LMS/MNT/S05378

Monticello Mill Tailings Site Operable Unit III Annual Groundwater Report May 2008 through April 2009

October 2009

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	contaminants of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
ft	feet
gpm	gallons per minute
IRA	interim remedial action
µg/L	micrograms per liter
LM	Office of Legacy Management
mg/L	milligrams per liter
MMTS	Monticello Mill Tailings Site
OU	Operable Unit
pCi/L	picocuries per liter
PRB	permeable reactive barrier
RI	Remedial Investigation
ROD	Record of Decision
UDEQ	Utah Department of Environmental Quality
ZVI	zero-valent iron
UMTRA	Uranium Mill Tailings Remedial Action

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1.0 Introduction

1.1 Scope and Objectives

This report provides the annual update of post-Record of Decision (ROD) environmental monitoring conducted through April 2009 for Operable Unit (OU) III, surface water and groundwater, of the U.S. Department of Energy (DOE) Office of Legacy Management (LM) Monticello Mill Tailings Site (MMTS). The MMTS is a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List Superfund Site located in and near the city of Monticello, San Juan County, Utah (Figure 1). The ROD for OU III (DOE 2004a) stipulates environmental monitoring and annual evaluation of the progress of the selected remedy, monitored natural attenuation with institutional controls, in attaining water-quality restoration objectives.

Environmental monitoring consists of twice-yearly collection and analysis of hydrologic and water-quality data from an established network of observation wells, seeps, and surface water locations. The ROD specifies a phased approach to evaluate potential risk to ecological receptors ("biomonitoring") from selenium accumulation in selected wetland areas. The post-ROD monitoring activities, rationale, and procedures are documented in *Monticello Mill Tailings Site Operable Unit III Post-ROD Monitoring Plan*, Draft Final, August 2004 (DOE 2004b).

As stipulated in *Performance Evaluation* "Plan for Monitored Natural Attenuation at Monticello Mill Tailings Site Operable Unit III" (Appendix B of the OU III ROD), this report includes:

- Post-ROD water quality monitoring data and data analysis,
- Post-ROD hydrogeological monitoring data and data analysis,
- Evaluation and comparison of contaminant concentration trends to ROD-established water quality improvement metrics,
- Interpretation of water quality restoration progress, and
- Cumulative biomonitoring results and comparison to establish toxicity thresholds.

This report also includes (1) a summary of the performance of the groundwater pump-and-treat system that was recently adopted as a remedy enhancement for OU III under *Explanation of Significant Difference* (ESD) *for the Monticello Mill Tailings (USDOE) Site, Operable Unit III, Surface Water and Ground Water, Monticello, Utah* (DOE 2009), and (2) a summary of post-ROD field investigation activities that were completed in the past year as directed under the ESD to provide additional characterization of the nature and extent of groundwater and surface water contamination at OU III.

2.0 Historical Information

2.1 Background Information

The MMTS was designated a CERCLA National Priorities List Superfund Site in 1989 (CERCLIS ID Number UT3890090035). It comprises the 110-acre site of a former uranium- and

vanadium-ore-processing mill (mill site) and about 1,700 acres of surrounding private and municipal property. The mill generated approximately 2.5 million cubic yards of low-level radioactive waste, primarily as tailings, during its operation from 1942 to 1960. Tailings are the sandy byproduct of ore milling and were impounded at four locations on the mill site. Some tailings were also dispersed by wind and water, contaminating properties surrounding and downstream of the mill site ("peripheral" properties). Groundwater and surface water contamination resulted from the leaching of radioactive and other inorganic constituents contained in the tailings to the underlying alluvial aquifer and into Montezuma Creek. Figure 2 depicts the approximate current extent of uranium contamination in groundwater. Uranium is the primary groundwater contaminant in OU III because of its relatively wide distribution at high concentrations, and it is the primary contributor to potential risk to human health. For these reasons, uranium is the focus of much of the evaluation of water quality restoration presented in this report.

2.1.1 OU III History

The MMTS ROD, signed in August 1990, designated OUs I and II for remediating radiologically contaminated soil, sediment, and debris on the mill site (OU I) and on the peripheral properties (OU II). Those remedial actions were completed in 1999. All OU I and II wastes are encapsulated at the engineered repository located 1 mile south of the former mill site and operated by LM. The MMTS ROD also designated OU III to address contaminated surface water and groundwater, stipulating that remedy selection would follow the completion of characterization activities through a CERCLA Remedial Investigation (RI) and Feasibility Study.

The RI report was issued in September 1998 (DOE 1998a); however, the companion Feasibility Study report was not completed beyond draft status because of ongoing OU I and II remedial actions that would significantly and unpredictably impact groundwater and surface water. This status precluded an accurate assessment of risk associated with these media, thereby deferring selection of a remedy for OU III. The U.S. Environmental Protection Agency (EPA) and the Utah Department of Environmental Quality (UDEQ) instead concurred with DOE to implement interim measures under an interim remedial action (IRA) ROD (DOE 1998b) and to complete the Feasibility Study later when site conditions had stabilized.

The interim measures included implementing institutional controls to restrict use of contaminated groundwater, continuing water quality and hydrologic monitoring, studying hydrologic and geochemical factors that affect fate and transport of contaminants at OU III, and implementing a treatability study of in situ permeable reactive barrier (PRB) technology using zero-valent iron (ZVI) as the treatment medium. The site groundwater model and the human health and ecological risk assessments were updated from those initially completed under the RI. Results of the IRA are documented in *Monticello Mill Tailings Site Operable Unit III Remedial Investigation Addendum/Focused Feasibility Study*, January 2004 (DOE 2004c). The updated groundwater model predicted a restoration period by natural processes of 42 years, beginning in 2002. This outcome, in conjunction with source control and no reasonable exposure scenario identified in the risk update, provided the technical basis in selecting the monitored natural attenuation remedy.

Since then, DOE implemented a contingency remedy in March 2009 in accordance with the above-cited ESD. This action was warranted because the progress of water quality improvement, as first recognized in 2006 and later confirmed in 2007 (DOE 2007b), did not meet the

performance criteria contained in the ROD. It was also recognized that the effectiveness of the PRB in treating the groundwater had diminished significantly due to mineral fouling. The contingency remedy was implemented to evaluate the feasibility of natural attenuation in combination with active groundwater treatment in attaining water-quality restoration objectives. Under the ESD, the contingency remedy adopted the existing pump-and-treat system at the site as an enhancement to the original remedy. Neither the original ROD nor the ESD incorporates the PRB as a remedy component.

3.0 Site Description

3.1 Physical Characteristics

The MMTS is located in rural San Juan County at an elevation of approximately 7,000 feet (ft), near and within the city of Monticello in southeastern Utah. According to the 2000 census, the population of Monticello is about 2,000 residents. The MMTS occupies the valley of Montezuma Creek, a small stream that flows eastward from its origins in the Abajo Mountains, which rise to 11,000 ft about 5 miles west of the site. The climate is semiarid with four distinct seasons. Average annual precipitation is 15 inches, most of which occurs during late summer and early fall storms. Native woody vegetation is dominated by oak brush, piñon/juniper, sagebrush, and rabbit brush. Willow thickets and other phreatophytes line much of the riparian zone of Montezuma Creek.

The mill site was restored to a native condition in 2000 and is a designated open-space public park. Land use within about 1 mile east of the mill site is agricultural and sparse residential. The valley then transitions eastward to the undeveloped canyon of Montezuma Creek.

3.2 Surface Water and Groundwater Hydrology

The valley of Montezuma Creek is underlain by a shallow, thin aquifer composed of alluvial sand and gravel (alluvial aquifer). These granular materials are overlain by about 5 ft of fine-textured floodplain deposits. Bedrock beneath the valley floor is generally within 10 to 15 ft of ground surface, and the saturated thickness of the aquifer averages about 5 ft. Groundwater flow is west to east following the slope of the valley. Where contaminated, the alluvial aquifer is underlain by low-permeability, variably saturated bedrock of the Dakota Sandstone. Contaminated water in the alluvial aquifer does not migrate to the deeper Burro Canyon Sandstone aquifer.

Montezuma Creek forms at the confluence of North and South creeks about 0.25 mile upstream of the mill site. Natural flow in Montezuma Creek is interrupted by the municipal reservoir (Loyd’s Lake), located about 0.5 mile farther upstream on South Creek, and by higher diversions from North Creek to the municipal drinking water treatment plant. Leakage through the reservoir dam is a main source of baseflow in Montezuma Creek and recharge to the alluvial aquifer. Leakage from North Creek is also a likely source of recharge to the alluvial aquifer. Montezuma Creek is often dry at the western boundary of the mill site but gains considerable flow (100 to 200 gallons per minute [gpm]) from groundwater discharge on the mill site.

To accommodate placement of the tailings during mill operation, the eastern reach of Montezuma Creek on the mill site was rerouted in a channel constructed 200 to 300 ft south of its natural course in the center of the valley. The new channel was about 25 ft above the natural grade where the creek exited the mill site. Early efforts to stabilize the site after milling ceased included constructing a concrete drop structure at that location to prevent creek erosion into the tailings areas. This structure was removed as remediation of the mill site proceeded, and Montezuma Creek was later restored to its natural position.

Remediation of the mill site required the removal of much of the native alluvium to bedrock. This temporarily exposed siltstone, shale, and coal seams that constitute the midsection of the Dakota Sandstone. Following remediation, the aquifer was reconstructed by placing uncontaminated sand and gravel in a narrow (30- to 40-ft wide) and thin (several feet thick) meandering corridor. Common fill was then placed over the granular material to result in a 3- to 4-ft-wide channel that contained the creek. This corridor was excavated several feet into bedrock in some areas and occupies the center and lowest portion of the valley.

During site restoration, artificial wetlands were constructed at three locations adjacent to the creek to provide wildlife habitat. Creek water enters each wetland by way of an infiltration gallery (cobbles and boulders) built into the upstream banks. The wetlands were excavated into bedrock, fully penetrating the alluvial aquifer, so are also fed by groundwater discharge from the alluvial aquifer. The eastern base of Wetland 3 rests on native alluvium, allowing some return leakage to the alluvial aquifer. A downstream outlet connects each wetland to Montezuma Creek. Additional description of the wetlands is provided in Section 7.0, “Biomonitoring.”

The reconstructed aquifer on the mill site is recharged by underflow from the west and by anthropogenic sources along the north margin of the valley, where a conspicuous seep zone is present. Montezuma Creek is strongly gaining through the mill site reach. Total flow of alluvial groundwater at the eastern boundary of the mill site is estimated to be 15 to 20 gpm. In the agricultural area east of the mill site, the alluvial aquifer widens to several hundred feet (north to south), and a losing stream condition prevails. The bedrock surface beneath the valley floor is relatively flat but steepens sharply at the valley margins against which the aquifer terminates. The slopes of the valley margin, particularly south of Montezuma creek in this area, are composed of up to 30 ft of sheetwash colluvium and loess.

Farther east at the head of the canyon, the alluvial aquifer narrows to about 100 ft and remains thin. This constriction forces alluvial groundwater into Montezuma Creek. Also in this reach, the Dakota Sandstone aquitard has been eroded by the creek, allowing semiconfined groundwater in the Burro Canyon aquifer to discharge to the overlying alluvium and to Montezuma Creek. These conditions form a natural hydrologic boundary that prevents eastward movement of contaminated alluvial groundwater beyond this location. The approximate location of the contact between the Dakota Sandstone (Kd) and Burro Canyon Sandstone (Kbc) in the valley floor is indicated in Figure 3.

The canyon remains narrow for nearly 1 mile farther east as the creek incises the Burro Canyon Sandstone (with a total thickness of approximately 120 ft). Numerous seeps near the base of the canyon walls in this reach attest to groundwater discharge from the Burro Canyon aquifer. The canyon then widens, coincident with the exposure of slope-forming mudstones of the Morrison Formation as the upper bedrock. The approximate location of the contact between the Burro

Canyon Sandstone (Kbc) and Morrison Formation (Jm) in the valley floor is indicated in Figure 3. At the downstream boundary of OU III (see Figure 1) the alluvial aquifer pinches out entirely in rugged canyon terrain. All alluvial groundwater presumably discharges to the creek by this point or is absorbed into the bedrock formation.

3.2.1 Groundwater Use

UDEQ classifies alluvial aquifer groundwater within OU III as Class II, Drinking Water Quality Groundwater; however, there is no current or historical use of the alluvial aquifer for human consumption, irrigation, or livestock watering. The potential to develop the alluvial aquifer for these purposes is low because the saturated zone is thin and generally low-yielding. Local private and municipal wells tap the Burro Canyon aquifer, and municipal water is readily available to residences within OU III.

The City of Monticello has historically distributed water from the Burro Canyon aquifer for nondomestic purposes (municipal and residential irrigation), but during recent drought, which peaked in 2002, the City began to augment the culinary supply with Burro Canyon groundwater. At that time, pumping records obtained from the City indicate that the 10 municipal extraction wells, located within a 1-mile radius of the town center, sustained a combined pumping rate of approximately 350 gpm over periods of several months. The primary source of domestic-use water for Monticello area residents continues to be surface runoff from the watershed of North Creek in the Abajo Mountains. Diversion systems in the mountains route the water to the municipal water treatment plant located on North Creek about 1.5 miles northwest (upstream) of the mill site. MMTS conditions or activities have no current or historical impact on the municipal water system.

3.2.2 Surface Water Use

The segment of Montezuma Creek within OU III is protected by the State of Utah for domestic use with prior treatment (Class 1C), secondary contact recreation (Class 2B), warm water aquatic life (Class 3B), and agricultural use (Class 4). There is no known use of Montezuma Creek for human consumption. The creek has insufficient water for boating and swimming and does not support fish. Montezuma Creek is used to for limited crop irrigation: water is diverted from the creek near the center of the mill site to irrigate crops on private land immediately downstream of the mill site, and creek water is diverted for crop and pasture irrigation about 1 mile east of the mill site. The creek is accessible for livestock watering at many locations in OU III. Water retained in the municipal reservoir is used primarily for residential irrigation; however, the reservoir was recently connected with the municipal treatment plant to augment the domestic-use supply.

3.2.3 Permeable Reactive Barrier

The PRB was designed to immobilize uranium and other site contaminants as groundwater flows passively through the reactive media. It was installed in June 1999 on private property about 750 ft east of the former mill site (see Figures 2 and 3 for location). The PRB measures 103 ft long (perpendicular to flow) by about 13 ft deep by 8 ft wide (parallel to flow) and is constructed of two treatment zones. The first zone is 2 ft wide and consists of crushed gravel and 13 percent by volume ZVI. The second zone is 4 ft wide and consists entirely of ZVI. A third zone, 2 ft

wide and consisting entirely of crushed gravel, distributes the treated water to the downgradient aquifer.

The PRB is keyed 1 to 2 ft into bedrock mudstone. Low-permeability slurry walls constructed of bentonite-amended soil extend north and south from the PRB to divert groundwater to the treatment zone. The north slurry wall is 97 ft long; the south slurry wall is 240 ft long. Each is about 15 ft tall, 3 to 4 ft wide, and keyed into bedrock. The slurry walls do not fully extend to the margins of the aquifer, so some contaminated groundwater bypasses treatment.

As a technology demonstration project, the PRB has been the subject of extensive scientific study and monitoring. Field and laboratory testing has revealed a progressive and significant loss of hydraulic conductivity of the ZVI, due mainly to the interstitial precipitation of calcium carbonate minerals. This has greatly reduced the capacity of the PRB to transmit and treat the groundwater treatment and has contributed to excessive groundwater mounding in the area immediately upgradient of the PRB.

3.2.4 Ex Situ Treatment System

An ex situ groundwater pump-and-treat system was installed in June 2005, and expanded in March 2007, as an alternate to the in situ PRB in studying treatment of inorganic contaminants using ZVI. In accordance with the ESD, DOE now operates the system as an enhancement to natural attenuation processes as part of the contingency remedy. The pump-and-treat system targets the aquifer region between the PRB and former mill site to evaluate the feasibility of this treatment technology in attaining groundwater restoration objectives.

The ex situ system functions by pumping groundwater through two cylindrical concrete vaults, serviceable from ground surface, that contain the treatment medium (ZVI and gravel mixture). Each vault, or cell, measures 6 ft in diameter by 6 ft in length, and is set approximately 4½ ft into the ground. Groundwater is extracted at a single well located in the groundwater mound upgradient of the PRB (well EW-1 in Figure 3) and pumped upward, in parallel, through the cells. A third vault (rectangular in outline in Figure 2) houses monitoring and flow control devices. A telemetry system allows remote monitoring of flow conditions, remote pump control, and automated data transmission to the LM data management system in Grand Junction, Colorado. As currently configured, the ex situ treatment system can treat about 13 gpm. The system is designed to discharge the treated water to Montezuma Creek and to the aquifer by way of an infiltration trench.

Until June 2008, treated water was discharged by way of the infiltration system. Since then, up to 10 gpm of the treated water is discharged to Montezuma Creek as allowed by the Utah Division of Water Quality. Influent and effluent water chemistry is tested monthly, and operating parameters (flow rate, line pressure, and water levels) are reviewed every week. The surface discharge allowance is conditional on a maximum discharge rate of 10 gpm, effluent not to exceed 45.4 milligrams per liter (mg/L) of total iron, and pH to remain between 6.5 and 9 standard units. Media change-out, triggered by excessive head loss through the media or poor treatment efficiency, is expected to occur yearly per cell. Treated water in excess of 10 gpm is diverted to the infiltration system. Since the ESD was adopted, DOE has agreed to formalize procedures for operating the ex situ treatment system (in progress).

4.0 Water Quality Assessment

4.1 Groundwater Contamination Source Removal

An outcome of OU I remedial actions, completed in 1999, was the removal of the primary source of groundwater and surface water contamination (mill tailings). All large-scale construction activities associated with OU I remediation and restoration that would impact the groundwater/surface water setting were completed by 2001. For these reasons, much of the current discussion regarding OU III water quality focuses on the period since tailings removal (or source removal) and site restoration.

4.2 Contaminants of Concern (COCs) and Remediation Goals

COCs for OU III surface water and groundwater are arsenic, manganese, molybdenum, nitrate, selenium, uranium, vanadium, and gross alpha and beta activity. Table 1 lists the remediation goals for these constituents in groundwater and surface water. The groundwater goals correspond to either a maximum contaminant level as established by EPA, a maximum concentration limit from the Uranium Mill Tailings Remedial Action (UMTRA) program, or a value derived from the OU III human health risk assessment, as indicated in the table. Surface water remediation goals correspond to the current water quality standards established by the State of Utah. When the OU III ROD became effective, there was no standard for uranium in surface water. Utah has since adopted 30 picocuries per liter (pCi/L) as the standard for domestic-use surface water (Class 1C). This standard was accepted as an OU III remediation goal under the ESD. Gross beta activity has no remediation goal because there is no activity-based standard for this constituent among the applicable or relevant and appropriate requirements for OU III, and risk factors to derive a risk-based goal are isotope-specific.

