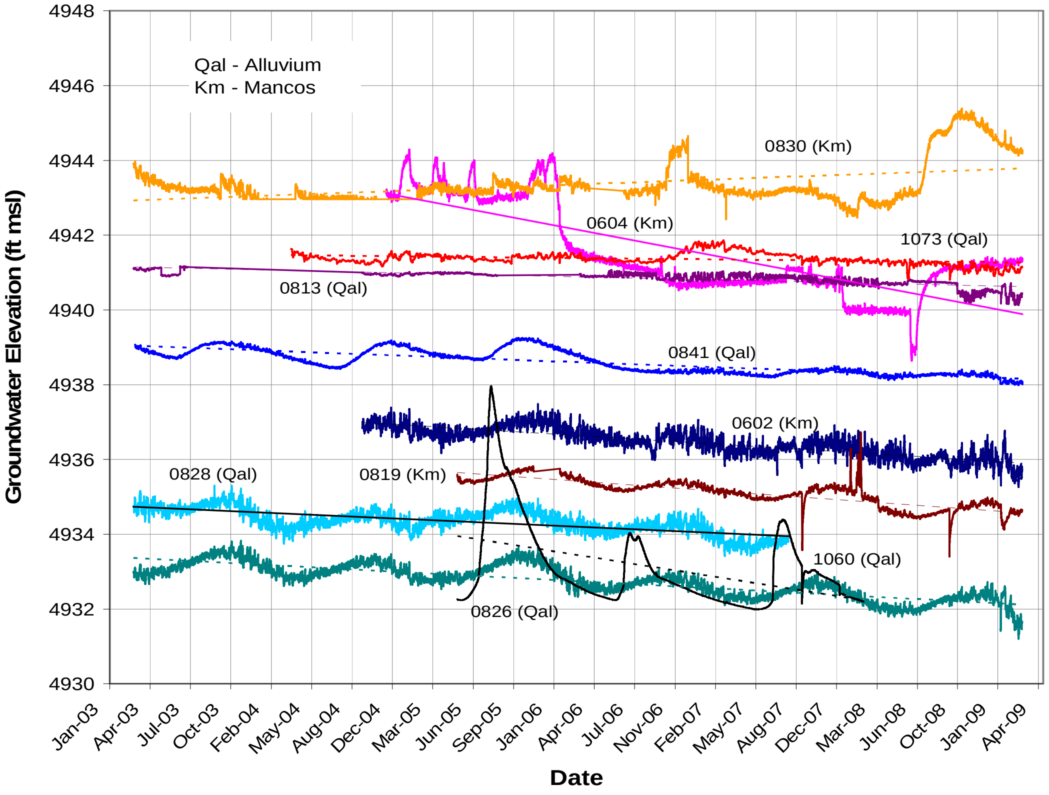


Figure 2–14. Terrace Datalogger Measurements, Wells with Water Elevations above 4,930 ft

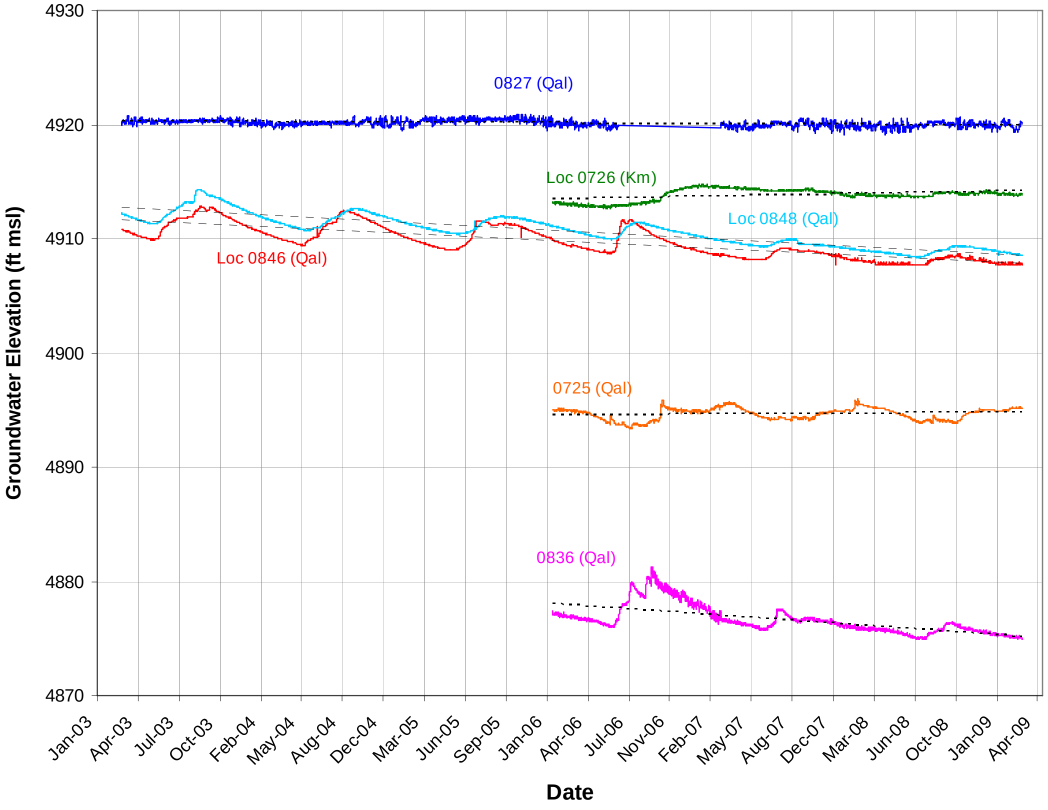


Figure 2–15. Terrace Datalogger Measurements, Deeper Wells

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 floodplain remediation system consists of the three major components shown in Figure 1–1: two extraction wells (wells 1089 and 1104); two drainage trenches (horizontal wells), Trench 1 and Trench 2; and a sump (or seep collection drain) used to collect discharges from seeps 0425 and 0426 on the escarpment wall.

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 well 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 2009, are shown in Figure 3−1 and Figure 3–2. From April 2008 to March 2009, approximately 3,195,300 gallons of water were removed from well 1089 at an average pumping rate of 6.1 gpm, and approximately 848,100 gallons of water were removed from well 1104 at an average pumping rate of 1.6 gpm. During the 6-year period since the start of operations in March 2003 through the end of March 2009, a total of approximately 16,700,000 gallons of water have been removed from well 1089 and about 3,100,000 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 2009, are shown in Figure 3–3 and Figure 3–4. From April 2008 to March 2009, approximately 4,856,000 gallons of water were removed from Trench 1 at an average pumping rate of 9.2 gpm, approximately 3 times the volume and rate reported last year (1,440,000 gallons at an average rate of 2.7 gpm) (DOE 2008). Approximately 8,485,000 gallons of water were removed from Trench 2 at an average pumping rate of 16.1 gpm (similar to last year’s performance).

3.1.3 Floodplain Seep Sump Performance

Rates of groundwater discharge at seeps 0425 and 0426 continue to decrease 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.