Table 1. Contaminants of Concern, Groundwater and Surface Water Remediation Goals

COC[a]	OU III Groundwater Remediation Goal [a,b]	Surface Water Remediation Goals [a,c]
Arsenic	10 µg/L[d]	10 µg/L
Manganese	880 µg/L[e]	-------
Molybdenum	100 µg/L[f]	-------
Nitrate (as nitrogen)	10,000 µg/L[d]	4,000 µg/L
Selenium	50 µg/L[d]	5 µg/L
Uranium—metal toxicity	30 µg/L[d]	-------
Vanadium	330 µg/L[e]	-------
Uranium-234/238—radiological dose	30 pCi/L[f]	30 pCi/L[c]
Gross alpha activity	15 pCi/L[d,g]	15 pCi/L[h]
Gross beta activity	-----	-----

[a]Source: DOE 2004a.
[b]µg/L = micrograms per liter; pCi/L = picocuries per liter.
[c]State of Utah standard for surface water; Utah uranium standard post-dates OU III ROD.
[d]EPA maximum contaminant level.
[e]Based on OU III human health risk assessment.
[f]UMTRA maximum concentration limit.
[g]Excluding uranium and radon.
[h]Excluding uranium and radon for MMTS OU III.

Analyses are no longer performed to determine activities of uranium-234 and uranium-238. The mass-concentration remediation goal for groundwater (30 micrograms per liter [μg/L]) is equivalent to about 20 pCi/L as uranium-234 plus uranium-238 and so is more stringent than the radiation dose-based goal (30 pCi/L). As aquifer restoration approaches the mass-concentration goal, sample analysis may then include uranium-234 and uranium-238 to confirm that the activity-based goal is also achieved. In comparing uranium concentrations in surface water, the 30 pCi/L Utah standard converts to approximately 44 μg/L.

4.3 Monitoring Schedule, Frequency, and Network

OU III groundwater and surface water samples are collected for analysis of COCs and other geochemical parameters in April and October of each year. Sampling conducted in October is slightly more comprehensive than in April, when several alluvial wells located beyond the extent of contamination and several bedrock wells are omitted from sample collection. Three bedrock wells are sampled on a 5-year frequency, as of October 2005. The current monitoring network is shown in Figure 3. This network is a subset of all locations monitored since January 2000 as data objectives or field conditions have changed (see Plate 1 for all locations that have been monitored on one or more occasion since January 2000 and Appendix D for monitor wells decommissioned since that time).

Hydrologic monitoring, conducted concurrently with semiannual water quality sampling, comprises water level measurement at observation wells, measurement of flow in Montezuma Creek at established stations, and visual inspection of known groundwater seeps. Appendix E contains all OU III water level data collected since January 2000. Tabulated results of stream flow measured since 1999 are provided in Appendix F. All water level and stream flow monitoring locations are provided on Plate 1 and Figure 3 or are described in the text.

The remainder of Section 4.0 presents and discusses the current extent of groundwater and surface water contamination. Analysis of contaminant concentration trending is deferred to Section 6.0 following a discussion of hydrologic monitoring results (Section 5.0).

4.4 Alluvial Aquifer Water Quality

Figures 4 through 10 illustrate the current extent of contamination in the alluvial aquifer for arsenic, manganese, molybdenum, nitrate (as nitrogen), selenium, uranium, and vanadium, respectively. Most posted results are from April 2009 samples; the several results for wells sampled in October 2008 are asterisked. Symbol coding identifies sample type (circles for groundwater and squares for surface water) and whether the remediation goal for the respective COC was exceeded (filled symbol) or not (open symbol) at the given location.

In the past year, each COC was present in alluvial groundwater at one or more location in excess of the respective remediation goal. Uranium remains the most widespread contaminant in groundwater, extending about 0.75 mile (4,000 ft) downgradient of the mill site, with concentrations that are greater than 10 times the remediation goal at many locations. Excepting uranium, COC concentrations generally do not exceed the remediation goal by more than a factor of 2 and are limited in distribution to the area between the former mill site and the PRB.

In summary:

- Arsenic contamination is limited to the area between the mill site and the PRB; concentrations are less than 2 times the remediation goal.
- Manganese contamination is limited in extent to several locations in the center and west portion of the mill site. Concentrations there are up to 8 times the remediation goal. Manganese levels have often slightly exceeded the remediation goal at several locations immediately downgradient of the PRB. This did not occur in April 2009. Excess manganese at these locations is likely a product of ZVI corrosion early in the operation of the PRB (see Section 4.4.1).
- Molybdenum contamination is limited to a single location at the outer end of the south slurry wall of the PRB and one location at the eastern boundary of the former mill site. The maximum concentration (110 μg/L) detected in April 2009 only marginally exceeds the remediation goal (100 μg/L).
- Nitrate contamination in April 2009 was limited to two locations that only marginally exceeded the standard. The two locations are on the north side of the aquifer, upgradient of the PRB. Nitrate contamination in this area is not uncommon and likely originates from known livestock feedlots nearby.
- Selenium contamination was limited to two locations in April 2009, at which time the maximum concentration (76 μg/L) was less than 2 times the standard (50 μg/L). The remnant selenium plume, at concentrations at or near the remediation goal, remains in the area of the PRB.
- Vanadium contamination is limited to two locations that are between the mill site and the PRB. The maximum concentration detected in April 2009 (390 μg/L) only marginally exceeds the remediation goal (330 μg/L).
- The remediation goal for gross alpha activity (15 pCi/L), which excludes uranium and radon, is not exceeded in OU III groundwater. Previous review of site data identified uranium-234 and uranium-238 as the sole contributors to gross alpha activity in OU III groundwater (DOE 1998a). Although radon-222 is present throughout OU III groundwater and is a significant alpha emitter, it is intentionally expelled during sample preparation and so does not contribute to the laboratory measurement of gross alpha activity.

4.4.1 PRB and Ex Situ Treatment System

Figures 4 through 10 (see PRB inset) show that the PRB continues to effectively reduce contaminant concentrations to acceptable levels; however, the PRB's ability to transmit water has been compromised by internal mineralization. High manganese concentrations immediately downgradient of the PRB may be a remnant of its early operation when, as a trace constituent of ZVI, dissolved manganese may have been released from the fresh ZVI and was then sorbed onto aquifer matrix grains. Manganese concentrations are much lower in the PRB because the primary control on mobility, pH, highly contrasts with that in the alluvium (DOE 2002).

Cumulatively through April 2009, the ex situ treatment system had treated about 10 million gallons of contaminated groundwater. The first media exchange occurred in March 2007 after the first cell had treated approximately 3.4 million gallons. At that time the second cell was installed

and brought online. The reactive media was changed in both cells in March 2009 after each had treated an additional 3.1 million gallons. On the basis of monthly inflow and outflow sampling, approximately 23.8 pounds of uranium have been removed by the treatment system from the alluvial aquifer cumulatively through April 2009. Additional information on treatment system performance, including influent and effluent water quality, is provided in quarterly reports distributed by DOE. DOE is currently developing criteria to better define the operational parameters of the treatment system and to establish trigger levels for media exchange and other response actions.

4.4.1.1 Discharge to Surface Water

Monthly sampling of treatment cell effluent began on June 26, 2008. The required parameters for discharge to the creek are total iron and pH. Analytical results for iron and pH in effluent samples are provided in Figures 11, 12, and 13 (effluent sample identified as location TCOUT). Uranium is monitored as a best management practice to protect water quality in Montezuma Creek. Similarly, a sample of creek water is collected monthly at a location approximately 100 ft downstream of the treatment system outfall for analysis of iron, pH, and uranium (creek location is identified as 0301). Location SW00-02 is provided in the figures to indicate water quality in Montezuma Creek upstream of the treatment system outfall (see Figure 3 for location).

The allowable concentration of total iron in the effluent is 45.4 mg/L at the maximum allowable discharge rate of 10 gpm. These allowances were negotiated with the Utah Division of Water Quality in May 2008. The pH of the effluent is to be within the range of 6.5 to 9.0 as established in the *Utah Administrative Code* for surface water quality protection. Operation of the treatment has complied with these allowances to date. The rise in iron concentration in April 2009 reflects the change-out of the reactive media in March 2009. Iron concentrations in the effluent have since remained between 30 and 35 mg/L. In Figure 13, uranium concentrations at the upstream and downstream sample locations (SW00-02 and 0301, respectively) are very similar, indicating that operation of the treatment system has no appreciable impact on Montezuma Creek. Discharge monitoring and performance assessment of the treatment system are reported quarterly in Federal Facilities Agreement reports.

4.5 Concentration Trends in the Alluvial Aquifer

Figures 14 through 20 illustrate the concentrations of arsenic, manganese, molybdenum, nitrate (as nitrogen), selenium, uranium, and vanadium, respectively, as they vary over time at selected monitor wells located along the west-to-east axis of the groundwater plume. Ordering of the wells in the legend of these figures is from west (upgradient) to east (downgradient). Monitoring data since 1992 are included in the figures to show the effect of mill site cleanup, evident at many locations by the sharp decrease in the concentration of many COCs in 1998 and 1999.

In Figure 14, arsenic concentrations are shown to have remained relatively stable since source removal. Laboratory column desorption and batch sorption tests conducted under the IRA indicated that arsenic is relatively immobile in the OU III groundwater environment (DOE 2001a). At the few locations where arsenic contamination remains, concentrations are less than twice the remediation goal. Manganese showed a sharp decrease in concentration at well 92-11 following source removal (Figure 15). At well T01-19, and at the remaining wells where manganese concentration exceeds the remediation goal (see Figure 5), obvious trending is

not evident. Molybdenum concentrations clearly show the effect of source removal (Figure 16) followed by subtle downward trends. Molybdenum desorption from aquifer solids to concentrations less than the remediation goal was shown to be relatively rapid (DOE 2001a). Molybdenum contamination is very limited in distribution and magnitude, as described in Section 4.4.

The sharp increase of nitrate in groundwater from 1999 through 2001 (Figure 17) is attributed to known fertilizer applications during site restoration. Dissipation of this pulse was complete by 2004, but again in April 2005 and 2008, order-of-magnitude increases occurred at many locations, including the upgradient monitor well (data for MW00-01 not shown in Figure 17). To have affected well MW00-01, these inputs of nitrate must originate off site and are possibly related to fertilizer applications on the golf course immediately upgradient (west) of the mill site. These recent inputs and the occurrence of nitrate downgradient of livestock operations suggest nitrate contamination since source removal is not related to past mill site operations.

Selenium concentrations in groundwater increased significantly following OU I remedial action (Figure 18), particularly in the eastern area of the mill site where an extensive area of carbonaceous, pyritic shale of the Dakota Sandstone was freshly exposed. Presumably, naturally occurring selenium in these deposits was mobilized by oxygenated groundwater of the newly reconstructed alluvial aquifer. Selenium concentrations in groundwater have decreased significantly since this initial effect. Several locations where selenium concentrations increased in April 2005 and April 2008 (Figure 18) coincided with those of increased nitrate concentration (Figure 17). This correlation, also apparent with the nitrate release in 1999, may be associated with the ability of nitrate to oxidize and mobilize selenium from bedrock formations or bedrock residuum similar in composition to those underlying the mill site (Wright 1999; Wright and Butler 1993; Weres et al. 1990). This analysis of selenium in OU III was first presented in DOE 2001a.

Uranium and vanadium concentrations each show large initial effects of source removal (Figures 19 and 20, respectively). Vanadium concentrations have slowly decreased to the extent that the remediation goal is now exceeded at one location only (well 92-11) at a concentration that only marginally exceeds the goal. Uranium trending is highly variable depending on location. This is because uranium was relatively mobile in the aquifer and the legacy plume is now subject to a greater variety of hydrologic and geochemical effects as it spans over a much greater region of the alluvial aquifer. Analysis of concentration trending for uranium is provided in greater detail in Section 6.0.

4.5.1 Plume Expansion in the Alluvial Aquifer

The uranium contamination plume terminates between well 92-09 and sentinel well 95-03 (see Figure 9). The OU III groundwater model predicted only slight increases in uranium concentrations east of the current extent of contamination but never to exceed the remediation goal at well 95-03. Figure 21 illustrates that contaminant levels observed at well 95-03, including uranium, are not increasing, and therefore plume expansion into uncontaminated regions of the aquifer is not significant at this time. Plume expansion into this area is prevented by the hydrologic discharge boundary described in Section 3.0 (alluvial aquifer and Burro Canyon aquifer groundwater discharge).

Manganese concentrations plot off the scale used in Figure 21. The presence of manganese at well 95-03 remains steady at concentrations between 300 and 400 µg/L, well below the remediation goal (880 µg/L). Enrichment of manganese in alluvial groundwater at the several downgradient-most wells results from the discharge of Burro Canyon groundwater, in which this element is naturally more abundant.

4.6 Burro Canyon Aquifer Water Quality

The Burro Canyon aquifer was sampled in the past year at wells 83-70, 92-10, and 93-01. These locations are monitored annually in October. Well 93-01 provides backgroundwater quality data for the Burro Canyon aquifer. Well 83-70 is completed beneath the main region of contamination in the alluvial aquifer, and well 92-10 is completed near the downgradient terminus of the uranium plume. Table 2 lists COC concentrations for these bedrock wells sampled in October 2008. Results indicate the Burro Canyon aquifer is not contaminated by site-related constituents at these locations.

Table 2. COC Concentrations in Burro Canyon Groundwater, October 2006 and 2008

Well	COC Concentration October 2008[a]						
	Arsenic	Manganese	Molybdenum	Nitrate[b]	Selenium	Uranium	Vanadium
83-70	0.15	270	1.1	10U[c]	0.02U	0.0003	0.1U
92-10	0.01	510	1.6	10U	0.02U	0.0003	0.26
93-01	0.37	88	0.03	10U	0.02U	0.06	0.1U
COC Concentration October 2006[a]							
93-205	31	650	1.4	10U	0.03U	0.16	0.21U
95-06	0.01	450	0.13	10U	0.023U	46	0.21U
95-07	0.7	61	0.13	10U	0.03U	1.1	0.21U

[a]Concentrations expressed as µg/L
[b]Nitrate + nitrite as nitrogen
[c]U = Undetected at listed value

Bedrock aquifer wells 93-205, 95-06, and 95-07 are sampled on a 5-year frequency that started in October 2006. Each of these wells was sampled at least yearly since their installation in 1993 (well 93-205) and 1995 (wells 95-06 and 95-07). The latest 5-year frequency sampling results for these wells are provided in Table 2. Arsenic and uranium were detected at wells 93-205 and 95-06, respectively, slightly in excess of the remediation goals. These analytes have been detected at similar concentrations since annual monitoring began at those locations following well installation. The occurrence of these analytes at the respective concentrations was attributed in previous OU III site characterization documents to localized natural sources (DOE 1998a). The cumulative monitoring data to date for Burro Canyon monitor wells indicates that the Burro Canyon aquifer is not contaminated by site-related constituents.

4.7 Surface Water Quality

Results for the surface water samples collected in April 2009 are shown in Figures 4 through 10. Surface water sites are identified in Figure 3. Uranium and selenium are the only COCs to exceed its respective remediation goal among the April 2009 samples collected from within Montezuma Creek (seeps and wetlands are addressed below). The uranium and selenium

standards are not exceeded on or within about 0.75 mile downstream of the mill site to the Sorenson location where concentrations increase. A relatively constant concentration of uranium and selenium then persists through the remainder of OU III. This is a familiar pattern for these analytes in the creek although selenium has only rarely exceeded the standards, and only marginally so, for more than 5 years. The increase of uranium and selenium at the Sorenson location is addressed further in the following section. The remaining COCs for which there is no applicable surface water standard (manganese, molybdenum, and vanadium) are present in Montezuma Creek at concentrations that exceed background values but are much less than the respective groundwater standard.

4.8 Concentration Trends in Surface Water and Seeps

Figures 22 and 23, respectively, present selenium and uranium concentrations in surface water samples collected from numerous sites along Montezuma Creek since April 2000 (seeps and wetlands are addressed separately in the following sections). Ordering of the sampling sites in the legend of these figures is from west to east in the direction of creek flow. These analytes were selected for presentation because uranium contamination is most extensive in OU III groundwater, and selenium concentrations in surface water are particularly relevant to the ongoing biomonitoring effort.

Selenium concentrations have trended downward since source removal and following the later bedrock effect described in Section 4.5. In the past 2 or 3 years however, selenium concentrations at several locations downstream of the mill site have fluctuated to occasionally exceed the remediation goal (locations Sorenson, SW00-04, and SW92-08 in Figure 22). Uranium concentrations in Montezuma Creek typically exceed the standard only at the Sorenson location and those farther downgradient (Figure 23). Concentrations of selenium, uranium, and molybdenum in Montezuma Creek have historically reached peak concentrations at the Sorenson location. The selenium and molybdenum contaminant plumes extend only a short distance downgradient of the mill site, far upstream of the Sorenson location, so groundwater discharge is not a likely source of these contaminants in the creek.

The uranium plume does extend nearly to the Sorenson location at concentrations that may be sufficient to account in part for uranium loading to the creek from groundwater discharge. Soil and sediment in the floodplain in the affected reach of the creek were remediated to supplemental standards, and deposits of residual mill tailings are known to exist in floodplain and creek bank deposits. These deposits may contribute to the rise in concentration of several COCs in Montezuma Creek near and downstream of the Sorenson location. Uranium concentrations at and downstream of the Sorenson location remain relatively constant following source removal (Figure 23). Wide seasonal fluctuations in concentration are negatively correlated to creek flow. The source of the increase in uranium concentration at the Sorenson site, whether by discharge of the contaminant plume, or from residual mill tailings in the floodplain deposits, is currently being investigated by DOE.

4.8.1 Groundwater Seeps

Seeps 3, 5, and 6 (see Figure 3 for seep locations) are located along the north margin of the mill site and originate from water sources above the valley of Montezuma Creek. The seeps are topographically much higher than the alluvial aquifer. Site COCs that historically have occurred

at one or more of these seeps in excess of a remediation goal are nitrate, selenium, and uranium. The high nitrate levels at Seeps 3 and 6 (Figures 7 and 24) are attributed to known livestock operations. Nitrate concentrations at Seeps 3 and 6 fluctuate widely over time with no apparent trending (Figure 24). Seep 5 is to the west of the livestock operations and so is not similarly affected.

Selenium concentrations at Seeps 3 and 6 are likely of bedrock origin. Selenium levels at Seep 6 are commonly below the groundwater remediation goal but show occasional spikes (Figure 25) that coincide with high nitrate at that location. Similarly, selenium concentrations decrease as nitrate does. Despite similar bedrock geology at Seep 3, selenium concentrations do not appear to correlate with nitrate. Selenium concentrations at Seep 3 have continued to decline since monitoring began there in 2001.

The origin of uranium contamination at Seep 6 (Figure 26), observed since monitoring began at that location in 2002, is currently being investigated by DOE. The status of that investigation is presented in Section 8.2 of this report.

4.8.1.1 Wetland 3

Groundwater from the alluvial aquifer discharges to Wetland 3 at Seeps 1 and 2, near the northwest corner of the pond. Since monitoring began at these locations in 2001, flow has sometimes been too diffuse for sample collection at Seep 1 while flow at Seep 2 has been nearly constant. Contaminant concentrations and trends at Seeps 1 and 2 are similar to those at nearby monitor wells, so moderate levels of many COCs discharge into the wetland at these seeps. Within Wetland 3, only uranium at location W3-03 is in excess of a surface water quality standard (Figure 9). The concentration reported for October 2008 (640 µg/L) at W3-03 is anomalous because it is much greater than the inflow concentration (Seeps 1 and 2), was not repeated in April 2009, and greatly exceeds previous measurements at that location. No surface water quality standard is exceeded at location SW00-02, located on Montezuma Creek immediately downstream of Wetland 3. At Seep 2, a downward trend of selenium entering the wetland, similar to that observed at Seep 3, is observed. Section 7.0 includes additional discussion of selenium concentrations in Wetland 3 (and the sediment retention pond) with respect to ecological receptors.

5.0 Hydrologic Monitoring Assessment

5.1 Stream Flow

Results of periodic measurements of flow at several locations on Montezuma Creek since April 2000 are depicted in Figure 27. The ordering of the flow measurement locations in the legend is from west to east, parallel to the direction of flow. The transitional reach identified in the figure refers to the segment of Montezuma Creek between wells 0200 and 92-09 (see Figure 3 for well locations) where the upper bedrock changes from the Dakota Sandstone to the Burro Canyon formation and the valley begins to narrow into a steep-walled canyon. Flow measurements for that reach were taken near former sampling locations SW00-03 and SW00-06, or just upstream of well 92-09, depending on field conditions and property access. Drainage ravines leading into Montezuma Creek are typically dry and have no influence on the reported

flow data. Two prominent gaining reaches of Montezuma Creek are apparent in Figure 27. The first is indicated between locations SW00-01 and SW00-02, spanning the mill site, and the second occurs at the transition reach, earlier described as the reach of Burro Canyon groundwater discharge.

Figure 27 clearly shows the effect of recent drought, culminating in the absence of measurable flow at any location during mid-summer 2003. At that time, the absence of a gaining-stream condition in Montezuma Creek between stations SW00-01 and SW00-02 not only represents reduced baseflow from the reservoir and North Creek, but also reflects the unavailability of water for residential irrigation during the peak dry years, thus eliminating aquifer recharge along the north margin of the mill site. Creek flow has since returned to approach normal levels.

In April 2005, following abundant winter and spring snow, measured creek flow was about 2,000 gpm (April 2005 results are off-scale in Figure 27). City officials reported a short-term peak flow in Montezuma Creek in spring 2005 of 30,000 gpm when deliberate releases from the reservoir occurred and from anomalously high flow in North Creek. The spring 2005 snowpack in the Abajo Mountains was 250 percent above normal. Recorded flows were approximately 3,000 gpm (off-scale in Figure 27) during the April 2008 monitoring event following another year of abundant winter and spring snow. This condition resulted in diluted COC concentrations in Montezuma Creek compared to more normal flow, as observed during spring 2009.

5.2 Alluvial Aquifer Water Levels

Leakage through the municipal reservoir dam and seepage from North Creek are the primary sources of water to baseflow in the alluvial aquifer west of the mill site. Irrigation of the golf course may also contribute to aquifer recharge in this area. As indicated in water level hydrographs for upgradient monitor wells (wells 82-20, MW00-01, and MW00-02, Figure 28), this area is subject to seasonal water table fluctuations of greater than 2 ft and is also sensitive to larger-scale climatic effects. For example, following the low-water years of 1999 through 2003, water levels responded to above-average precipitation in 2005 by rebounding nearly 10 ft to peak levels in April 2005. This response was then followed by water table declines of similar magnitude into 2007 and 2008. The water table is currently at normal levels at the upgradient boundary of the mill site.

On the mill site, the water table does not fluctuate as widely as at MW00-01 and MW00-02. For example, the unusually dry year of 2002 and into 2003 produced only minor variation, one foot or less, in the water table elevation (Figure 29). Similarly, the water table response to abundant moisture in spring 2005 and 2008 was relatively mild. The construction of the aquifer in a narrow corridor and connection to the creek on the mill site may dampen seasonal and larger-scale scale climatic effects on the water table elevation. Water levels at many wells on the mill site exhibit a net increase of about 1 ft since 2000.

Water level hydrographs for selected monitor wells located downgradient of the mill site are shown in Figure 30. The effect of aquifer dewatering during mill site remediation is evident as the declining water levels at wells 92-11, 88-85, and 92-07 from mid-1998 through mid-1999. During that time, nearly all groundwater underlying the mill site was captured at interceptor trenches and diverted to the creek at the east boundary of the mill site to facilitate tailings excavation. After dewatering ceased, the water table in the area upgradient of the PRB

rebounded within about 6 months to levels approaching pre-remediation conditions (at wells 88-85 and 92-07, for example). Water level rebound in this region was enhanced by mounding at the PRB (installed summer 1999).

East of the PRB, the same period of mill site dewatering likely accounts for the observed water table decline and subsequent recovery at wells 92-08 and P92-06 (Figure 30). Because of the greater distance from the dewatering activities, the response at these locations is delayed by several months or more. The effect of dewatering is not apparent farther east at well 92-09, possibly because of greater dampening with distance. In response to the abundant snowpack and runoff of winter/spring 2008, water levels in the aquifer up- and downgradient of the PRB increased typically by 2 to 3 ft.

5.2.1 Groundwater Mound at the PRB

Water level hydrographs for wells nearest the PRB (Figure 31) indicate that groundwater extraction from well EW-1 has not significantly reduced the groundwater mound at the PRB. The water table decline apparent at wells 88-85 and T1-D is a regional effect unrelated to groundwater extraction. Groundwater extraction has had no apparent effect on water levels at monitoring wells 92-07 and PW-17 (Figure 31), located about 200 and 300 ft from the extraction well, respectively. The water table in the mounded area was about 3.5 ft below ground surface in April 2009.

5.3 Burro Canyon Aquifer Water Levels

Well pairs 95-01/95-02 and 95-03/95-04 are the easternmost groundwater monitoring locations in OU III (see Figure 3 for well pair locations). Wells 95-01 and 95-03 are completed in the alluvial aquifer and wells 95-02 and 95-04 are completed in the upper 20 ft of the Burro Canyon aquifer. Groundwater is not contaminated at these locations. Water levels are monitored at these wells to confirm the long-term stability of the hydrologic barrier in this part of the canyon that prevents further eastward migration of the contaminant plume.

The water table at these well pairs is shown to be relatively stable over time with a consistent upward flow gradient from the Burro Canyon aquifer to the alluvial aquifer (see Figure 32). Groundwater withdrawal from the Burro Canyon aquifer by the city of Monticello during 2001 to 2004 did not affect the direction or magnitude of this gradient at these locations, nor was the hydraulic head at 95-08 significantly affected (Figure 33). This Burro Canyon well is located on the mesa above well pair 95-03/95-04. The much greater hydraulic head at well 95-08 as compared to those at 95-02 and 95-04 is evidence of the driving force for Burro Canyon discharge in the canyon.

At Burro Canyon monitor wells nearest the municipal well field (wells 83-70, 93-205, and 93-01), municipal pumping during the recent drought accounted for as much as 15 to 20 ft of water level drawdown in the aquifer (Figure 33). Water levels in those wells have since rebounded to near pre-pumping levels. Well 83-70 is used occasionally by the landowner for limited irrigation since about 2006 but this use has had no measurable drawdown.

6.0 Groundwater Restoration Assessment

6.1 Uranium Trending Compared to Model Prediction

The ROD for OU III stipulates that observed concentrations for uranium will be compared to those predicted by the groundwater model for OU III as a measure of restoration progress. For this purpose, the alluvial aquifer is divided into five regions (see Figure 34) distinguished by contaminant distribution and hydrogeology. Beginning with the October 2004 monitoring results, the average uranium concentration is computed for each of these regions from a selected group of monitoring wells. The averages are then graphed with a corresponding uncertainty range of ±30 percent to illustrate how each region is progressing toward water quality restoration. The rationale for the uncertainty range is provided in Appendix B of the ROD.

Model-predicted concentrations (see Appendix G) for the corresponding wells are similarly averaged, normalized to calendar date (model time zero is October 2002), and graphed along with the observed averages, as shown in Figures 35 and 36. In these figures, solid lines represent averaged model-predicted concentrations, and the individual points, with the corresponding uncertainty range, represent the average of the observed concentrations for the given region. The ROD states that as of October 2004, if the model-predicted average is less than the lower limit of uncertainty for the observed average for three consecutive sampling events, aquifer restoration progress is significantly less than the model prediction. According to this measure, and as shown in Figures 35 and 36, as of April 2008 the rate of aquifer restoration in Regions 1, 2, 3, and 5 is significantly less than the model prediction. In most of the aquifer therefore, the predicted restoration period (42 years from 2002) is not likely to be attained at current rates of attenuation. Observed concentrations in Region 4 deviate significantly from the model prediction; however, observed values are less than predicted.

6.2 Nonparametric Trend Analysis

The OU III ROD also stipulates that if the acceptance criterion defined above is not met for any aquifer region, DOE would perform an additional statistical analysis of time-varying uranium concentrations. DOE met this requirement by in August 2007 using a nonparametric statistical test to determine if statistically significant trends are present, and if so, is aquifer cleanup feasible within the 42-year period predicted by the groundwater model. The analysis applied the Mann-Kendall test for trend detection, the Sen's estimate of slope, and the Seasonal Kendall test for trend and slope (EPA 1994, Gilbert 1987). Uranium concentrations were evaluated by these tests on a well-by-well basis, as regional averages, and under assumptions of cyclical and noncyclical seasonal variation.

Statistically significant downward trends were recognized at many of the OU III monitor wells, and non-trending was identified at most of the remaining wells. Upward trending was recognized at several wells in an area where an apparent localized area of high uranium concentration in groundwater (hot spot) is flowing downgradient. Region-by-region averages provided results very similar to those of the original ROD-specified evaluation method. Well-by-well analysis identified specific areas of potential concern that are currently under investigation (see Section 7.0). Seasonal and non seasonal trend analysis suggested that seasonal effects on uranium concentration are negligible. The conclusion of the nonparametric trend analysis was that aquifer restoration within the 42-year period was not likely based on current trends.

6.3 Summary of Restoration Progress

The following summary is based on the results of the analytical methods described in Sections 6.1 and 6.2 and the uranium concentrations shown in Figures 37 to 41.

Region 1 Most wells in the region are non-trending. This implies a cleanup time in excess of the established 42-year period. Uranium persists at concentrations between about 100 and 200 µg/L. Only well T01-19 is recognized as trending downward (Figure 37).

Region 2 All wells exhibit downward trending (Figure 38) at rates that project cleanup of this region in 22 years since 2002. Contamination from Region 1 is not expected to impact Region 2 because most of the groundwater in Region 1 is expected to discharge to Montezuma Creek.

Region 3 Three of five wells exhibit a downward trend, and the remaining two wells show upward trends (Figure 39). Wells 92-07 and PW-17 are located within a mobile hot spot of groundwater contamination located at the outer end of the south slurry wall of the PRB (see Section 8.0 for additional discussion). Trends at wells 92-11, 88-85, and PW-28 suggest that at current rates, a large portion of this region will attain cleanup within about 20 years of 2002.

Regions 4 Trending is absent in this region (Figure 40), and concentrations are highly variable over time. Upward trending is anticipated in this region as the groundwater hot spot in Region 3 migrates eastward into Region 4.

Region 5 Upward trending at well P92-06 (Figure 41) may indicate movement of a localized hot spot of groundwater contamination. The remaining wells in Region 5 show no concentration trend. Groundwater restoration in Region 5 will not occur within the 42-year period based on current projections.

6.3.1 Uranium Trending and Hydrologic Factors

Figures 42 to 45 depict the variation of uranium concentration with water level at wells T01-01, 92-11, 88-85, and P92-06, respectively. Each data point represents the difference in uranium concentration ("del uranium") and in water level ("del water table") between successive monitoring events. There is no apparent correlation between these variables at either location, suggesting that uranium concentration is not sensitive to seasonal variation in water levels. As a result, it cannot be concluded that climate conditions, whether drought or surplus water, significantly affect the rate of water quality restoration in the portion of the aquifer in which these wells are located.

6.3.2 Uranium Trending and Geochemical Factors

Uranium concentrations at Region 1 monitor wells have remained relatively constant at levels between about 100 and 200 µg/L since monitoring began at those locations in 2001 (Figure 37). The Region 1 wells are completed in native alluvium that was not removed during site remediation or restoration. Persistent uranium concentration in this range may exemplify the "tailing effect" demonstrated in column desorption tests conducted under the interim record of decision (DOE 1998b) to evaluate COC mobility at OU III. In these tests, which were designed

as physical analogs of the OU III groundwater environment, uranium was rapidly removed from the aquifer substrate through the first several pore volumes. Uranium concentrations in the column effluent then stabilized at between 100 and 200 µg/L through the passage of an additional 20 to 25 pore volumes of water (in DOE 2001). This outcome suggests that Region 1 may be in this tailing phase of the restoration process. Region 2 wells have recently reached this concentration range, so a decrease in the attenuation rate may be expected in the future for this region.

7.0 Biomonitoring

7.1 Biomonitoring Scope

DOE conducts biomonitoring to evaluate possible risk to ecological receptors from post-remediation increases of selenium in surface water and groundwater. Biomonitoring began in 2004 and was focused on the constructed wetland areas on the former mill site (Wetlands 1, 2, and 3; Figure 3) and the sediment retention pond (Sediment Pond; Figure 3) located on Montezuma Creek about 1 mile downstream of the mill site. The 2007 and 2008 biomonitoring focused only on Wetland 3 and the Sediment Pond, where selenium levels remain elevated. The surface area of Wetland 3 is approximately 1.5 acres, with 18- to 24-inch water depths in the deepest portion of the wetland. Most of the wetland is covered with dense cattails and rushes. The Sediment Pond, about 1 acre in size, is predominantly open water. The center of the pond reaches depths of about 6 ft with shallow areas around the margin. The banks of the pond are lined with willows. Beds of emergent aquatic grass and rushes are present in several locations along the bank, and the pond becomes dense with green algae in late summer. A 6- to 12-inch layer of black organic mud covers the base of the pond.

Biomonitoring activities are conducted in accordance with the ROD and the Post-ROD Monitoring Plan (DOE 2004a and DOE 2004b), and in consultation with the Biological Technical Assistance Group (BTAG), consisting of representatives from the U.S. Fish and Wildlife Service, EPA, UDEQ, and DOE. Biomonitoring has been implemented in phases; its scope is determined annually in consultation with BTAG, following a review of the previous year's results. Field activities are then implemented through program directives prepared by DOE. Surface water and sediment samples have been collected from October 2004 through April 2008; the results are summarized in DOE 2008a and in Section 7.2 below. Macroinvertebrate sampling occurred from 2005 to 2008, with the most recent sampling in June 2008 (Section 7.3). Avian surveys were conducted in spring and summer of 2005, 2006, and 2008 (Section 7.4). Tabulated results for selenium in biotic and abiotic samples are provided in Appendix H.

7.2 Surface Water and Sediment Results

Surface water and sediment samples were collected and analyzed for selenium in Wetlands 1 and 2 between October 2004 and April 2007. All surface water samples have been below the no-effects level since October 2005, and all sediment samples were well below the no-effects level during the entire monitoring period (Figures 47 and 48). Because selenium benchmarks have not been exceeded in Wetlands 1 and 2, monitoring at these wetlands was discontinued in 2007. Detailed results are in DOE 2005a, DOE 2007c, and DOE 2007d.

In Wetland 3, samples were collected between October 2004 and April 2008. Selenium concentrations in surface water were generally below the no-effects level except at location W3-S1 (see Figure 46 for sampling location), which is near the point where Seep 2 discharges into the wetland. The geometric mean for surface water selenium has remained near the no-effects level and no trending is apparent (Figure 47). Selenium sediment concentrations have remained well below the no-effects level except near Seep 2. Mean concentrations of selenium remained below the no-effects level during the entire monitoring period, with no apparent trending (Figure 48).

Samples were collected at the Sediment Pond between October 2004 and April 2008. Selenium levels in surface water were generally higher than the no-effects level but below the toxicity threshold (Figure 47). An early upward trend in the geometric mean for surface water appears to have leveled off since 2006. Most sediment samples fell below both the toxicity threshold and the no-effects level, and a downward trend may be evident in the geometric mean for sediments (Figure 48). Detailed results for both Wetland 3 and the Sediment Pond are in DOE 2005a, DOE 2007c, DOE 2007d, and DOE 2008b.

7.3 Macroinvertebrate Results

Aquatic macroinvertebrates were sampled at Wetlands 1 and 2 in 2005 using kicknets and light traps. Only kicknet samples yielded organisms, which were analyzed for selenium. Mean values were below the no-effects level in both wetlands (see Figure 49; error bars represent 1 standard deviation of the geometric mean), so sampling was discontinued in these areas. Detailed results are in DOE 2005a.

In Wetland 3, macroinvertebrates were sampled with a kicknet from 2005 through 2008. The geometric mean for selenium in macroinvertebrate tissue has remained between the no-effects level and the toxicity threshold during the monitoring period, with no obvious trending (Figure 49). At the Sediment Pond, both kicknet and Hester-Dendy (artificial substrate) samplers were used to collect macroinvertebrates from 2005 through 2008. Hester-Dendy samplers yielded few organisms with low biomass between 2005 and 2007; the organisms that were collected comprised species similar to those collected with a kicknet. No organisms colonized the Hester-Dendy samplers in 2008. Figure 49 shows selenium concentrations from kicknet samples in the Sediment Pond between 2005 and 2008. Most samples fell between the no-effects level and the toxicity threshold. Although the geometric mean for selenium in macroinvertebrate tissue has remained below the toxicity threshold, an upward trend may be evident.

7.4 Avian Survey Results

Avian surveys, each with a different scope, were conducted in 2005, 2006, and 2008. The 2005 survey (detailed in DOE 2005b), focused on all observed bird species at Wetlands 1, 2, and 3 and the Sediment Pond. Most species identified during these surveys did not directly depend on the wetland habitat. Of those that did, red-winged blackbirds were most abundant at Wetlands 1, 2, and 3, and several common species of swallow were most abundant at the Sediment Pond. Other species observed using the wetlands were sora, mallard ducks, killdeer, Canada geese, gadwalls, and several species of teal. No federally listed or state sensitive species were observed. A black-

throated grey warbler and an olive-sided flycatcher, both species of concern, were each observed once near the Sediment Pond. Migrating white-faced ibis were also observed in the wetlands.