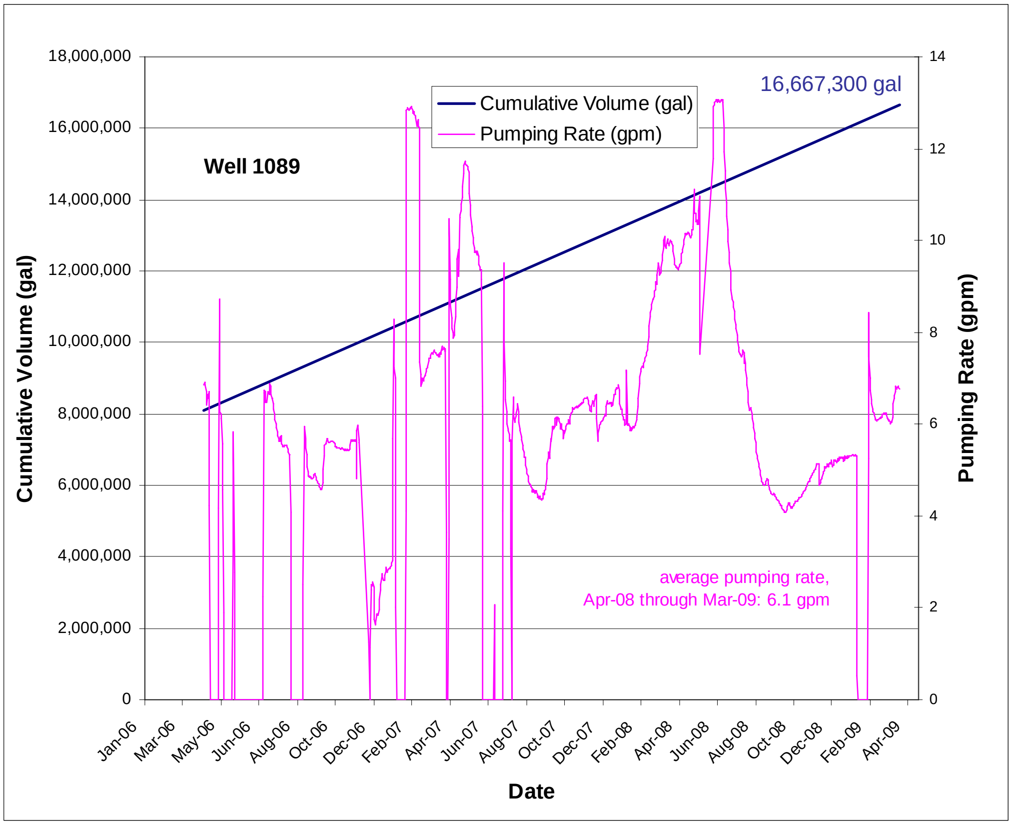


Figure 3–1. Floodplain Well 1089 Pumping Rate and Cumulative Groundwater Volume Extracted

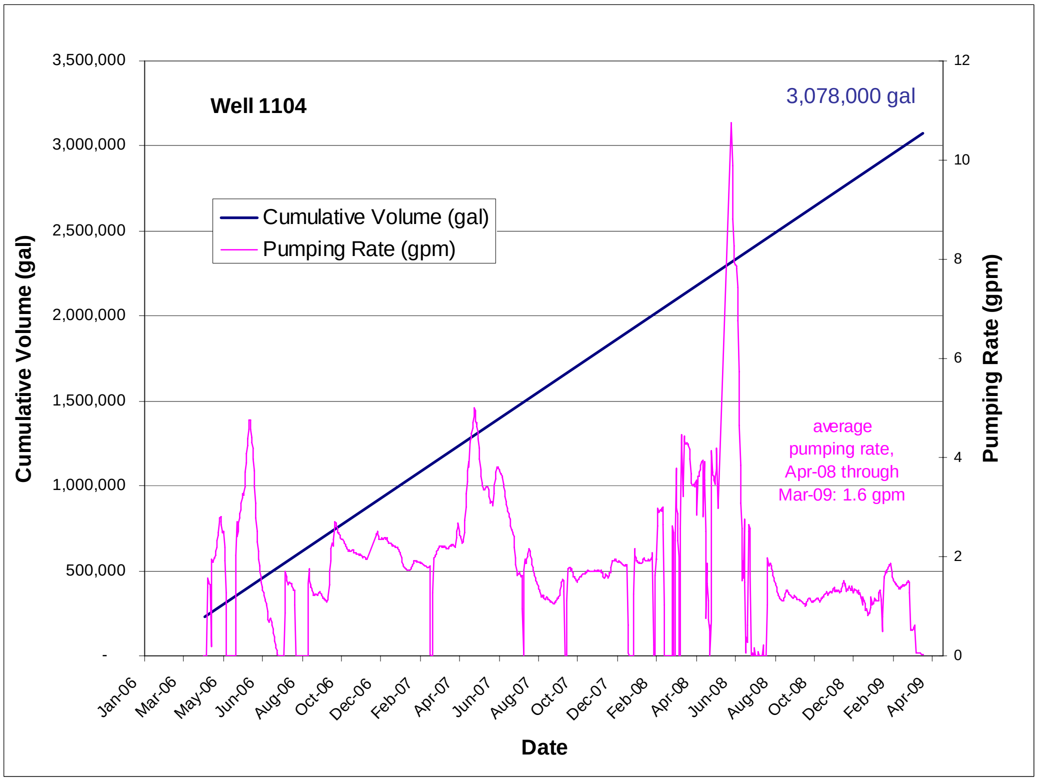


Figure 3–2. Floodplain Well 1104 Pumping Rate and Cumulative Groundwater Volume Extracted

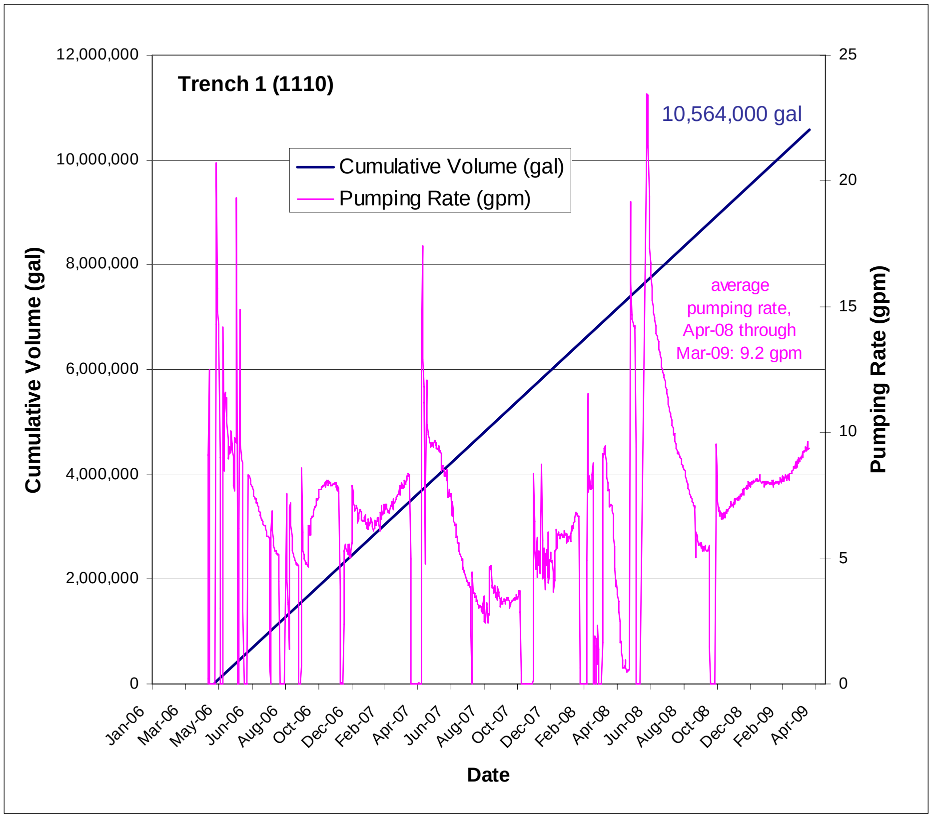


Figure 3–3. Floodplain Trench 1 Pumping Rate and Cumulative Groundwater Volume Extracted