In 2006, surveys focused primarily on waterfowl and other species directly dependent on the wetlands. As in 2005, the most common species at the wetlands were red-winged blackbirds and the most common species at the Sediment Pond were swallows. Smaller numbers of mallards, Canada geese, killdeer, and sora were also suspected to be breeding in the area. No federally listed or state sensitive species were observed during these surveys. Detailed results are in DOE 2006.

The main purpose of the 2008 surveys was to determine whether federally protected, state-of-Utah-listed, or other avian species of concern not identified in previous surveys exist on or near Wetland 3 or the Sediment Pond. Comprehensive avian surveys were conducted in 2008 at these locations, as in 2005, by surveyors trained and experienced in the identification of threatened, endangered, and sensitive bird species. Eight field surveys were conducted between May 2 and August 12, 2008. In addition, five willow flycatcher surveys were conducted between May 22 and July 16, 2008. Migrant willow flycatchers were observed near the Sediment Pond in May and June, but additional surveys revealed that they were not nesting in the area. The subspecies of willow flycatcher was not identified, but southwest willow flycatchers (federally listed as endangered) can potentially be observed in the area. A migrating bobolink, a state-listed species, was observed once near Wetland 3. Two Birds of Conservation Concern (as listed by the U.S. Fish and Wildlife Service) were each observed once: a black-throated grey warbler, and a Virginia's warbler. A pair of northern harriers, also a Bird of Conservation Concern, were observed throughout the summer at Wetland 3, where they nested and fledged three young. As in 2005 and 2006, the most common bird species at Wetland 3 was the red-winged blackbird, and cliff swallows were most common at the Sediment Pond. Detailed results of the surveys are in DOE 2008c.

7.5 Future Scope of Biomonitoring

The BTAG agreed at the April 2009 Federal Facilities Agreement meeting to postpone biomonitoring for 1 year and to resume it in 2010. The scope of biomonitoring conducted in 2010 will be similar to that completed in 2008 except that an avian survey will not be completed in 2010. If anomalously high selenium is detected in benthic macroinvertebrates in 2010, an avian survey may be repeated in 2011. Details of the 2010 scope will be determined by the BTAG early in 2010 and directed through a program directive and accompanying sampling and analysis plan similar to those that guided biomonitoring work in previous years.

8.0 Water Quality Investigations (2009−2012)

8.1 Groundwater Hot Spot Investigation

DOE recognizes that the rate of groundwater restoration in Region 3 of the aquifer may be less than predicted, in part because the extent of uranium contamination in groundwater in this region, particularly south of Montezuma Creek, may be greater than represented by the starting concentrations in the model. Although downward trending in uranium concentration is observed at the monitoring wells north of and nearest the creek in this region, trends of increasing uranium

concentration are evident farther south (see Figure 39). This region of the aquifer is the current target of groundwater extraction and treatment.

A subsurface investigation was conducted in April 2009 to better define the uranium plume and subsurface geology in the southern portions of Regions 2 and 3 of the alluvial aquifer. The goals of the study were to determine if the uranium plume is much greater in extent than was represented by the starting concentrations specified in the model and to determine if a continuing source of contaminated groundwater exists in the southeast area of the former mill site.

The scope, results, and conclusions of the April 2009 field study are summarized in the following subsections of this report. Data collected in the April 2009 field study are complemented with results of previous studies that were implemented in the same area ("South Millsite Source Investigation," in DOE 2001a) and in PRB design studies (DOE 1998c).

8.1.1 Scope of Work

The hot spot field study was conducted under Program Directive MNT-2009-02 and the associated sampling and analysis plan (Monticello Program Directives with attachments issued after September 30, 2008, are provided in Appendix I). The directive identified the locations of 24 temporary borings to be installed in a regular pattern over a 100-ft-by-100-ft grid. A total of 36 borings were completed between April 6 and 9, 2009, at the locations shown in Figure 50. Many of the boring locations were moved from the proposed location based on field conditions (steep topography or exposed bedrock, for example). Borings 25 to 36 were completed to investigate certain areas in greater detail based on observations at preceding bores. For example, several borings were relocated or added downgradient of well MW00-03 to better understand the source of water intercepted by that well, and several borings were added surrounding boring HS-05 to better understand the effect of the former channel of Montezuma Creek on local flow conditions and uranium distribution. Bores identified with the suffix –OS are locations where a boring was completed a short distance from the original bore in order to offset from a large cobble or boulder or to confirm the location's depth to bedrock.

At the locations identified in Figure 50, a borehole was advanced to the bedrock using a track-mounted direct-push boring machine. Bedrock was confirmed by collecting a core sample upon encountering increased resistance in borehole advancement. Records of previous borings and monitor wells in the area were available in the field to guide the study. Samples of the aquifer substrate or bedrock were not retained for evaluation in the April 2009 field study (see DOE 2000 for aquifer substrate analysis and COC leaching behavior).

Upon confirming that bedrock was reached, the inner rod and core tube were extracted from the outer drive rods, and a polyethylene tube was inserted, through which a sample of the groundwater was withdrawn using a peristaltic pump. At some locations, it was necessary to remove the down-hole equipment to allow water level entry to the bore for subsequent sample collection. Water samples were placed on ice until delivery to the Environmental Sciences Laboratory for analysis of uranium. Because uranium mobility is sensitive to alkalinity and pH, these indicator parameters were also measured for possible future use in evaluating water quality restoration in this portion of the aquifer.

All boreholes were left open following sample collection to allow the water level to stabilize. Depth to groundwater was then measured and recorded at each location. The location of each borehole was measured in site coordinates using the global positioning system. Ground surface elevation at each borehole and the waterline elevation at several locations on Montezuma Creek were measured using conventional land survey leveling methods. Reference elevations were from nearby monitoring wells that had been previously surveyed. Each borehole was abandoned after the elevation survey by placing commercial sand to within 4 ft of ground surface and bentonite chips to surface.

8.1.2 Results

8.1.2.1 Water Table Configuration

Figure 51 illustrates the depth to groundwater in the alluvial aquifer encountered in the April 2009 boreholes and in nearby OU III monitoring wells. Locations where groundwater saturation was not encountered above the bedrock surface are labeled dry in the figure. The position of the dry boreholes identifies the southern margin of the aquifer to trend northwest to southeast approximately coincident with the 6,810-ft land surface contour. This delineation also coincides with the southern extent of the modern-day, flat-lying floodplain in this area. Depth to groundwater beneath land surface on the floodplain is generally between 7 and 10 ft. Depth to groundwater increases in the southeast portion of the area because of higher land surface topography and lower bedrock elevation.

In Table 3, which summarizes the April 2009 borehole information and other information from nearby existing and previous wells and boreholes, the depth to water subtracted from land surface elevation provides the elevation of the water table at each location. Computer interpolation of the groundwater elevations and creek stage using the natural neighbor method resulted in the water table contours shown in Figure 52. Groundwater flow south of the creek is to the southeast, a finding that is similar to the previous studies in this area. However, flow resistance through the PRB has resulted in more pronounced southward flow along the south slurry wall. The south slurry wall does not fully span the aquifer, so converging flow to the gap between the slurry wall and aquifer boundary results in steep hydraulic gradient locally. Once through the gap, groundwater spreads into a relatively wide expanse of the aquifer.

The shape of the water table is also observed to suggest leakage from Montezuma Creek to the aquifer. This losing stream potential is apparent by the higher elevation of the creek than the water table at adjacent wells or boreholes, resulting in the characteristic downstream-pointing water table contours.

8.1.2.2 Bedrock Surface and Aquifer Saturated Thickness

Figure 53 illustrates the depth to bedrock encountered in the April 2009 boreholes, at other temporary boreholes and wells installed in 2000 and 2001, and at existing OU III monitoring wells. The location of a prominent bedrock ledge that bounds the aquifer in this area is also indicated. Depth to bedrock beneath the floodplain ranges between about 7 and 15 ft. Depth to bedrock is locally greatest, up to 36 ft, where relatively thick colluvium and loess have been deposited on the hillside that bounds the valley (see DOE 1998c and 2004c for lithologic descriptions of subsurface materials).

The shape of the bedrock surface, as depicted in Figure 54, influences the local distribution of groundwater and the direction of groundwater flow. For example, the southern limit of the alluvial aquifer, as indicated by the dry bores and former wells shown in Figure 51, coincides with the change in bedrock slope beneath the floodplain and the hillside of the valley margin. It is along this contact that the alluvial deposits terminate against the steep bedrock slope. The shape of the bedrock surface also contributes to the component of southeasterly flow because, as measured across the valley, the bedrock surface is lowest toward the outer end of the south slurry wall. Local variation in the bedrock surface accounts for up to 4 or 5 ft of relief (for example, a mild bedrock high or shelf is apparent at location HS-31 relative to location HS-04).

Figure 55 shows the saturated thickness of the alluvial aquifer, computed as the difference between the water table and the top of the bedrock elevation (Table 3). The aquifer is thickest in the central area of the floodplain between the PRB and mill site, reaching 8 to 10 ft thick. This range is 2 to 3 ft greater than observed in June and July 1998, prior to construction of the PRB, possibly in response to subsequent groundwater mounding at the PRB. The aquifer is much thinner nearest the mill site. For example, at locations HS-10 and T00-01, only 1 ft of saturation is present. This is likely because Montezuma Creek changes from a gaining stream to a losing one at the east boundary of the mill site. At this transition, therefore, the depleted aquifer begins to receive significant recharge in the form of creek leakage.

Generally dry conditions are observed east of the former creek channel near the PRB. The former channel was about 15 to 20 ft deep in this area and extended to or came very near the bedrock surface. Remedial actions further expanded the dimensions of the creek channel to remove all contaminated sediment and floodplain soil. Fine-grained borrow material is believed to have been used to backfill most of this excavation. This was confirmed by the recovery of soft silt and clay to depth at HS-05. Such material would be less conductive to groundwater flow than the original granular alluvium and could result in less groundwater flow to the area southeast of the former channel and groundwater mounding on the opposite side. For example, the water table elevation at bores HS-05OS and HS-29 (approximately 6,792 ft, and 5 to 10 ft of saturated thickness), both on the northeast side of the former channel, is higher than the bedrock surface on the opposite side at dry locations HS-26 and HS-27 (6,784 and 6,779 ft, respectively). Flow characteristics near the former channel are also likely complicated by greater variability in the bedrock surface, the transition to increasingly steeper bedrock topography to the south, and flow converging on the outer end of the south slurry wall.

8.1.2.3 Uranium in Groundwater

The distribution of uranium in groundwater at the April 2009 temporary borings, from nearby monitoring wells sampled at that time, and at seeps and temporary borings that were sampled in 2000 or 2001 is shown in Figure 56. East of the mill site, the central portion of the floodplain extending to the PRB contains the greatest concentrations of uranium at relatively uniform concentrations that average about 1,250 µg/L. Concentrations are observed to decrease toward Montezuma Creek, likely the result of the transition to a losing stream condition and subsequent local dilution of the uranium plume. The concentration of uranium in Montezuma Creek at the mill site boundary has been consistently about 20 µg/L since site remediation (21 µg/L at location SW00-02 in April 2009; Figure 56). A similar but past effect may account for the observed decrease in uranium concentrations in groundwater toward the former channel of the creek.

Table 3. Summary of April 2009 Borehole Information

Location	Measurement Date	Northing ft	Easting ft	Elev Ground ft	Total Depth ft bgs	Depth To BR ft bgs	Elev BR ft	DTW ft bgs	Elev WT ft	Saturated Thickness ft	Uranium µg/L	Comment
88-85	9-Apr-09	10336	23983	6797.0	12.5	12.5	6784.5	4.8	6792.3	7.8	267	
92-07	9-Apr-09	10162	23918	6804.0	20.7	20.3	6783.7	16.8	6787.2	3.5	1048	
92-11	8-Apr-09	10618	23652	6813.0	14.2	14.1	6792.4	17.9	6795.1	2.7	220	
CREEK 1	30-Apr-09	10402	23967	6792.4	NA	NA	NA	NA	6792.4	NA	NO DATA	WEST END OF PRB CULVERT
CREEK 2	30-Apr-09	10376	23668	6795.9	NA	NA	NA	NA	6795.9	NA	NO DATA	250 FT WEST OF PRB CULVERT
CREEK 3	30-Apr-09	10434	23396	6800.1	NA	NA	NA	NA	6800.1	NA	NO DATA	AT MILL SITE EAST FENCE
CREEK 4	30-Apr-09	10522	23153	6801.9	NA	NA	NA	NA	6801.9	NA	NO DATA	DUE NORTH OF T01-08
HS01	6-Apr-09	10100	23812	6810.0	27.5	25.5	6784.5	DRY	DRY	0.0	DRY	
HS02	6-Apr-09	10191	23805	6800.2	18.0	18.0	6782.2	8.9	6791.3	9.1	1275	
HS03	6-Apr-09	10288	23805	6799.3	15.0	15.0	6784.3	6.1	6793.2	8.9	1486	
HS04	6-Apr-09	10241	23704	6799.9	16.5	16.5	6783.4	8	6791.9	8.5	1486	
HS05	7-Apr-09	10140	23704	6803.7	17.0	NO DATA	NO DATA	NO DATA	NA	NA	NO DATA	
HS05-OS	7-Apr-09	10157	23705	6802.7	16.0	16.0	6786.7	11	6791.7	5.0	479	
HS06	7-Apr-09	10038	23705	6819.6	19.0	19.0	6800.6	DRY	DRY	0.0	DRY	
HS07	7-Apr-09	10088	23597	6816.7	16.0	15.0	6801.7	13	6803.7	2.0	471	BR ELEV FROM SITE GEOLOGIC MAP
HS08	7-Apr-09	10192	23611	6802.3	15.0	15.0	6787.3	9	6793.3	6.0	452	
HS09	7-Apr-09	10282	23603	6800.2	14.0	14.0	6786.2	6.5	6793.7	7.5	792	
HS10	7-Apr-09	10337	23506	6800.7	7.5	7.5	6793.2	6.5	6794.2	1.0	644	
HS11	7-Apr-09	10238	23506	6802.4	12.0	12.0	6790.4	8.7	6793.7	3.3	1086	
HS12	7-Apr-09	10142	23508	6813.4	12.0	3.0	6810.4	DRY	DRY	0.0	DRY	
HS13	7-Apr-09	10062	23505	6826.8	18.5	15.0	6811.8	DRY	DRY	0.0	DRY	
HS14	8-Apr-09	10139	23368	6826.4	15.0	14.5	6811.9	DRY	DRY	0.0	DRY	
HS15	8-Apr-09	10289	23310	6817.9	18.5	18.5	6799.4	DRY	DRY	0.0	DRY	
HS16	8-Apr-09	10215	23311	6823.3	12.0	12.0	6811.3	DRY	DRY	0.0	DRY	
HS17	9-Apr-09	10109	23273	6831.8	13.5	13.5	6818.3	DRY	DRY	0.0	DRY	
HS18	9-Apr-09	10123	23229	6830.3	8.5	8.5	6821.8	DRY	DRY	0.0	DRY	
HS19	9-Apr-09	10142	23166	6829.0	9.5	9.5	6819.5	DRY	DRY	0.0	DRY	
HS20	8-Apr-09	10247	23216	6821.3	9.5	8.5	6812.8	DRY	DRY	0.0	DRY	
HS21	8-Apr-09	10341	23199	6809.6	7.0	7.0	6802.6	DRY	DRY	0.0	DRY	
HS22	8-Apr-09	10281	23117	6823.7	2.0	2.0	6821.7	DRY	DRY	0.0	DRY	
HS23	9-Apr-09	10195	23093	6827.5	7.5	6.5	6821.0	DRY	DRY	0.0	DRY	
HS24	9-Apr-09	10095	23069	6838.9	14.5	8.5	6830.4	DRY	DRY	0.0	DRY	
HS25	7-Apr-09	10027	23823	6820.0	36.0	36.0	6784.0	DRY	DRY	0.0	DRY	GROUND ELEV IS APPROX
HS26	8-Apr-09	10116	23736	6806.0	22.5	22.5	6783.5	DRY	DRY	0.0	DRY	
HS27	8-Apr-09	10158	23782	6803.1	24.0	24.0	6779.1	DRY	DRY	0.0	DRY	
HS28	8-Apr-09	10245	23859	6799.3	15.0	15.0	6784.3	8	6791.3	7.0	1516	
HS29	8-Apr-09	10207	23747	6800.2	18.0	18.0	6782.2	8.1	6792.1	9.9	1116	
HS30	8-Apr-09	10148	23654	6803.4	11.5	11.5	6791.9	DRY	DRY	0.0	DRY	
HS30-OS	8-Apr-09	10165	23660	6802.7	15.0	13.0	6789.7	DRY	DRY	0.0	DRY	
HS31	8-Apr-09	10244	23656	6800.8	12.5	12.5	6788.3	7.5	6793.3	5.0	NO DATA	
HS31-OS	8-Apr-09	10229	23659	6800.9	12.5	12.5	6788.4	7.5	6793.4	5.0	1547	
HS32	8-Apr-09	10287	23697	6799.0	15.0	15.0	6784.0	6.8	6792.2	8.2	1232	
HS33	8-Apr-09	10380	23301	6806.3	9.0	9.0	6797.3	DRY	DRY	0.0	DRY	
HS34	9-Apr-09	10112	23327	6832.7	16.0	16.0	6816.7	DRY	DRY	0.0	DRY	
HS35	9-Apr-09	10123	23185	6831.3	NO DATA	NO DATA	NO DATA	DRY	DRY	0.0	DRY	TD NOT RECORDED