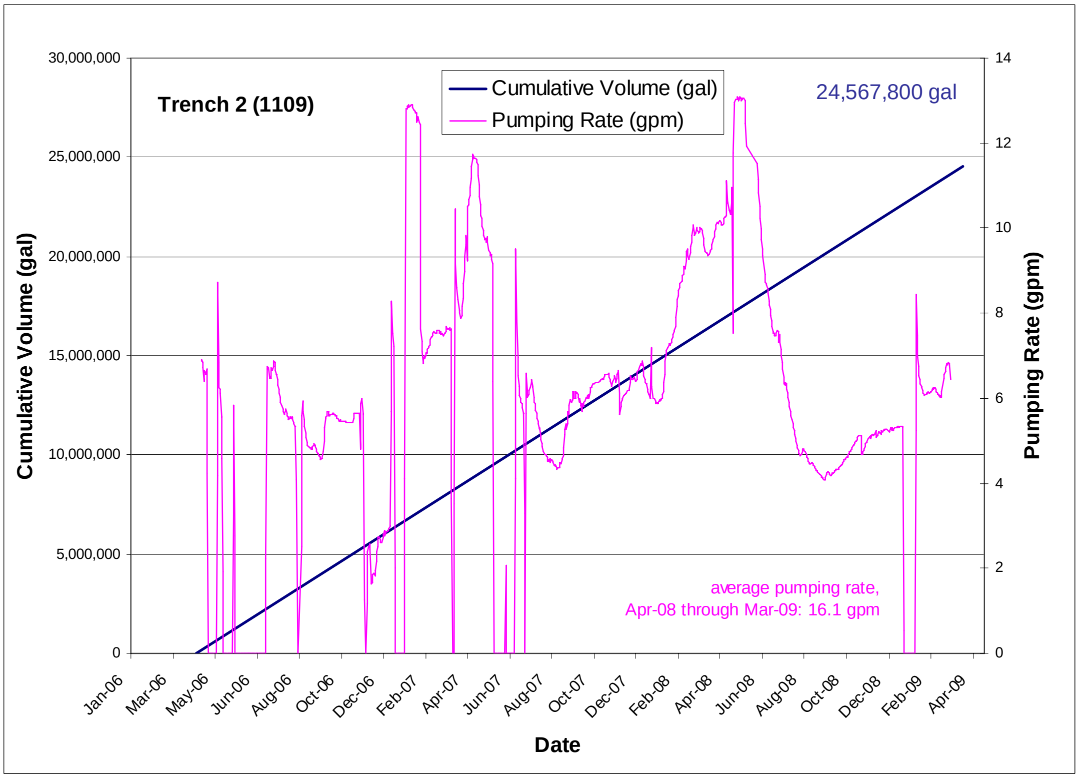


Figure 3–4. Floodplain Trench 2 Pumping Rate and Cumulative Groundwater Volume Extracted

From April 2008 to March 2009, the average discharge rate from the seep sump was 0.34 gpm (less than half the rate reported for 2007–2008, 0.87 gpm). Approximately 177,600 gallons were pumped from the floodplain seeps during this period, yielding a total cumulative volume of approximately 999,000 gallons.

3.2 Terrace Remediation System

The objective of the terrace remediation system is to remove groundwater from the southern portion of the terrace area so that potential 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. The terrace remediation system consists of four major components shown in Figure 1–1: the extraction wells, the evaporation pond, the terrace drains (Bob Lee Wash and Many Devils Wash), and the terrace outfall drainage channel diversion. DOE also continues to evaluate the feasibility of phytoremediation on the terrace, using deep-rooted plants to enhance evapotranspiration in the radon barrier borrow pit area south of the disposal cell, and also between the disposal cell and the escarpment above the San Juan River floodplain. The four irrigated phytoremediation test plots, established in 2006 and measuring 15 meters by 15 meters, are shown on Figure 1–1. The goal of phytoremediation in these areas is hydraulic control, to limit the spread of contaminants in groundwater.

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 2009 are presented in Figure 3–5 through Figure 3–13.

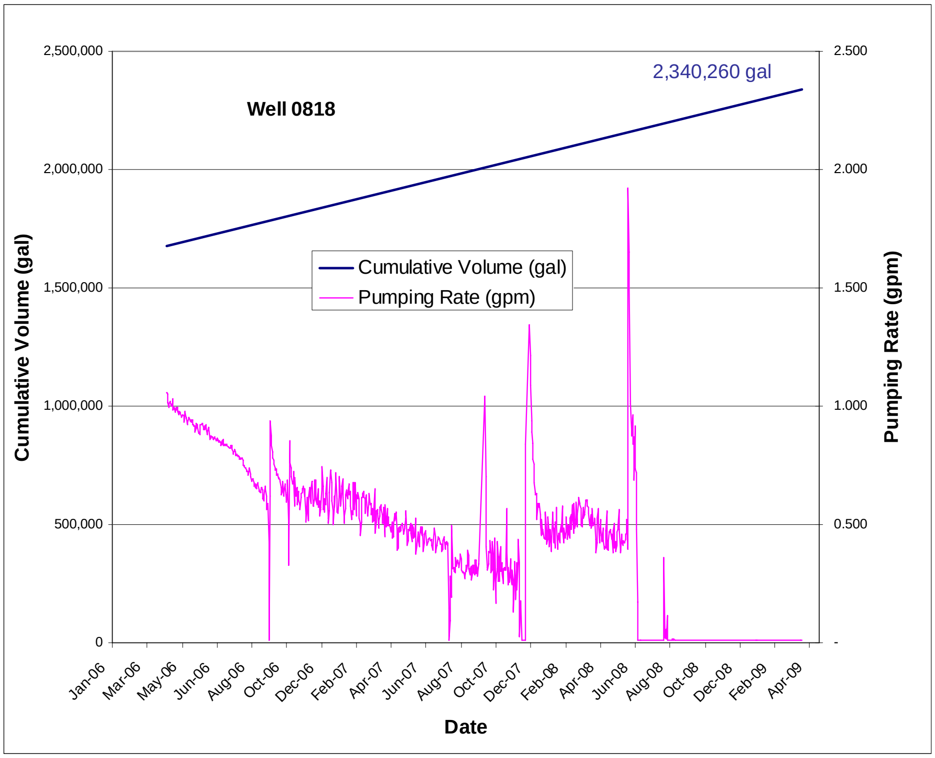


Figure 3–5. Terrace Well 0818 Pumping Rate and Cumulative Groundwater Volume Extracted

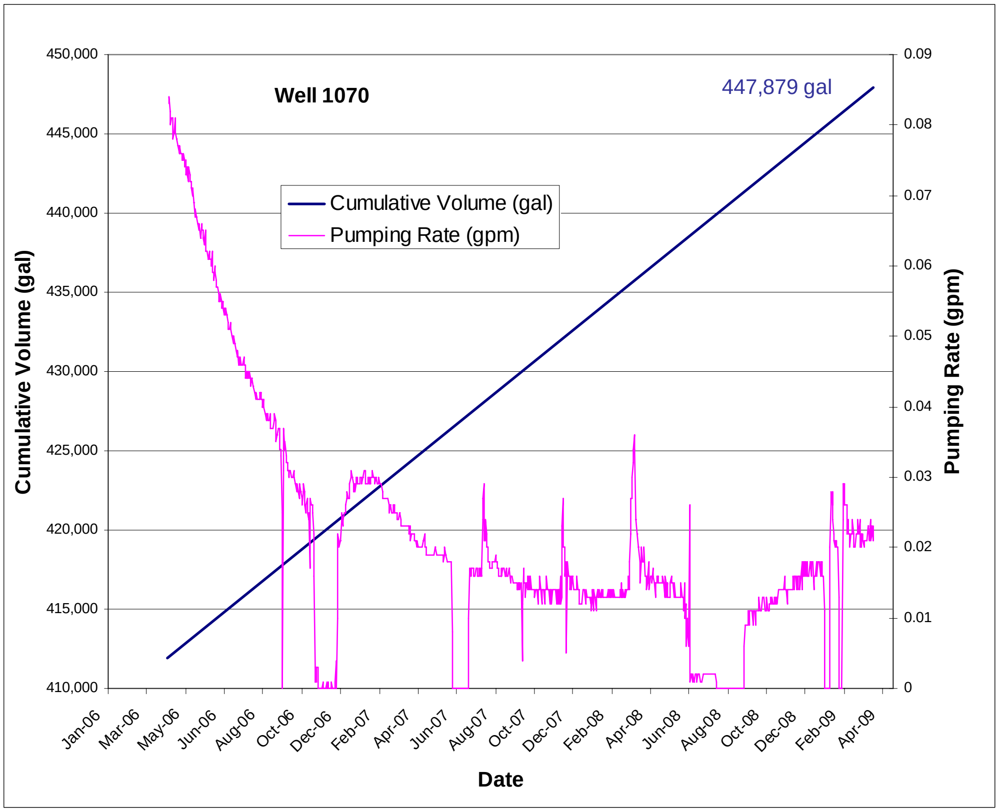


Figure 3–6. Terrace Well 1070 Pumping Rate and Cumulative Groundwater Volume Extracted