Table 3 (continued). Summary of April 2009 Borehole Information

Location	Measurement Date	Northing ft	Easting ft	Elev Ground ft	Total Depth ft bgs	Depth To BR ft bgs	Elev BR ft	DTW ft bgs	Elev WT ft	Saturated Thickness ft	Uranium µg/L	Comment
HS36	9-Apr-09	10125	23125	6825.3	5.0	5.0	6820.3	DRY	DRY	0.0	DRY	
MW00-03	9-Apr-09	10016	23082	6850.7	9.2	8.5	6842.2	6.0	6844.8	2.6	598	
PW-10	8-Apr-09	10062	23911	6813.9	33.4	32.2	6781.8	31.7	6782.2	0.4	1100	
PW-17	8-Apr-09	10055	23854	6817.6	35.9	34.8	6782.8	33.0	6784.4	1.6	960	
PW-18	8-Apr-09	10417	24030	6795.7	10.5	11.5	6784.2	4.1	6791.6	7.4	NO DATA	
PW-23	NA	10129	23836	6809.2	25.0	24.6	6784.4	23.5	6785.7	1.3	NO DATA	HISTORICAL DTW AND SAT THICK
PW-28	8-Apr-09	10446	23994	6800.0	14.3	14.0	6786.0	8.7	6791.3	5.3	200	
Seep 4307	Apr-00	10085	22618	NA	NA	NA	NA	NA	NA	NA	824	
Seep 5215	Apr-00	10249	23176	NA	NA	NA	NA	NA	NA	NA	1480	
T00-01	Apr-09	10523	23399	6806.6	12.5	11.8	6794.8	8.6	6798.0	3.2	NO DATA	
T00-02	Apr-00	10476	23400	6804.5	8.0	7.0	6797.5	NO DATA	NA	NO DATA	NO DATA	
T00-03	9-Apr-09	10397	23400	6803.3	7.0	6.8	6796.6	5.68	6797.6	1.1	150	
T00-04	9-Apr-09	10354	23401	6804.4	8.0	7.5	6796.9	5.0	6797.4	0.5	511	
T00-05	9-Apr-09	10314	23401	6807.5	10.8	10.5	6797.0	10.15	6797.4	0.4	2339	
T00-06	9-Apr-09	10246	23399	6818.9	12.8	12.3	6806.7	DRY	DRY	0.0	DRY	
T00-07	9-Apr-09	10190	23400	6821.2	12.0	11.0	6810.2	10.26	6810.9	0.7	700	
T00-17	Aug-00	10049	22572	6860.6	9.5	8.5	6852.1	8.0	6852.6	0.5	638	
T00-18	Aug-00	10043	22624	6860.2	10.5	9.0	6851.0	9.0	6851.2	0.2	1110	
T00-19	Aug-00	10033	22805	6856.5	9.5	8.5	6848.0	5.5	6851.0	3.0	935	
T00-20	Aug-00	10019	22956	6855.5	9.8	8.0	6847.5	DRY	DRY	0.0	DRY	
T00-21	Aug-00	10008	23067	6850.8	10.5	7.5	6843.3	DRY	DRY	0.0	DRY	
T00-22	Aug-00	10010	23212	6846.0	6.5	5.0	6841.0	DRY	DRY	0.0	DRY	
T00-23	Aug-00	10011	23371	6837.8	12.5	9.5	6828.3	DRY	DRY	0.0	DRY	
T00-24	Aug-00	9920	23004	6862.1	12.5	9.5	6852.6	DRY	DRY	0.0	DRY	
T00-25	Aug-00	9897	23096	6867.1	6.3	6.0	6861.1	DRY	DRY	0.0	DRY	
T00-26	Aug-00	9906	23051	6864.8	15.5	12.3	6852.5	DRY	DRY	0.0	DRY	
T01-01	7-Apr-09	10571	23368	6804.9	10.5	9.0	6795.9	6.6	6798.3	2.4	110	
T01-02	7-Apr-09	10621	23370	6806.1	10.5	10.0	6796.1	7.8	6798.3	2.2	220	
T01-08	9-Apr-09	10433	23162	6807.7	7.5	7.0	6800.8	3.7	6804.3	3.5	1451	
T01-11	May-01	10310	22751	6839.1	7.7	7.5	6831.6	DRY	NA	0.0	DRY	
T01-16	May-01	10166	22424	6866.6	15.7	9.5	6857.1	DRY	NA	0.0	DRY	
T01-17	May-01	10106	22750	6854.8	11.0	7.0	6847.8	DRY	NA	0.0	DRY	
T01-40	Oct-01	10034	23877	6818.4	37.3	36.3	6782.1	DRY	DRY	0.0	DRY	

bgs = Below ground surface
BR = Bedrock
DTW = Depth to water
WT = Water table
NA = Not applicable

An objective of the April 2009 study was to confirm that the area studied in 2000 and 2001 was not a continuing source of contaminated water to the alluvial aquifer. At that time, Seep 4307 and temporary wells T00-17, T00-18, and T00-19 contained moderately high concentrations of uranium (Figure 56). Uranium concentrations at well MW00-03 at that time were also high, and remain so. Numerous other temporary wells installed in the area as part of those studies were dry to bedrock. That finding, and the preponderance of dry holes installed in April 2009 downgradient of the 2000/2001 temporary wells, and downgradient of existing well MW00-03, suggests that the uranium contamination in the area of the 2000/2001 sample locations (excepting former Seep 5215) and MMW00-03 is isolated from the alluvial aquifer.

The source of uranium contamination at Seep 4307; temporary wells T00-17, T00-18, and T00-19; and well MW00-03 is attributed to the old Acid Plant waste ponds (unlined) identified in Figure 56, where process liquids were stored and allowed to evaporate (or infiltrate) during later stages of mill operation. The waste liquid has since dissipated; however, residual uranium from the liquids likely remains in the soil matrix. Re-saturation of the soil could then release uranium to the aqueous phase. A previous investigation conducted (DOE 2001a) attributed the slight amount of groundwater at those wells and Seep 4307 to originate from seepage from a nearby run-on control ditch constructed by the remediation contractor. This ditch was deliberately filled during the final grading of the site in 2002, likely eliminating the source of recharge to those locations (excepting well MW00-03). Well MW00-03 is upslope of the former ditch, so the ditch would not affect groundwater there. Well MW00-03 is in the down slope terminus of a prominent drainage ravine ("Deer Draw"). Temporary wells T00-21, T00-24, T00-25, and T00-26, in the axis of the ravine upgradient of well MW00-03, did not intercept groundwater saturation; however, some moisture was present in the sediments immediately above the bedrock surface during well installation. Persistent groundwater at well MW00-03 likely originates as seepage of moisture in the partially saturated basal sediments, which moves down the ravine and accumulates in a possible bedrock depression at well MW00-03. Temporary borings installed in the axis of the ravine a short distance downgradient of well MW00-03 were dry, and no seeps are present in the area. These observations suggest that groundwater flow from the area of well MW00-03 is very diffuse.

Seep 5215 was in an area of the alluvial aquifer where remedial actions removed much of the aquifer substrate to the bedrock surface. The area was subsequently reconstructed, thereby eliminating the seep. The water sample collected there in 2000 emanated from exposed sand and gravel deposits constituting the alluvial aquifer. This location is adjacent to the southeast toe of the former East Tailings Pile. The immediate area surrounding the location of former Seep 5215 currently is dry, likely because extensive creek and aquifer reconstruction create a strong drain effect on the mill site.

8.1.3 Summary and Conclusions

The goals of the groundwater hot spot study were to determine if the uranium plume is greater in area and magnitude of concentration than was represented by the starting concentrations specified in the OU III model and to determine if a continuing source of contaminated groundwater exists in the southeast area of the former mill site. With respect to these goals, the following summary and conclusions are presented:

- Uranium contamination characterized by the present field study is much greater in area and magnitude of concentration than is configured as the starting condition in the OU III groundwater model. The configuration of the initial plume represented in the model, based on October 2002 monitoring data, is very similar to that shown in Figure 2 (based on April 2009 data). In that figure, only a small area is encompassed by the 750 pCi/L isopleths. By comparison, nearly the entire study area is shown to be underlain by uranium concentrations between about 1,000 to 2,000 pCi/L—higher concentrations are distributed over a larger area than represented in the model. The model also assumes that the entire area is saturated and is not influenced by possible barrier or stagnation effects created at the former creek channel. These conditions could lead to a longer restoration period than predicted by the model.
- The general absence of groundwater in the southeast portion of the former mill site indicates that the area is not a continuing source of contamination to the alluvial aquifer. Uranium detected at well MW00-03 and at the former temporary wells and a former seep in the area likely originated from former waste storage ponds that leaked contaminated process water, leaving residual uranium in the soil matrix. The source of water to the former temporary wells and the seep (seepage from a run-on control ditch) was eliminated through site reconstruction. Groundwater saturation at well MW00-03 is persistent; however, the field studies provide no evidence of significant groundwater flow from that location.
- Results of the field study indicate that expansion of the groundwater treatment system between the mill site and PRB is feasible with respect to hydrogeologic conditions and uranium distribution. The maximum saturated thickness and uranium concentrations occur within the central portion of the floodplain. In this area, the water table is shallow (less than 10 ft), ground surface and bedrock surface topography is relatively flat, and the base of the aquifer is uniformly only about 15 ft below ground surface. These conditions suggest that the greatest volume of contaminated water and the greatest mass of contamination is readily accessible for extraction. Conditions for expanding the groundwater extraction system are less favorable toward the creek because uranium concentrations decrease in that direction and an extraction system would draw a greater proportion of uncontaminated water from the creek. Conditions for expansion are least favorable toward the south margin of the aquifer because of discontinuous and thinner groundwater saturation, lower uranium concentrations, and increased variability in bedrock and ground surface topography.

8.2 Seep 6 Investigation

Post-remediation monitoring has shown elevated concentrations of uranium at Seep 6 (Figure 26), typically at about 2,000 pCi/L. Other COCs detected at elevated concentrations at Seep 6 are vanadium and molybdenum, typically about 200 and 150 µg/L, respectively. Arsenic and manganese concentrations are not elevated, and as discussed in Section 4.8.1, elevated concentrations of nitrate and selenium at this location are not attributed to the mill.

The occurrence of persistent high uranium concentrations at Seep 6 prompted DOE to investigate the source of contamination and water to the seep and to assess potential impact to water quality in the alluvial aquifer, Montezuma Creek, and adjoining wetlands. The investigation was

conducted through a review of OU I remedial action documents, OU III water quality and hydrogeologic documents, and field study.

Seep 6 is located on the south-facing hillside of the former mill site, northwest of Wetland 2, just uphill of the site access road (see Figure 57). Seep 6 was first identified as Hillside East Seep during wetlands delineation activities after the completion of OU I remediation activities in 1998 (DOE 2005c). Before remediation, the Seep 6 area was located at the north edge of the Carbonate Tailings Pile, where no water emerged at the surface. Following remediation, which altered surface topography to expose shallow groundwater in this area, wetland vegetation established naturally at the new seep and was not significantly disturbed during subsequent regrading and topsoiling phases of site reclamation. The seep hosts predominantly obligate wetland plant species, indicating a probable year-round water source.

8.2.1 Seep 6 Contaminant Source

No known mill structures, processing or storage areas, or ore stockpiles were located over the present location of Seep 6, or between Seep 6 and uphill peripheral property MP−00180−VL (identified in Figure 57 as 180). Most of the hillside soil on the mill site was removed during remediation, leaving exposed weathered or competent Mancos Shale bedrock. A thin layer of clean, off-site material was placed over the remediated surface prior to revegetation.

The area immediately south of Seep 6 was excavated during remediation beyond the required radium-226 cleanup standard for removing mill tailings, and radiologically contaminated soil, sediment, and debris. Excavation beyond this standard was done because this area, and others formerly underlain by mill tailings, was identified in OU III characterization activities to contain uranium at concentrations that could present a long term source of groundwater contamination. In these areas, dissolved uranium that originated from the mill tailings had percolated into and accumulated in the sub-pile soil that was uncontaminated relative to the Ra-226 cleanup standard. The OU III characterization activities that evaluated this sub-pile soil (or residual vadose zone) are presented in DOE 2000 and DOE 2001a.

Three buried water lines are located on property 180: a municipal sanitary sewer line, an irrigation line, and a domestic water line. The sewer and irrigation pipelines are located close together on the west edge of the property (see Figure 57). In a phased approach to remediate the property, test pits, excavated in late 1998, showed radiological contamination to the burial depth of the sewer line (22 ft); soils near the sewer line had higher levels of contamination than soils near the irrigation pipe (DOE 2001b). The irrigation line is buried at about 7 ft below ground surface. DOE, UDEQ, and EPA determined to remediate the water line corridor to a depth of 4 ft and to leave the deeper contamination in place and to designate and manage the contamination in this utility corridor as a supplemental standards area.

The remainder of property 180, with contamination extending to depths of 3 to 4 ft, was remediated to the Ra-226 cleanup standard. Tailings and ore were found during surface remediation, and it is assumed that the deep contamination left in place in the water utility corridor contains both tailings and ore. Additionally, use of mill tailings as bedding material for utilities was a common practice in Monticello before environmental controls were established.

8.2.2 Seep 6 Hydrology

Subsurface water is expressed at Seep 6 as diffuse flow of 1 to 2 gpm from exposed Mancos Shale in an area of about 1,000 square feet on the steep hillside. The seep is not an expression of groundwater discharge from the alluvial aquifer because it is topographically much higher than the alluvial deposits. Open water is not present at Seep 6. Seep water collects in a small roadside drain from where it flows through a culvert beneath the road. Below the outfall of the culvert, the seep water is absorbed into the soil or is consumed through evapotranspiration; there is no direct surface flow from Seep 6 to Wetland 2.

The composition of the shale locally comprises an upper weathered zone that transitions to competent rock within about 10 ft of ground surface. The upper 1 to 2 ft of the weathered zone is decomposed shale. The remainder of the weathered zone is typically highly fractured and moderately consolidated. The shallow bedrock beneath the weathered zone is fractured. Three test holes drilled above Seep 6 in April 2009 at the locations shown in Figure 57 met refusal at competent bedrock at a depth of about 8 ft, and no groundwater was encountered. Only a thin veneer of imported topsoil (less than 1 ft thick) overlies weathered shale at these locations. The borings were located immediately downslope of a ditch that diverts run-off from property 180 to a rock-lined channel leading to Montezuma Creek.

Monitoring wells installed in the Mancos Shale during prior OUs I and III characterization activities identified that groundwater saturation in the formation is generally absent, and where present, it is associated with occasional fractures in competent rock (for example, at wells 31SW93-197-2 through 197-5, and wells 31SW93-200-1 through 200-3 [see Plate 1 for location]). An exception is saturation of the upper weathered zone at well 200-1 because this location directly underlies the alluvial aquifer. The formation is primarily dry below this zone and the Mancos Shale is in general regarded as an aquitard.

At monitoring well 31SW93-202-2, formerly located a short distance above Seep 6 (see Figure 57), groundwater was encountered in fractured, competent Mancos Shale at depths between about 20 and 30 ft (total borehole depth of 35 ft). The weathered zone at that location was dry. The well was sampled on one occasion (November 1993), at which time uranium was detected at 1,300 µg/L, similar to concentrations detected at Seep 6. Water level monitoring at well 202-02 during 1994 through 1996 indicated a water table elevation of approximately 6,892.5 ft. The top of the discharge zone at Seep 6 is about 6,890 ft, hydraulically downgradient of well 202-2.

The water expressed at Seep 6 is not likely derived from local percolation of precipitation because the surrounding steep topography and fine-textured soil favor rapid runoff, and because saturation of the Mancos Shale is atypical. Instead, the source of water expressed at Seep 6 (and encountered at former well 202-2) is suspected to be of cultural origin. Possible cultural sources of water are leakage from the sewer and irrigation water lines on property 180, irrigation returns or water line leakage from the neighboring residential area to the west and northwest, or stockyard watering and process water associated with the meat processing facility on property 139.

Of these possible sources, the domestic water service on property 139 was replaced by DOE during remediation in 1992 to 1994; the condition of the irrigation line (24-in diameter plastic

pipe), which transits water only seasonally, is not known; and, the condition of the sewer line is not known. Field records associated with radiological assessment and remediation activities in the area of these water lines provide no information on subsurface conditions regarding soil or rock type, or evidence of pipe leakage or groundwater saturation. Assuming that subsurface flow paths are influenced by ground surface topography (see Figure 57), if the water expressed at Seep 6 originates from water line leakage, the leak is likely located in the northern portion of property 180. Leakage in the south portion of the property would likely flow well west of Seep 6.

DOE has identified numerous seeps, including Seep 6, in previous investigations (DOE 1998a and DOE 2005c) that are downslope of a water utility (see Figure 58) and are located above the alluvial valley. The few seeps observed south of Montezuma Creek (Seep 4, well T01-27 Seep, and well T01-28 Seep) are near a domestic water line or are associated with local alluvial aquifer discharge to surface water to Wetland 1 or Montezuma Creek.

8.2.3 Local Surface Water and Groundwater Quality

Groundwater and surface water locations that are routinely monitored downgradient of Seep 6 include alluvial aquifer well T01-23 and Montezuma Creek site SW01-03 (Figure 57). Uranium concentrations at well T01-23 average about 40 µg/L and show a subtle downward trend. Uranium concentrations in Montezuma Creek at site SW01-03, located immediately downstream of the Wetland 2 outlet, range between about 10 and 20 µg/L and also have shown a subtle downward trend. In June 2009, a water sample was collected from Wetland 2 at the point closest to the Seep 6 outfall. The uranium concentration in that sample was 37 µg/L, very similar to that at alluvial aquifer well T01-23. This area of the wetland has long been recognized as a discharge zone of the alluvial aquifer. Uranium concentrations at alluvial aquifer well T01-24 (see Figure 57 for well location), which was monitored in 2001 to 2004, averaged about 30 µg/L. Surface water samples collected at location Upper North Drainage (see Figure 58 for sample location) in 1994 contained uranium at 20 and 35 µg/L. Water samples were collected from Steele Pond in October 2001 and February 2002. These samples contained uranium at background levels.

8.2.4 Seep 6 Conceptual Model

- Surface remediation removed a thin veneer of soil and shale residuum to expose shallow, pre-existing groundwater at the location of Seep 6.
- Radiologic contamination remains in place to depths of 20 ft in the corridor of the sewer and irrigation lines along the west side of property MP−00180−VL. This supplemental standards material is hydraulically upgradient of Seep 6 (and former well 202-2) and is the suspected source of uranium contamination at Seep 6 (and at former well 202-2).
- Water expressed at Seep 6 is likely from a man-made source because local conditions do not favor significant natural recharge. Leaking water utilities on the north portion of property MP−00180−VL are possible sources of the water expressed at Seep 6. Water from the leaking pipes contacts mill tailings or uranium ore in the utility corridor, from which uranium is mobilized. The contaminated water then flows southeast by way of fracture flow in the upper weathered zone of the Mancos Shale.
- High uranium concentrations at Seep 6 are not reflected locally in the alluvial aquifer, Wetland 2, or Montezuma Creek. The impact of Seep 6 on water quality in the alluvial aquifer, Wetland 2, and Montezuma Creek appears to be minimal. Relatively low-level

uranium contamination in the alluvial aquifer in the area of Wetland 2 is likely associated with contamination derived from the Carbonate Tailings Pile which formerly overlaid this portion of the alluvial aquifer.

- The inferred source of contamination (mill tailings or uranium ore) is likely to remain in place until the water utilities are accessed for maintenance or replacement at which time DOE will manage the radiological waste in accordance with procedures provided in the *Long-Term Surveillance and Maintenance Plan for the Monticello NPL Sites* (DOE 2007a). Improved water quality at Seep 6 would depend on the extent and location of source removal.
- The inferred source of water to Seep 6 (leaking water lines) is likely to remain until leaks are repaired or if other possible cultural sources (irrigation returns or meat processing facility) are eliminated.

9.0 References

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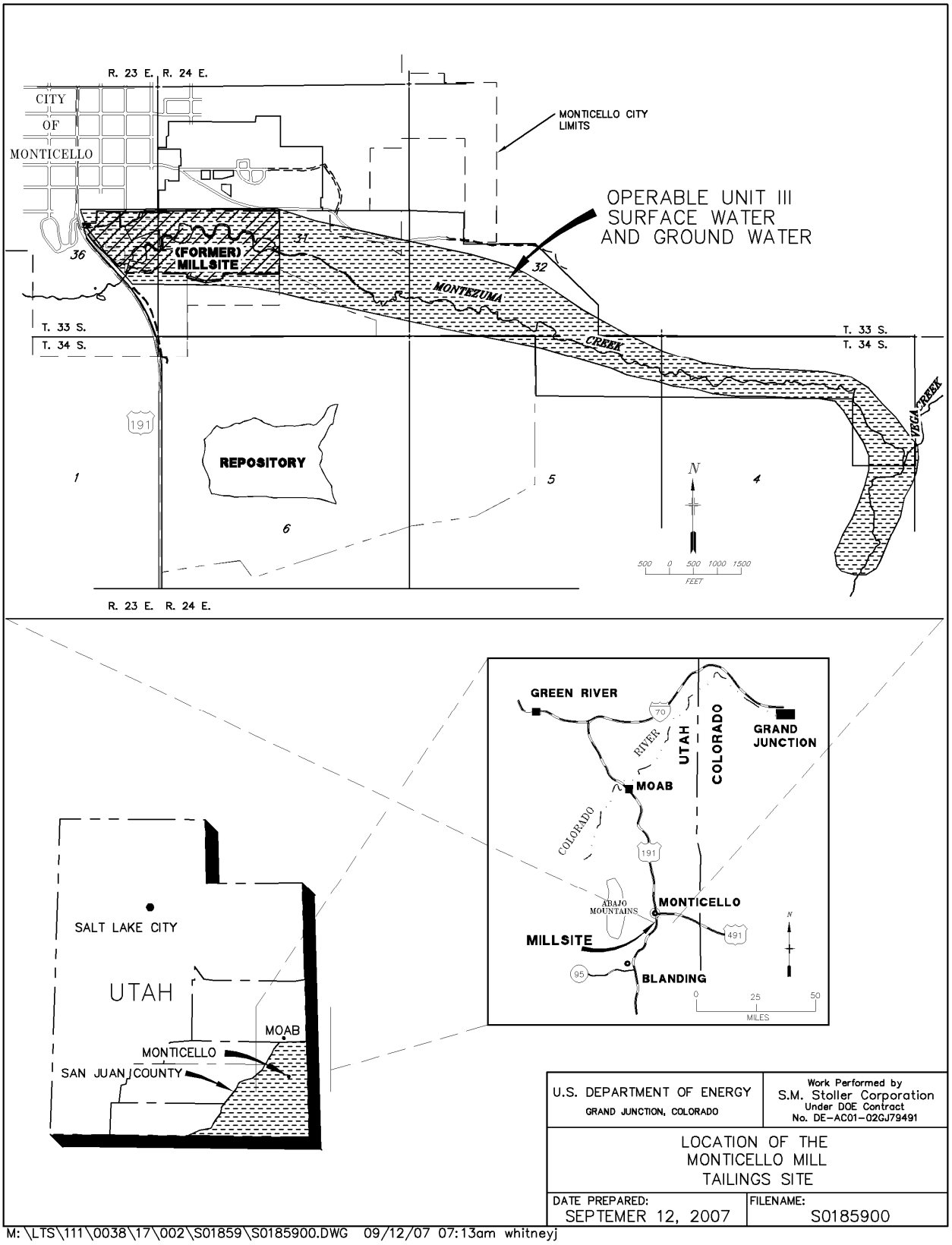

Figure 1. Location of the Monticello Mill Tailings Site

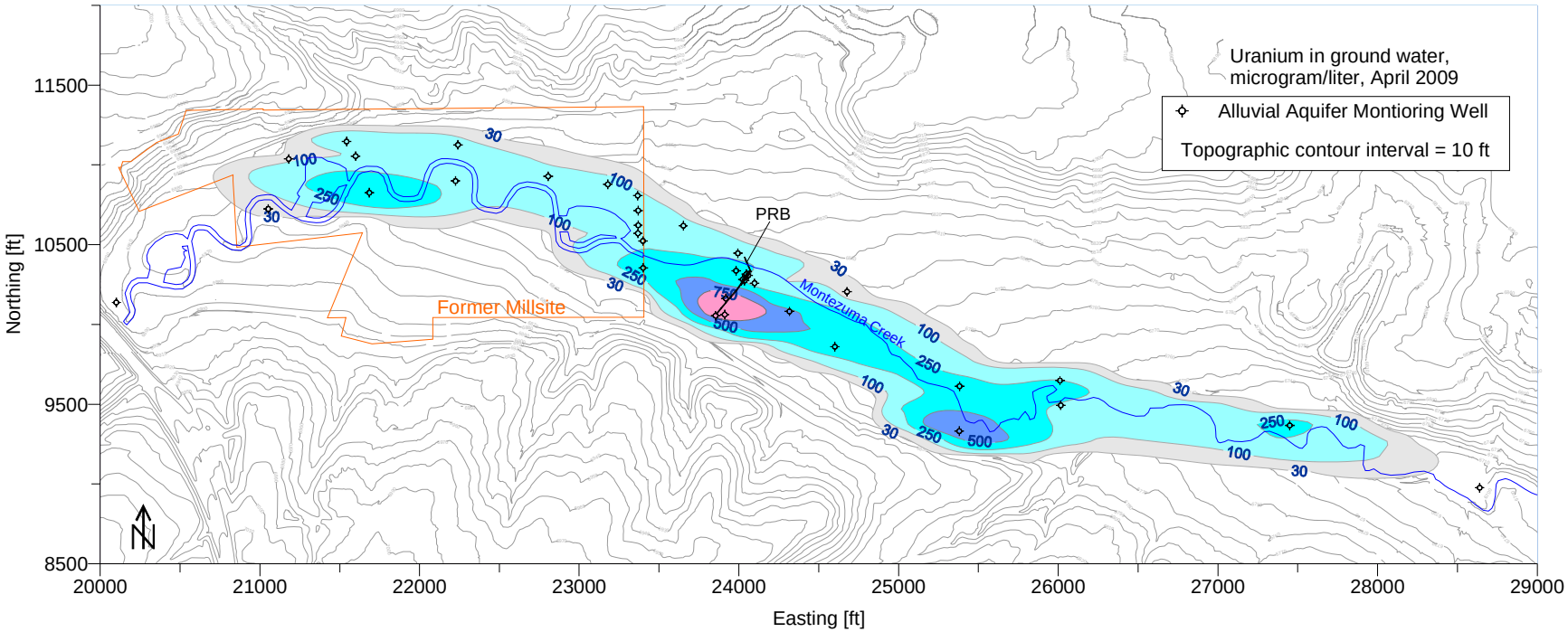

Figure 2. Uranium Groundwater Plume, April 2009

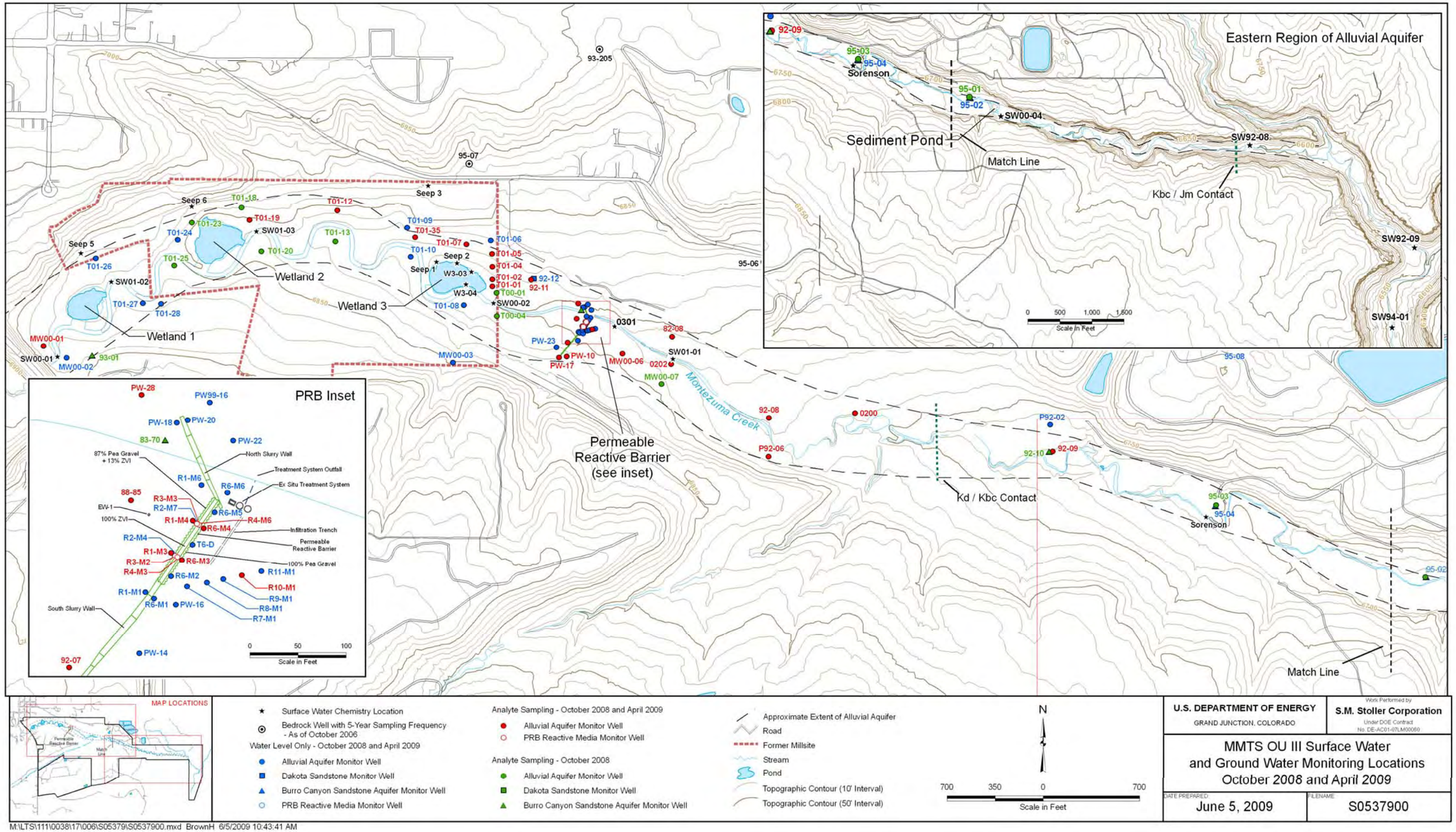

Figure 3. Reference Map for OU III Water Quality Monitoring Locations

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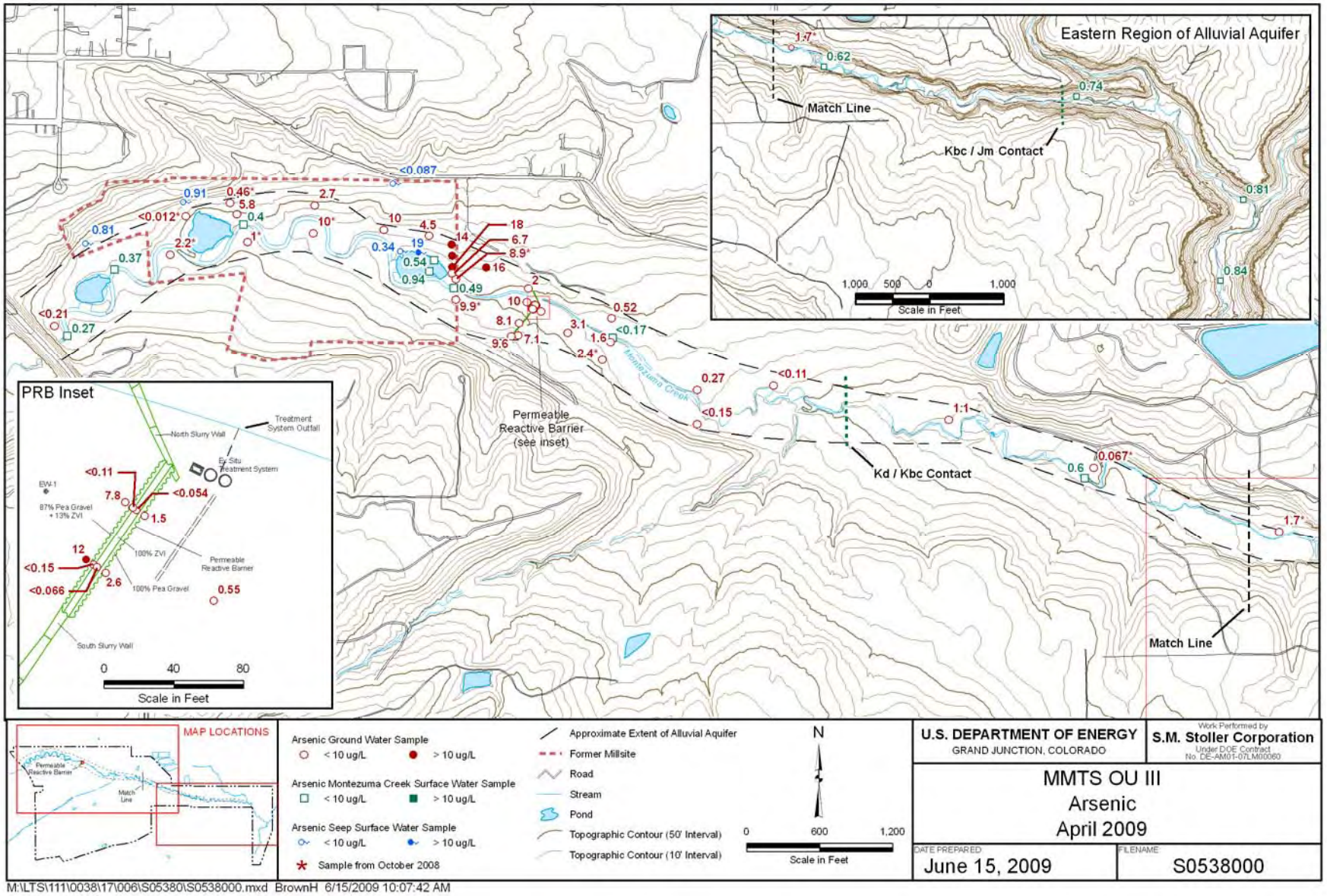

Figure 4. Distribution of Arsenic in Surface Water and Alluvial Aquifer Groundwater, April 2009

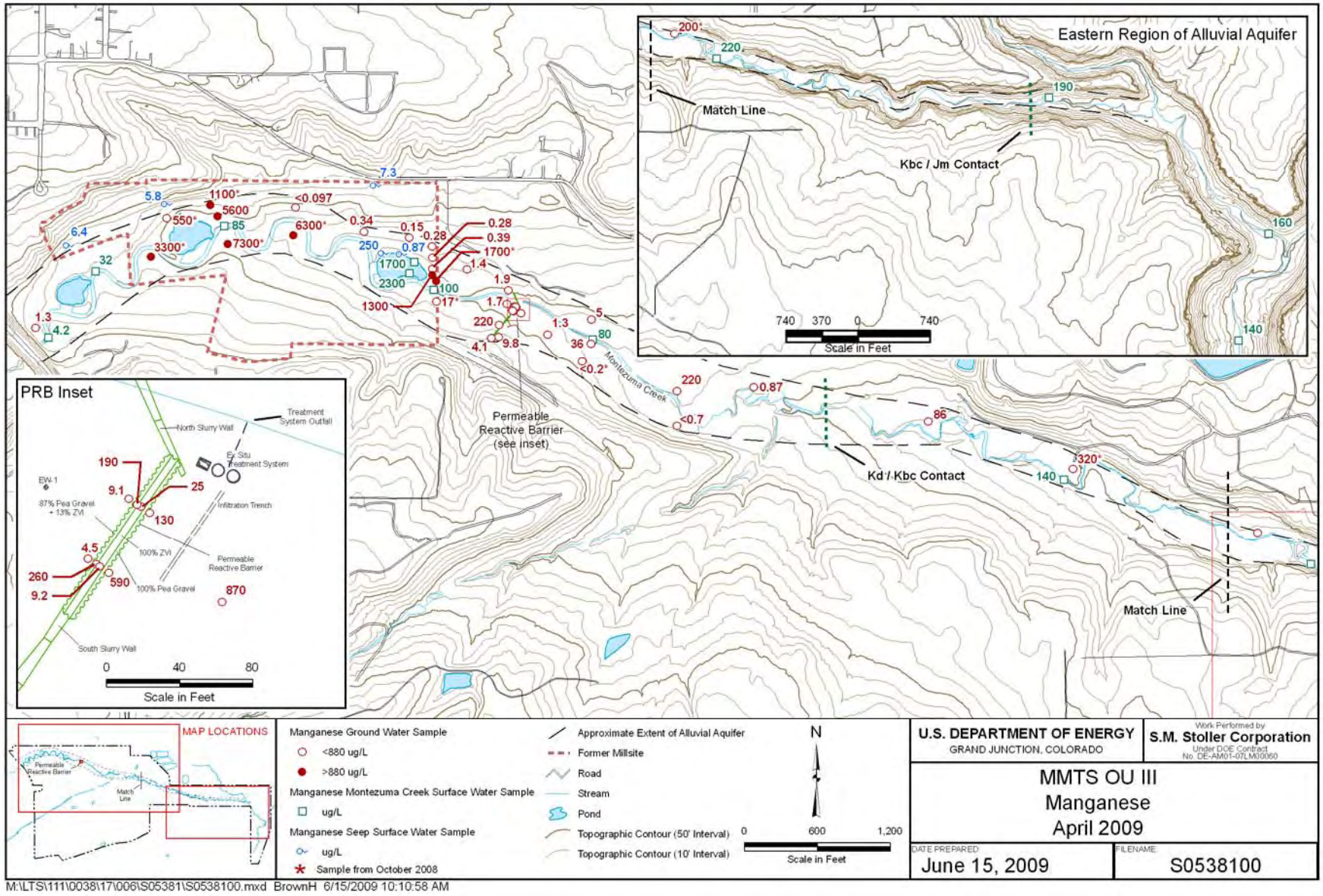

Figure 5. Distribution of Manganese in Surface Water and Alluvial Aquifer Groundwater, April 2009