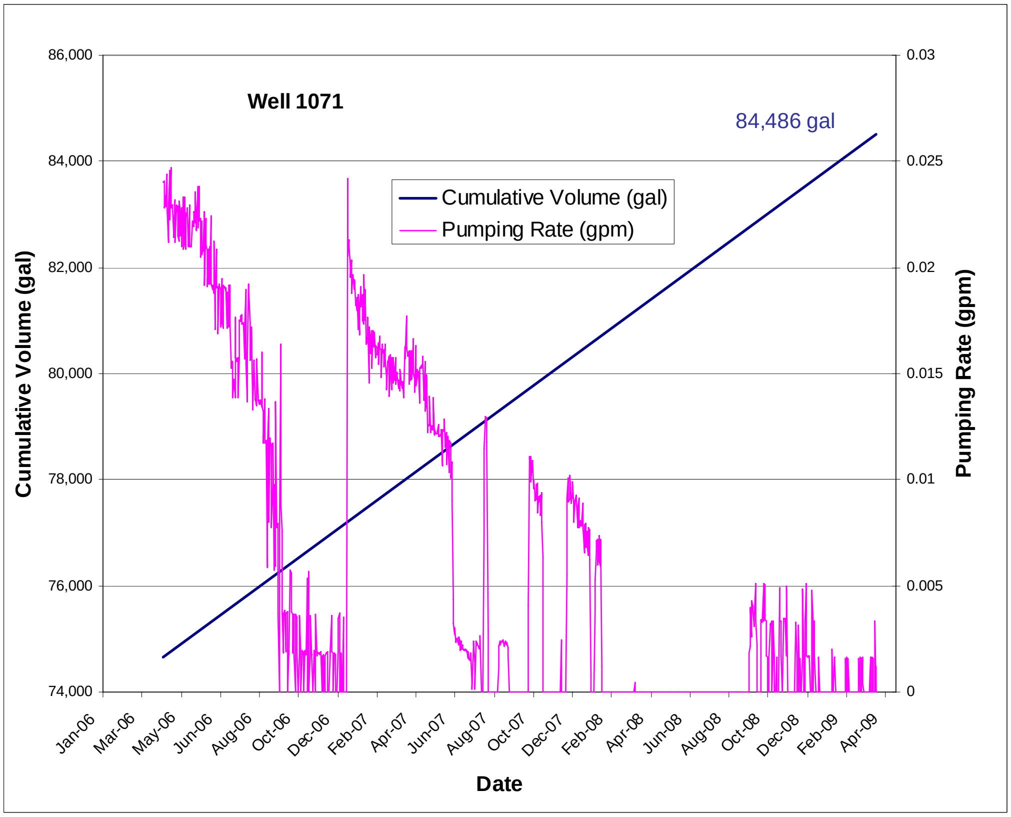


Figure 3–7. Terrace Well 1071 Pumping Rate and Cumulative Groundwater Volume Extracted

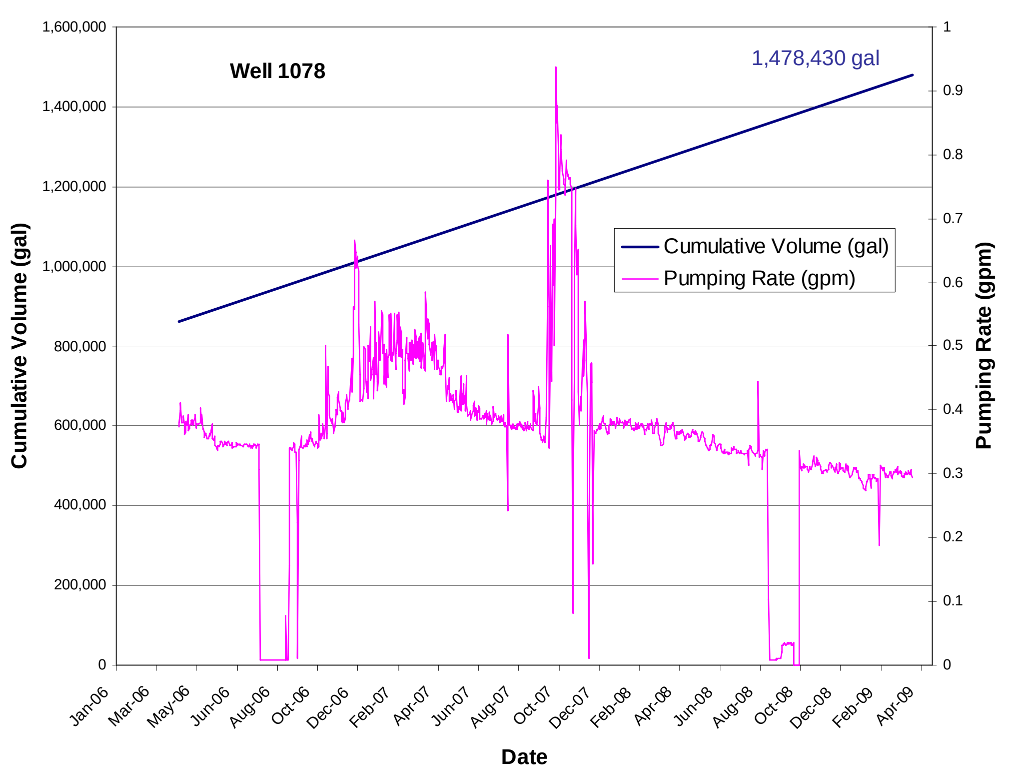


Figure 3–8. Terrace Well 1078 Pumping Rate and Cumulative Groundwater Volume Extracted

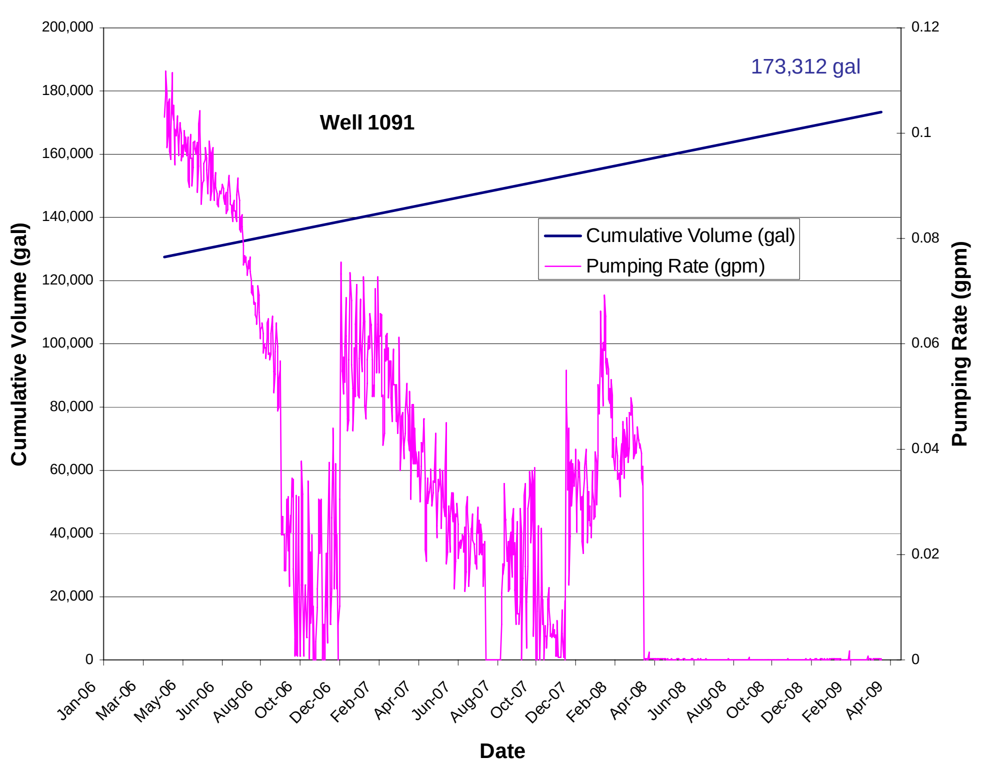


Figure 3–9. Terrace Well 1091 Pumping Rate and Cumulative Groundwater Volume Extracted

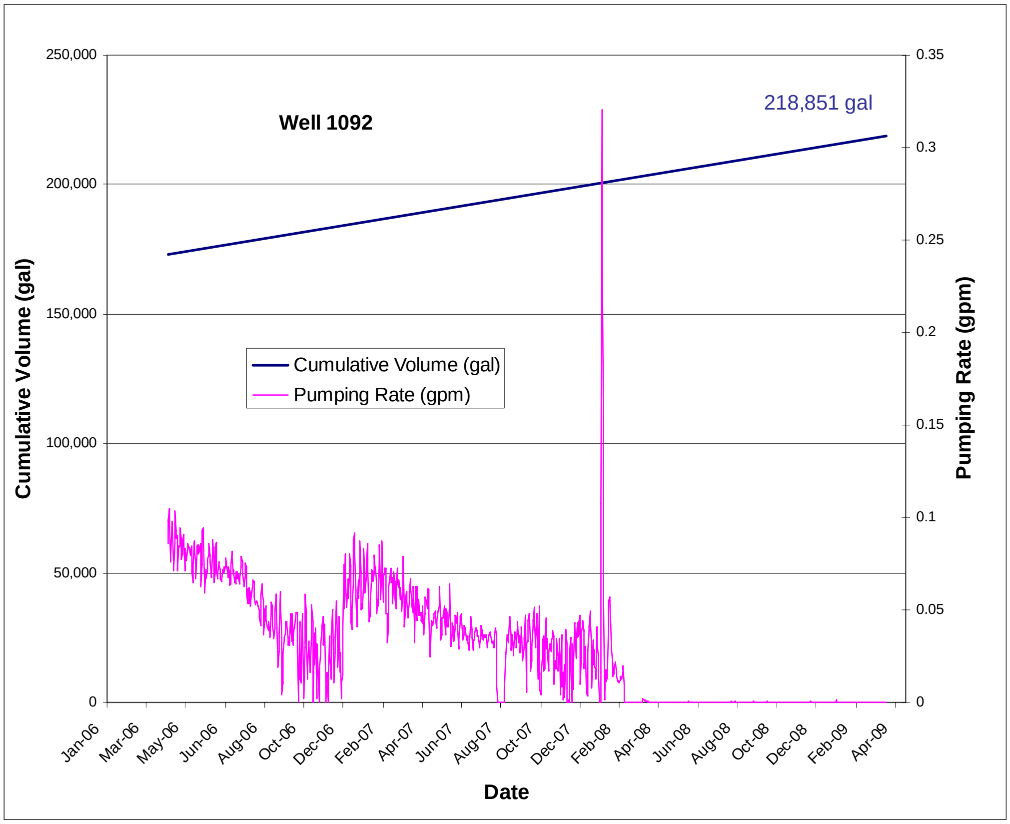


Figure 3–10. Terrace Well 1092 Pumping Rate and Cumulative Groundwater Volume Extracted

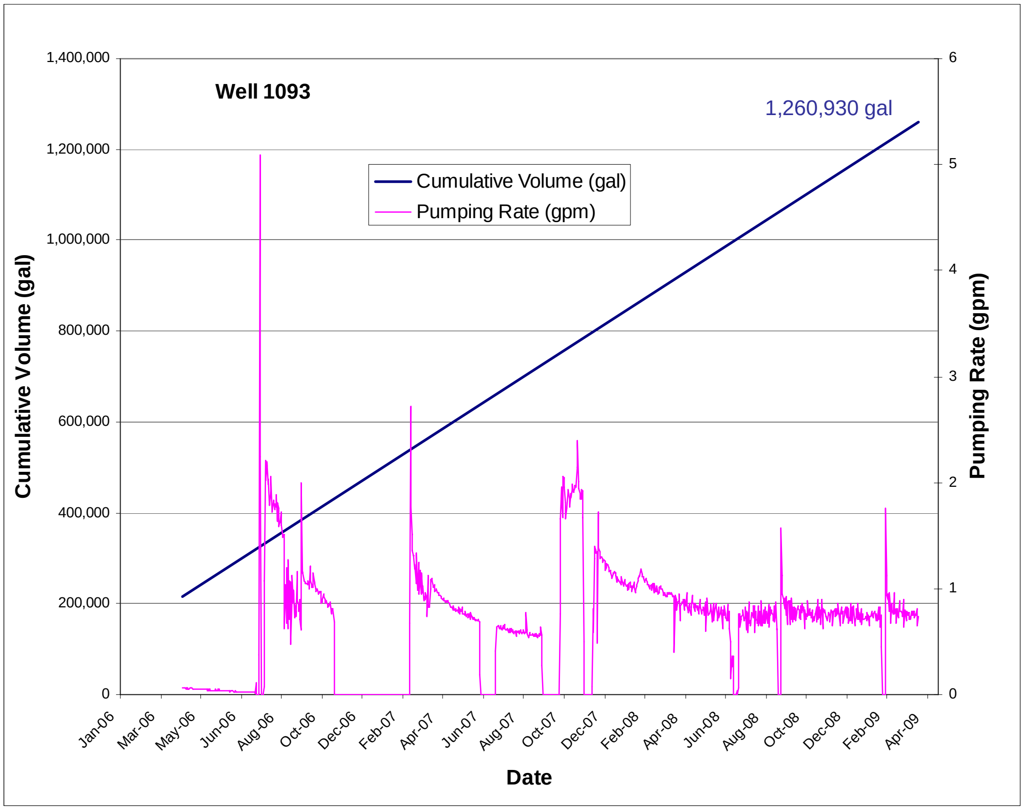


Figure 3–11. Terrace Well 1093 Pumping Rate and Cumulative Groundwater Volume Extracted

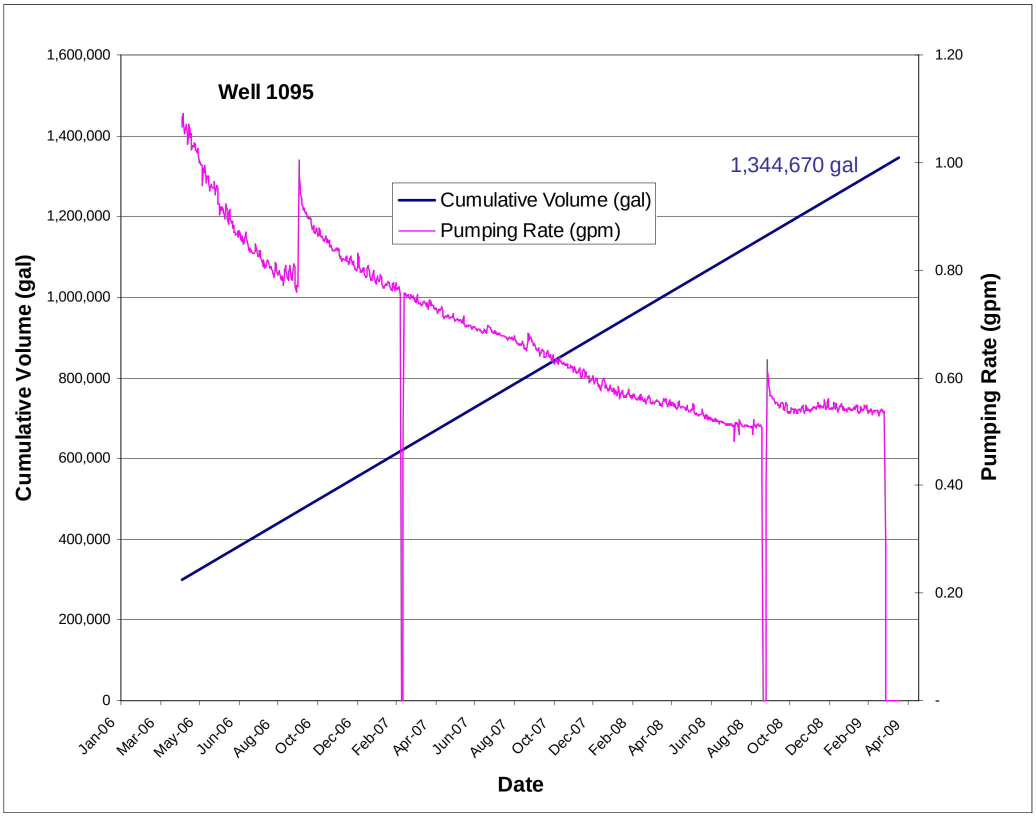


Figure 3–12. Terrace Well 1095 Pumping Rate and Cumulative Groundwater Volume Extracted