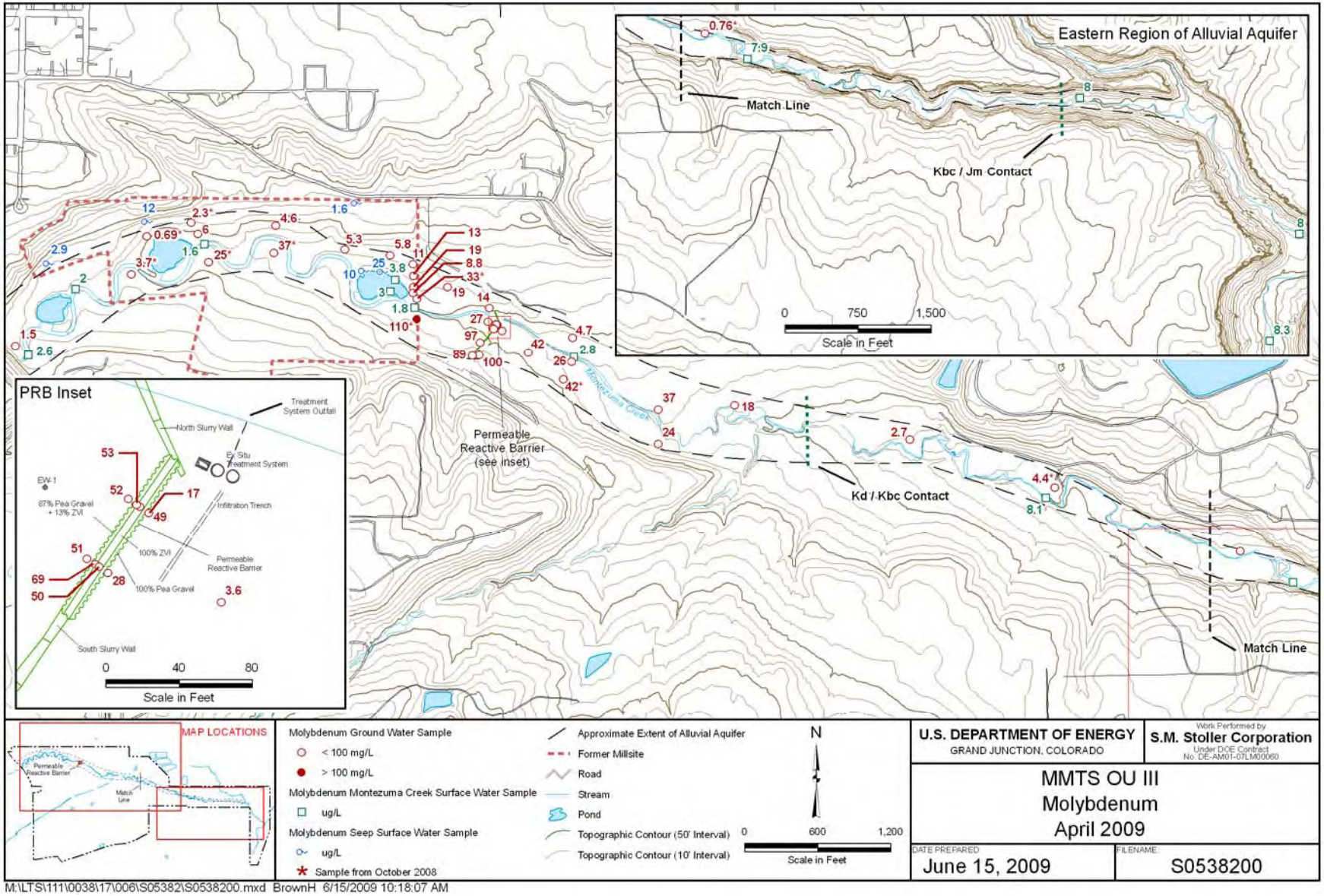

Figure 6. Distribution of Molybdenum in Surface Water and Alluvial Aquifer Groundwater, April 2009

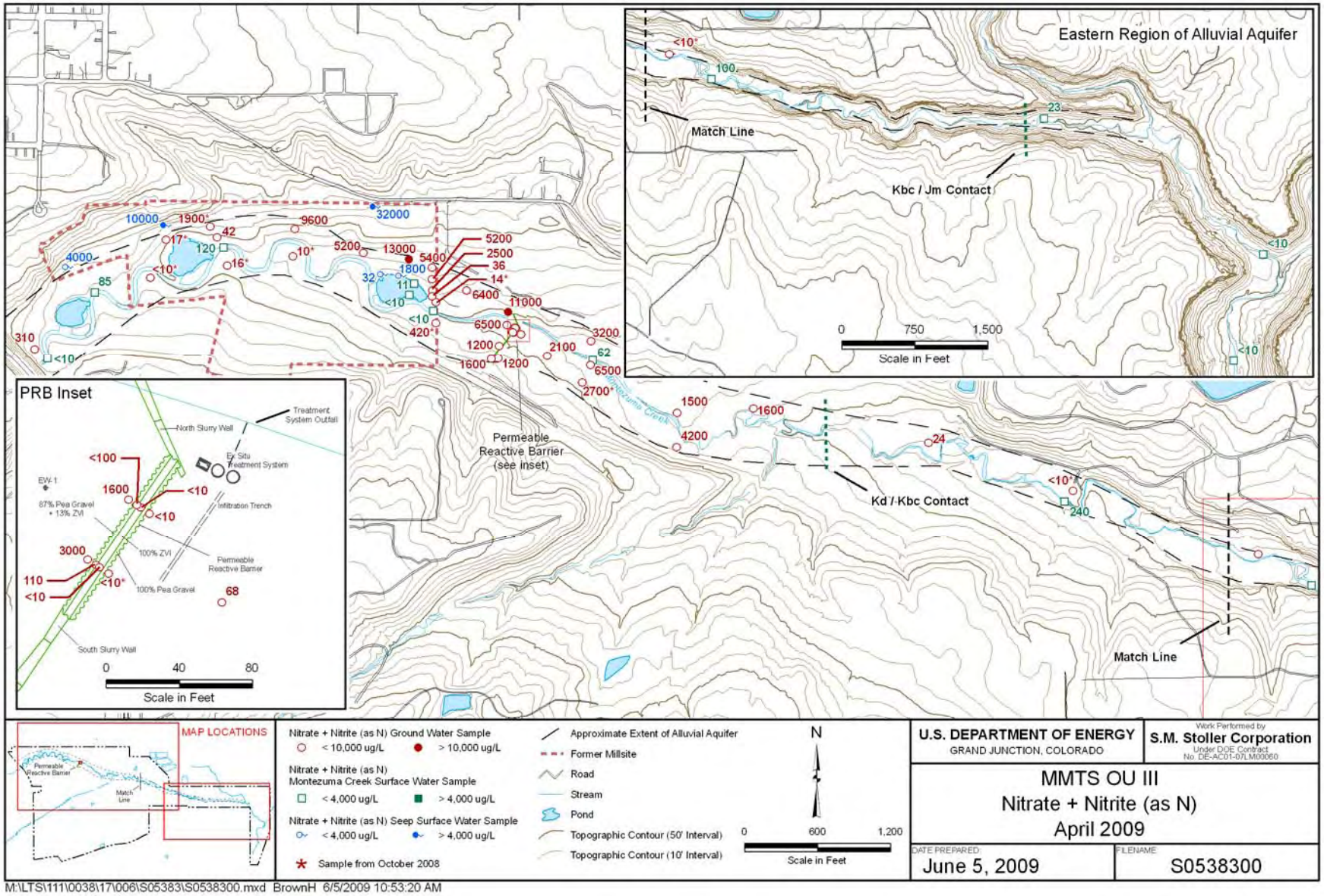

Figure 7. Distribution of Nitrate (as Nitrogen) in Surface Water and Alluvial Aquifer Groundwater, April 2009

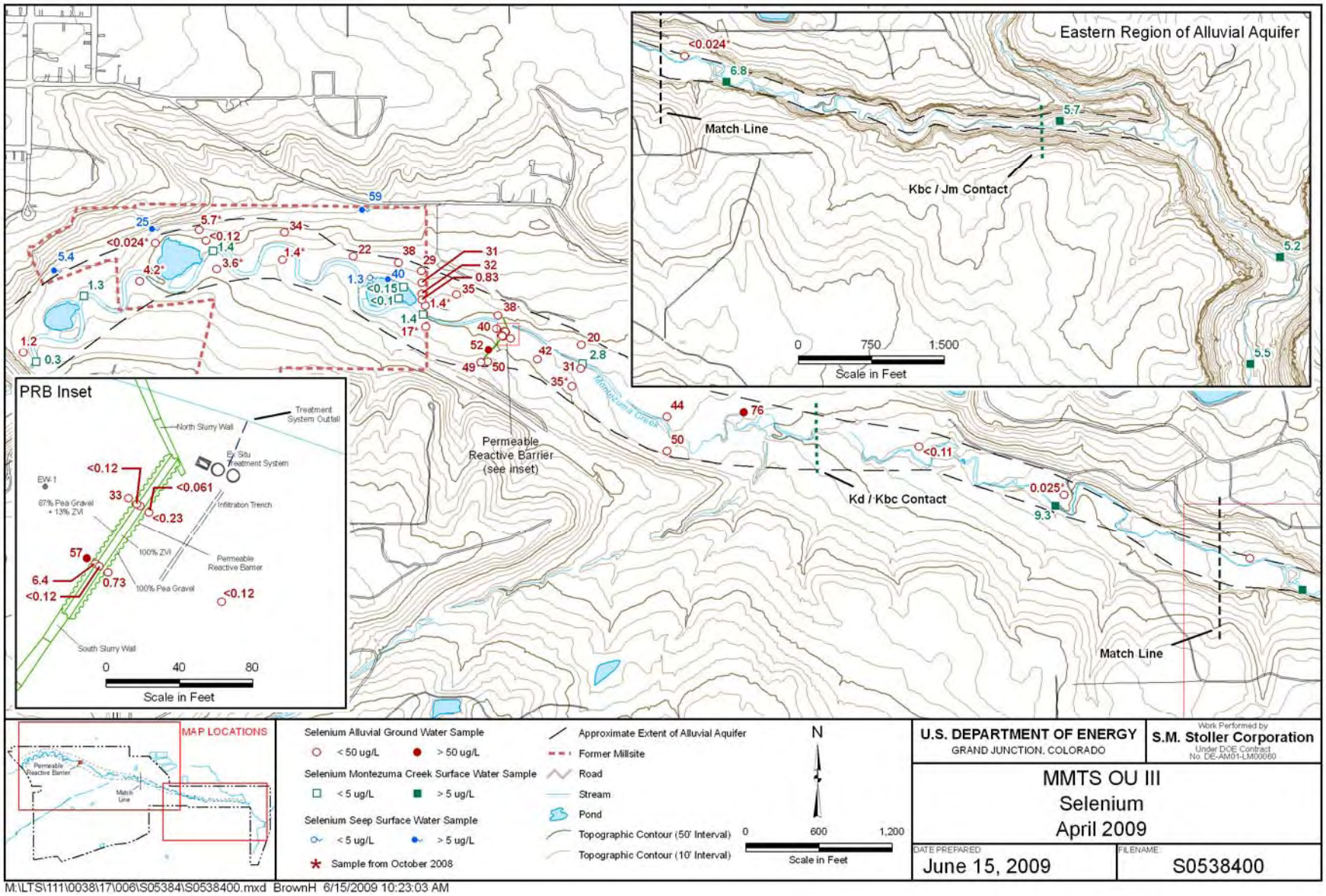

Figure 8. Distribution of Selenium in Surface Water and Alluvial Aquifer Groundwater, April 2009

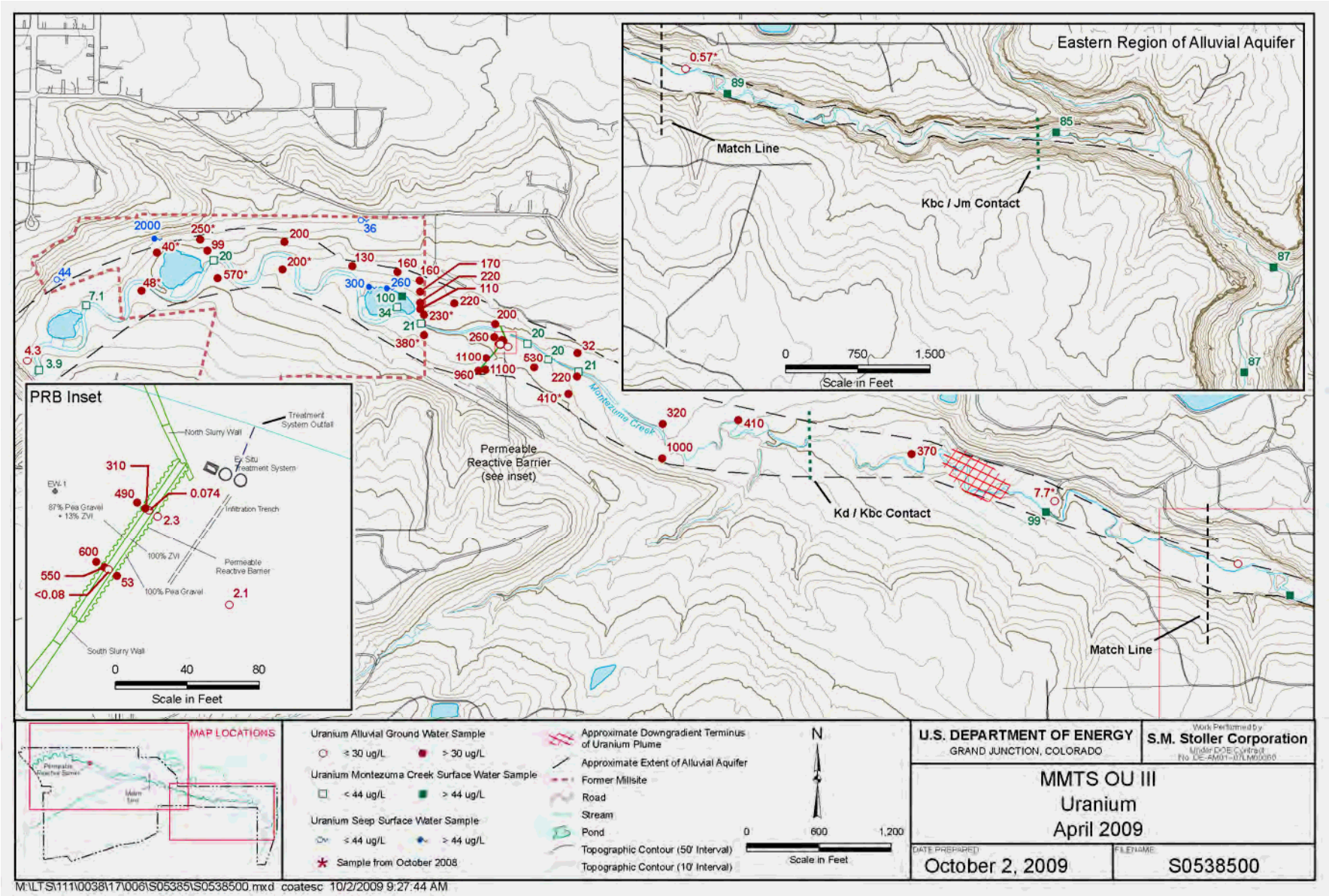

Figure 9. Distribution of Uranium in Surface Water and Alluvial Aquifer Groundwater, April 2009

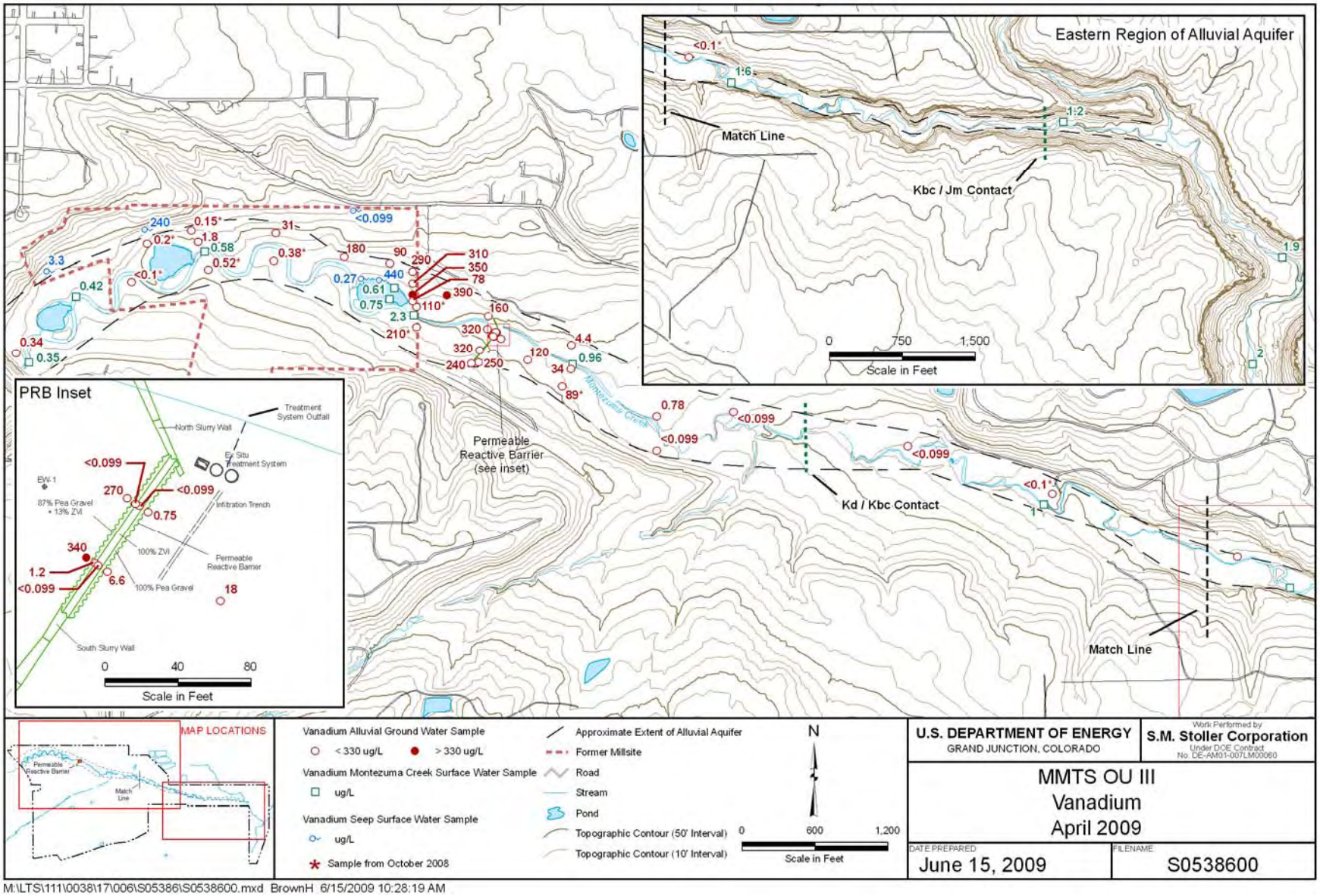

Figure 10. Distribution of Vanadium in Surface Water and Alluvial Aquifer Groundwater, April 2009