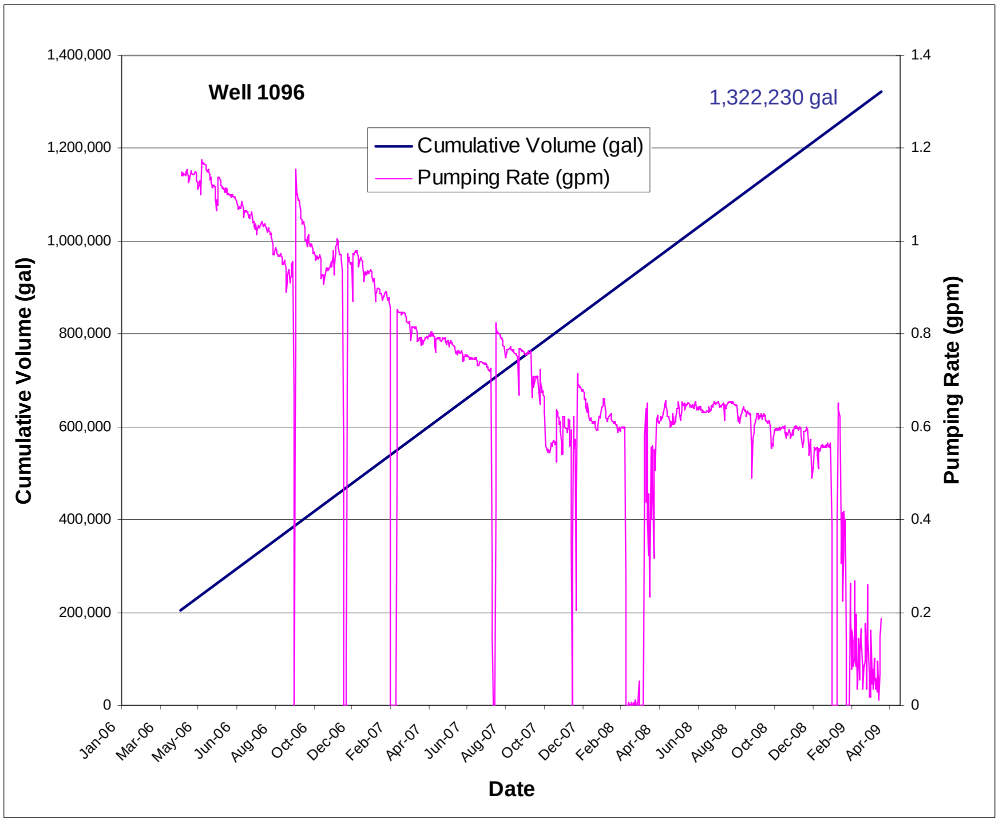


Figure 3–13. Terrace Well 1096 Pumping Rate and Cumulative Groundwater Volume Extracted

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 0.00002 gpm (well 1092) to 0.75 gpm (well 1093), and the total groundwater volume removed from each well during this period ranged from only 12 gallons (well 1092) to approximately 397,000 gallons (well 1093). (In the last several years, wells 1070, 1071, 1091, and 1092 have been low producers relative to the other extraction wells.) The cumulative total volume removed during the current period was approximately 26 percent less than during the previous reporting period. This decrease is expected to continue 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, 2007, through March 31, 2008)**		**Current Period (April 1, 2008, through March 31, 2009)**	
	Average Pumping Rate (gpm)	**Total Groundwater Volume Removed (gallons)**	**Average Pumping Rate (gpm)**	**Total Groundwater Volume Removed (gallons)**
0818	0.41	218,088	0.13	67,413
1070	0.015	8,125	0.012	6,307
1071	0.005	2,702	0.0006	287
1078	0.43	209,963	0.28	148,730
1091	0.027	14,093	0.0004	189
1092	0.031	16,502	0.00002	12
1093	0.83	433,945	0.75	396,577
1095	0.65	339,435	0.5	260,910
1096	0.59	311,345	0.5	266,560
Total	2.99	1,554,198	2.2	1,146,985

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 plotted in Figure 3–14. During the current performance period, the average pumping rate from Bob Lee Wash was 2.2 gpm, and the groundwater interceptor drain removed approximately 1,151,000 gallons of water.

The pumping rates and volume of water removed from the groundwater interceptor drain in Many Devils Wash (location 1088) are plotted in Figure 3–15. During the current performance period, the average pumping rate from Many Devils Wash was 0.31 gpm, and the groundwater interceptor drain removed approximately 164,100 gallons of water. As discussed in the previous section, because of increasing flows, possibly due to a decreased effectiveness of the drain, DOE installed a diversion structure in August 2009.

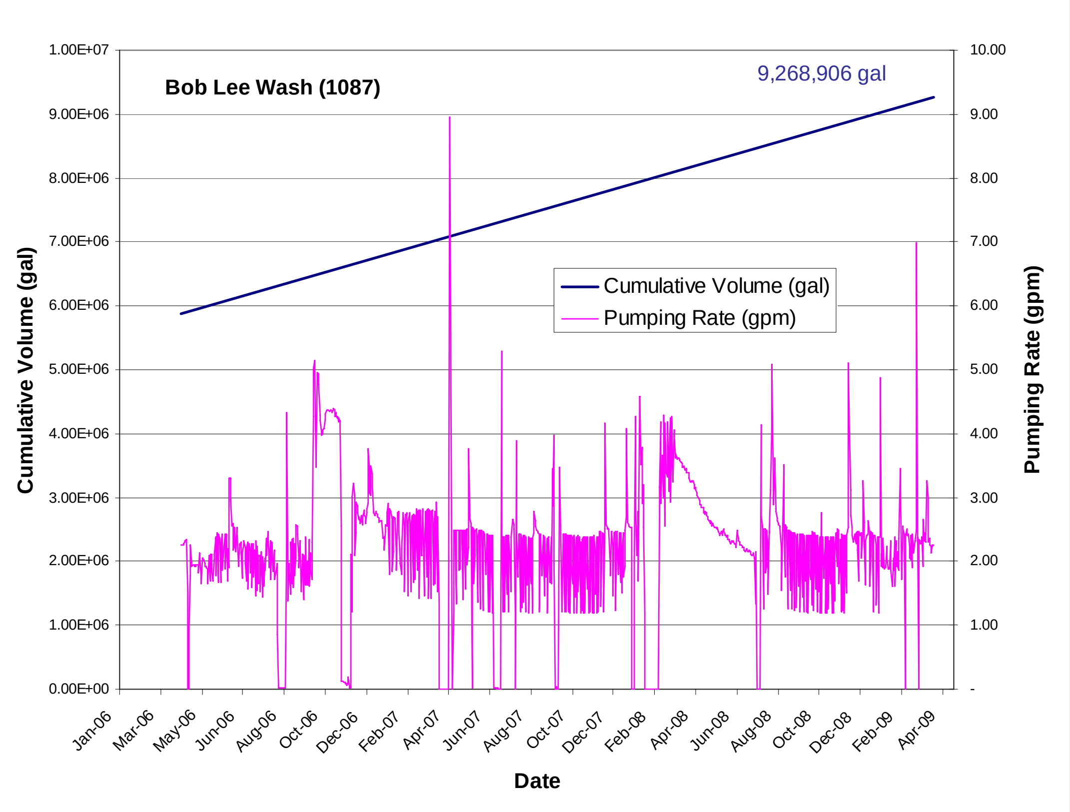


Figure 3–14. Bob Lee Wash Pumping Rate and Cumulative Groundwater Volume Extracted

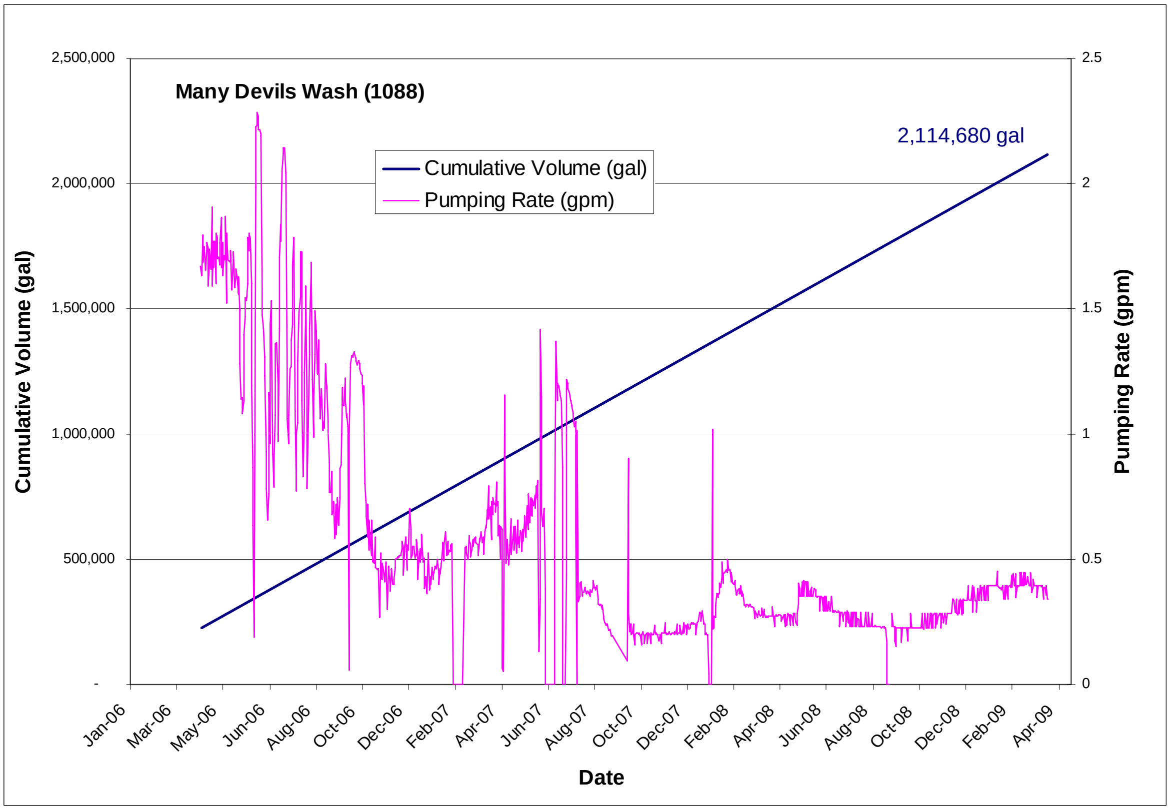


Figure 3–15. Many Devils Wash Pumping Rate and Cumulative Groundwater Volume Extracted

3.2.3 Evaporation Pond

The selected method for handling 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 5.8 ft deep in March 2009 (measured as distance above transducers, up from 2.2 ft in March 2008), leaving approximately 2.2 ft of unfilled pond capacity.

From April 2008 to March 2009, approximately 88 percent of the influent liquids entering the evaporation pond came from the floodplain aquifer; only about 12 percent of the inflow originated from the terrace groundwater system. At the end of this reporting period, a cumulative volume of approximately 74,428,000 gallons of water have been pumped to the evaporation pond from all sources since the start of operations in March 2003. Figure 3–16 plots the total volume of water transported to the pond and the relative contributions from the floodplain and terrace systems.

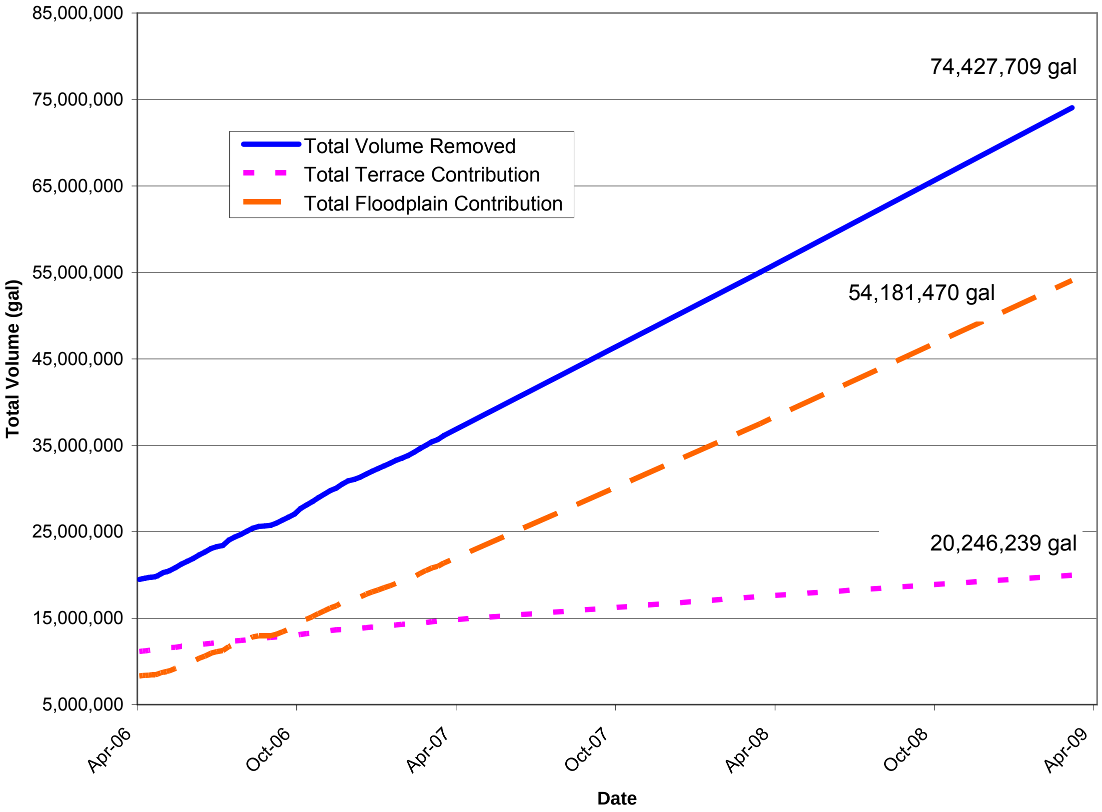


Figure 3–16. Total Groundwater Volume Transported to the Evaporation Pond

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 concentrations 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 830,430 pounds of sulfate, 28,670 pounds of nitrate, and 81 pounds of uranium. The estimate was computed from the average COC concentrations in each extraction well (Table 3−2) and the total flows at each well for the performance period.

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	67,413	0.337	970	248	546	14,000	3,572	7,875	0.135	0.034	0.076
1070	6,307	0.031	875	20.9	46.0	16,500	394	868	0.095	0.002	0.005
1071	287	0.001	2,000	2.2	4.8	12,000	13.0	28.7	0.145	0.0002	0.0003
1078	148,730	0.743	745	419	925	15,000	8,444	18,616	0.135	0.076	0.168
1091	189	0.001	1,900	1.36	3.00	11,000	7.9	17.35	0.101	0.0001	0.00016
1092	12.0	0.0001	2,800	0.13	0.28	5,400	0.25	0.54	0.104	0.000005	0.00001
1093	396,577	1.981	2,900	4,353	9,597	5,350	8,031	17,704	0.110	0.165	0.364
1095	260,910	1.303	1,800	1,778	3,919	6,350	6,271	13,825	0.063	0.062	0.137
1096	266,560	1.331	635	641	1,412	14,500	14,629	32,252	0.102	0.103	0.227
1087 (BLW)	1,151,086	5.749	420	1,830	4,034	8,600	37,469	82,604	0.660	2.876	6.339
1088 (MDW)	164,108	0.820	710	441	972	18,000	11,181	24,649	0.200	0.124	0.274
Floodplain											
1089	3,195,300	15.96	24.0	290	640	7,350	88,892	195,972	0.865	10.46	23.063
1104	848,100	4.24	89.5	287	633	9,050	29,051	64,046	0.139	0.44	0.980
Trench 1 (1110)	4,855,790	24.25	88	1,617	3,566	7,700	141,520	311,994	0.990	18.20	40.114
Trench 2 (1109)	8,484,700	42.37	33	1,060	2,336	730	23,444	51,684	0.120	3.85	8.496
Seep sump (1118)	177,580	0.89	26	17	39	5,600	3,764	8,298	0.480	0.32	0.711
			Total Masses:	13,006	28,673		376,683	830,435		36.7	81.0
Total Terrace	2,462,179	12.3									
Total Floodplain	17,561,470	87.7									
Total to Pond	20,023,649										

[a] Annual cumulative volumes derived from data used to generate plots in Figure 3–1 through Figure 3–15 (data from April 1, 2008, through March 31, 2009.

[b] Mass in kilogram (kg) derived = annual volume × 3.785 (liters to gallons) × average concentration × (1/1,000,000)

[c] Conversion to pounds (lb) = kg × 2.2046

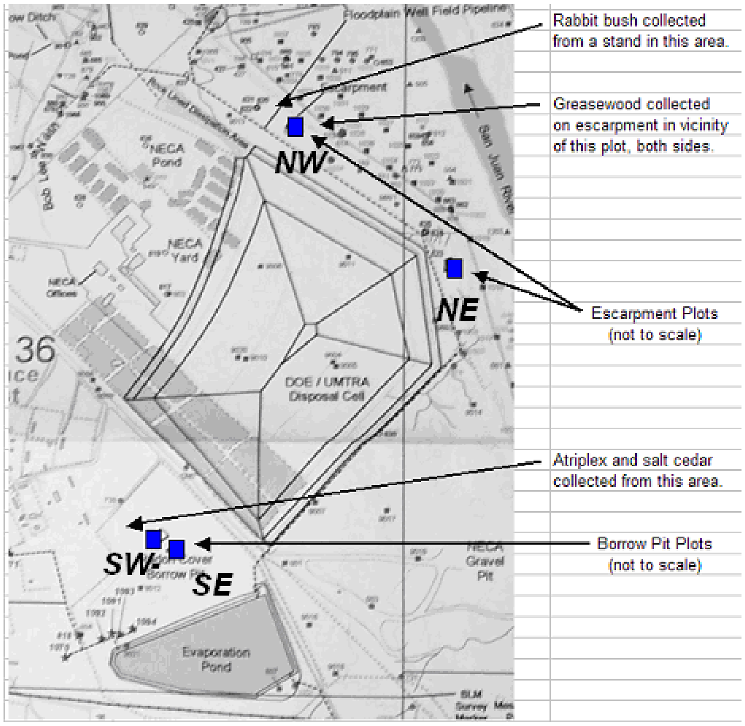
MDW = Many Devils Wash; BLW = Bob Lee Wash

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 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.

3.2.5 Passive and Enhanced Phytoremediation

Passive phytoremediation (no human intervention) and hydraulic control are ongoing at the Shiprock site in the radon barrier borrow pit area and on the terrace between the disposal cell and the San Juan River floodplain (shown in Figure 1–1 and Figure 3–17 below). Volunteer tamarisk, black greasewood, and four-wing saltbush currently growing in the borrow pit area are likely extracting water, nitrate, and possibly other groundwater constituents. A few scattered black greasewood plants that have established on the terrace above the floodplain are also likely removing water that might otherwise daylight in contaminated seeps at the base of the escarpment. Higher rates of water extraction by woody plants in both locations may improve hydraulic control.



Rabbit bush collected from a stand in this area.

Greasewood collected on escarpment in vicinity of this plot, both sides.

Escarpment Plots (not to scale)

Atriplex and salt cedar collected from this area.

Borrow Pit Plots (not to scale)

Figure 3–17. Map of Phytoremediation Test Plots in the Radon Barrier Borrow Pit and on the Terrace above the San Juan River Escarpment

More recently, DOE began evaluating the feasibility of enhanced phytoremediation, which entails deliberate planting of the areas (vs. the volunteer growth discussed above). This technique, still in early experimental stages, may be an economical addition to the current groundwater compliance strategy.

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4.0 Performance Summary

This section summarizes the findings of the most recent (April 2008 through March 2009) assessment of the floodplain and terrace groundwater remediation systems at the Shiprock site, marking the end of the sixth year of the site remediation program.

- 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 (Trench 1 and Trench 2) and the seep collection sump were added to the system in 2006 to enhance the removal of contaminated groundwater from the alluvial system. Approximately 17,560,000 gallons of groundwater were extracted from the floodplain aquifer system during this performance period, yielding a cumulative total of about 54,180,000 gallons extracted since March 2003.
- Groundwater in the terrace system is currently being extracted from two drainage trenches and nine wells. From April 2008 to March 2009, approximately 2,460,000 gallons of groundwater were extracted from the terrace system, yielding a total cumulative volume (extracted since March 2003) of about 20,246,000 gallons. The cumulative volume removed for terrace and floodplain combined was approximately 74,428,000 gallons.
- Terrace-wide, of the 23 alluvial groundwater level measurements taken during this performance period, elevations in all declined relative to the baseline (2003) period; average and maximum decreases were 1.4 ft and 4.4 ft, respectively. These findings indicate that the extraction well field is attaining the terrace performance objectives.
- Contaminated groundwater that could potentially discharge to the San Juan River is now being intercepted by the remediation system. This contaminated groundwater is transported to the evaporation pond on the terrace just south of the disposal cell. The estimated dissolved masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields during this performance period were 830,435 pounds, 28,673 pounds, and 81 pounds, respectively.
- At the same time, marked decreases in contaminant concentrations are evident in selected floodplain wells—in particular, Trench 1 area wells 0614 and 0615. COC concentrations in easternmost Trench 2 area wells (closest to the San Juan River) are also markedly lower than those nearer the escarpment, demonstrating the effectiveness of the Trench 2 system. COC concentrations in groundwater in the floodplain alluvium continue to be affected by seasonal changes in climate, changes in river stage, discharge of groundwater from artesian well 0648, and pumping rates of the extraction wells and collection trenches.
- In response to stakeholder concerns that large storm events could generate runoff from Many Devils Wash, causing contaminants to flush into the San Juan River, DOE installed an automated sampling system in the lower end of the wash in May 2009. Also, because the effectiveness of the subsurface drain in Many Devils Wash had been decreasing in previous years, DOE installed a new diversion structure in August 2009.

In summary, 23 years following stabilization of the tailings in 1986 and 6 years after initiation of active groundwater remediation in 2003, although elevated concentrations of contaminants remain in groundwater beneath the floodplain, concentrations in some areas are decreasing, and the implementation of two collection drains appears to be enhancing the cleanup rate.

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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. However, given the success demonstrated in the previous evaluation of Trench 2 (DOE 2009), DOE is proposing similar instrumentation and investigation for Trench 1. These proposals are outlined below.
- Two existing alluvial wells in Trench 1 will be instrumented to provide data to estimate horizontal well efficiency and to monitor contamination entering the floodplain from the terrace. In addition, two new alluvial wells will be installed about 50 ft from the east side of Trench 1 (nearest the river) using an in-house Geoprobe.
- Six Geoprobe wells will be installed near the San Juan River to evaluate groundwater flow and monitor contamination levels in groundwater that could enter the river.
- DOE also plans to monitor surface water levels and water temperatures in the river at selected locations. These data will be combined with simultaneously collected groundwater level information to ascertain flow directions between the river and the alluvial aquifer under different flow conditions. These data will be collected continuously at one location on the river, an existing stilling well located near the USGS river gauging station, and periodically at others.
- DOE will continue to monitor contaminant concentration trends in background floodplain alluvial wells (0797 and 0850), in particular uranium and sulfate (which have increased in the last several years).
- The terrace extraction system is operating adequately, and water levels are gradually declining. No additions to this system are recommended at this time. As the remediation system continues to operate, however, it will become more important to monitor the fluid level in the evaporation pond. Between April 2008 and April 2009, an additional 3.5 ft of water was pumped into the 11-acre pond, leaving only about 2.2 ft of unfilled pond capacity. Additionally, to mitigate potential ecological risks, DOE plans to treat the pond with an algaecide.
- 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.

As stated initially, concomitant with the development of this annual report, DOE is conducting a second reevaluation of the remediation strategy for both the floodplain and the terrace. Subsequent annual reports will be developed taking into account any revised recommendations and strategies issued as a result of this effort.

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6.0 References

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