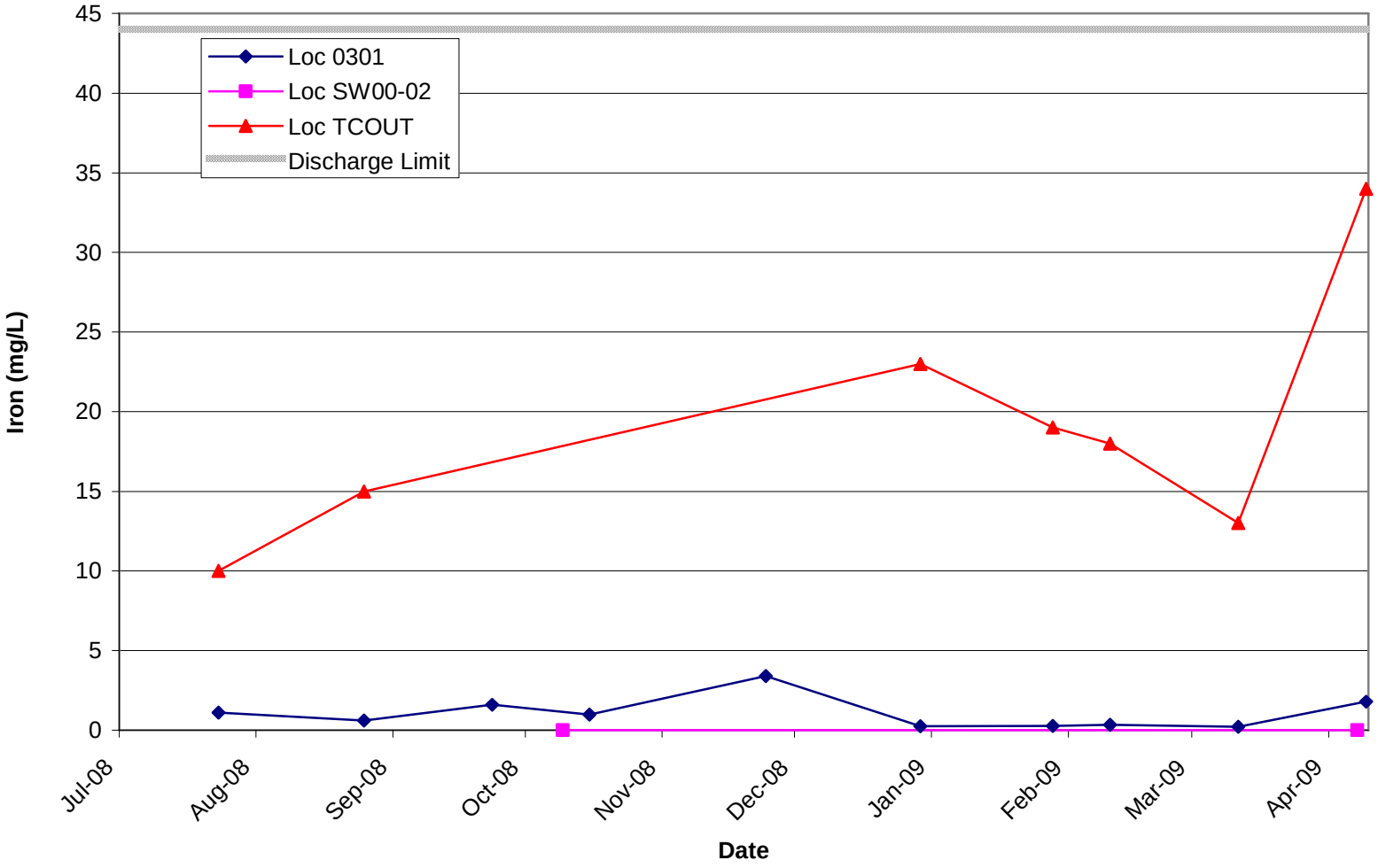

Figure 11. Ex Situ Treatment System Monitoring Results, Iron

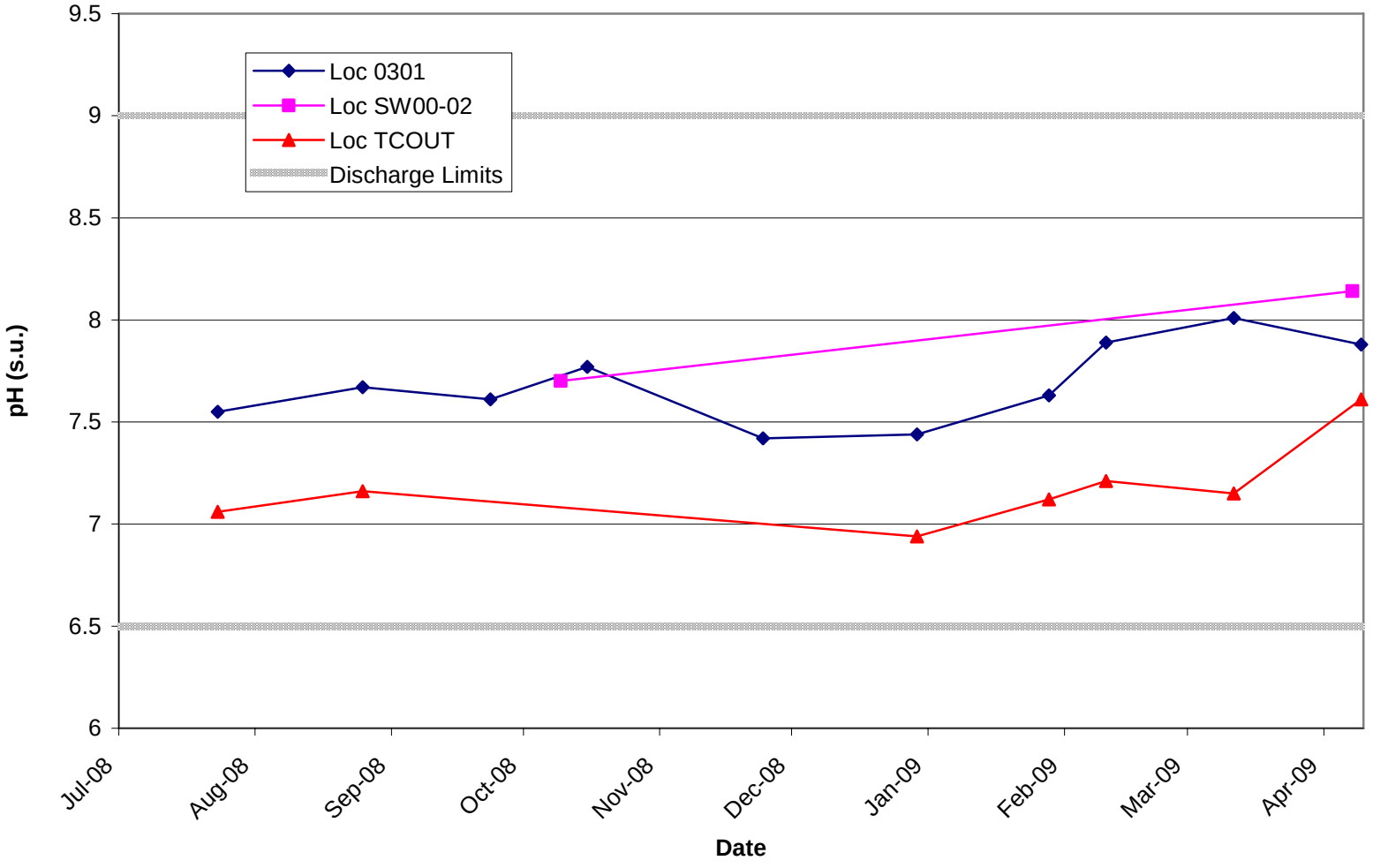

Figure 12. Ex Situ Treatment System Monitoring Results, pH

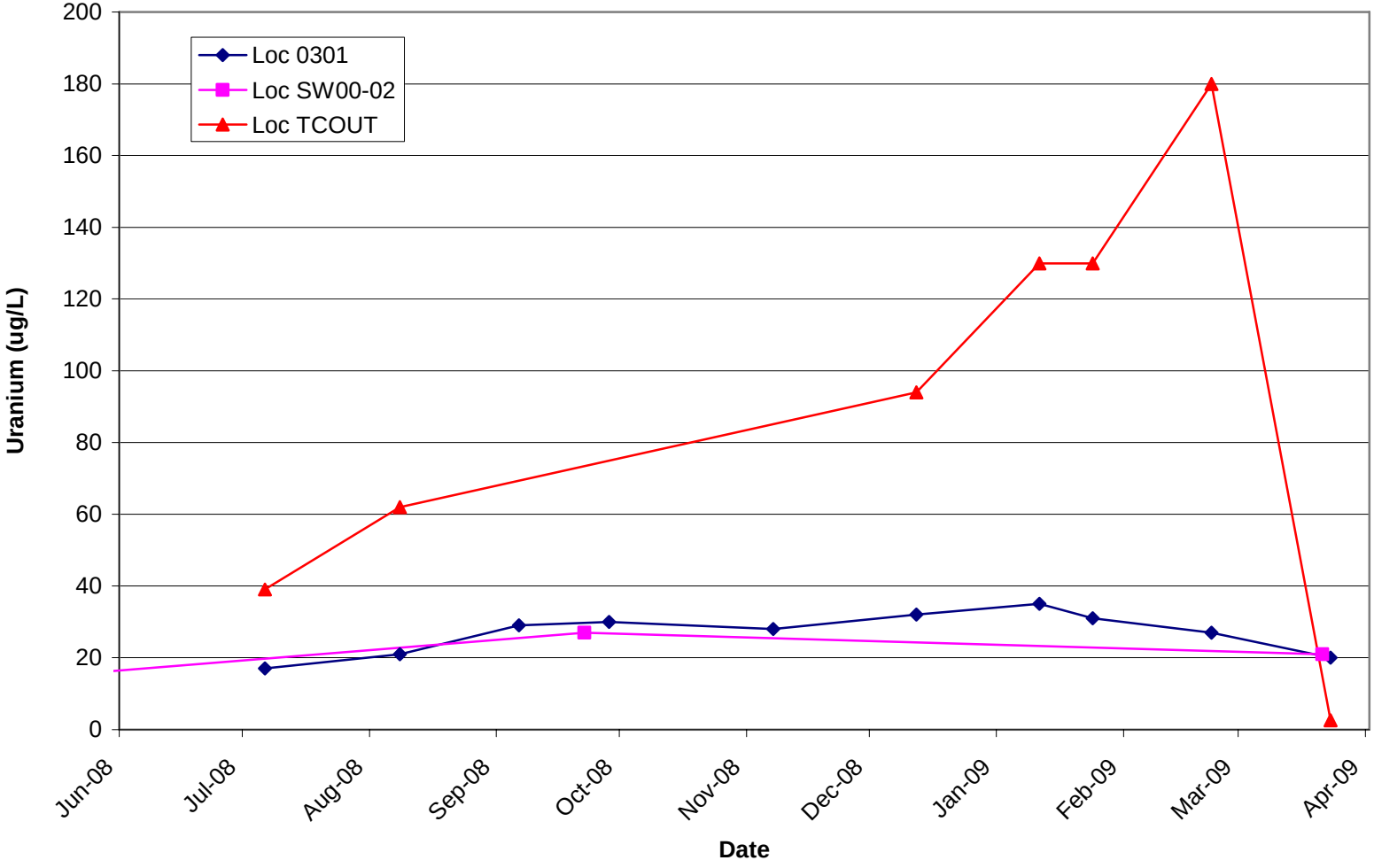

Figure 13. Ex Situ Treatment System Monitoring Results, Uranium

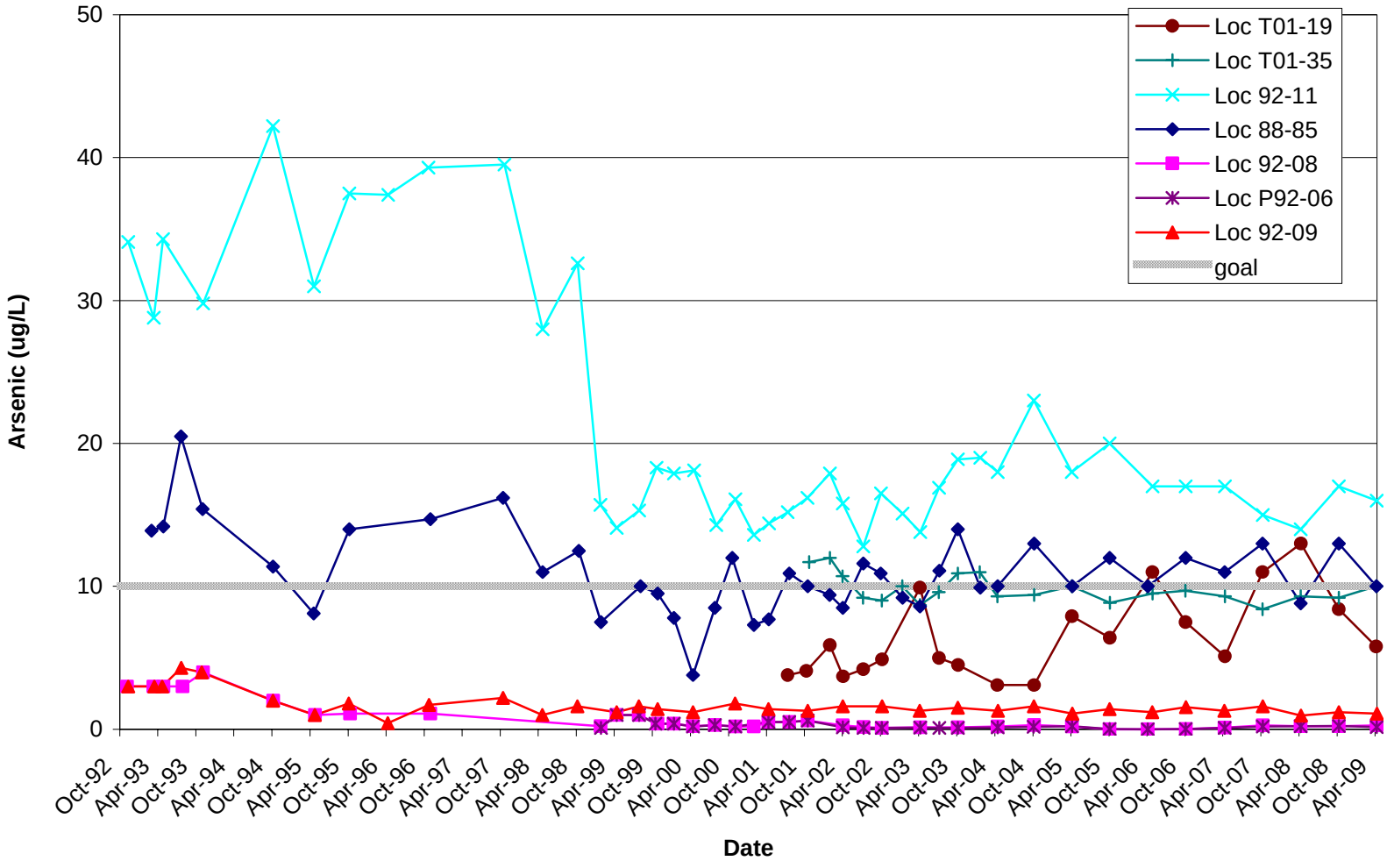

Figure 14. Arsenic Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

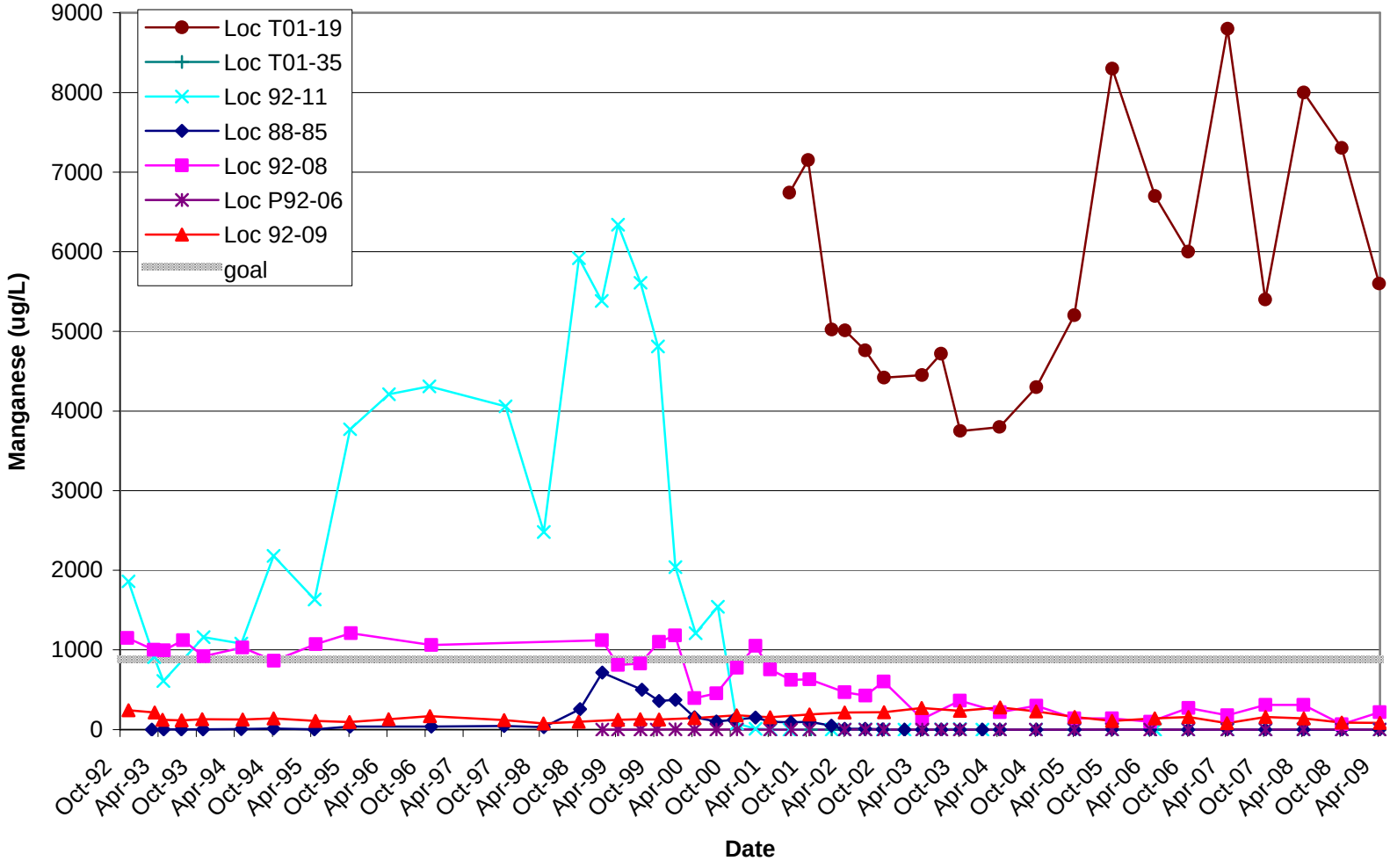

Figure 15. Manganese Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

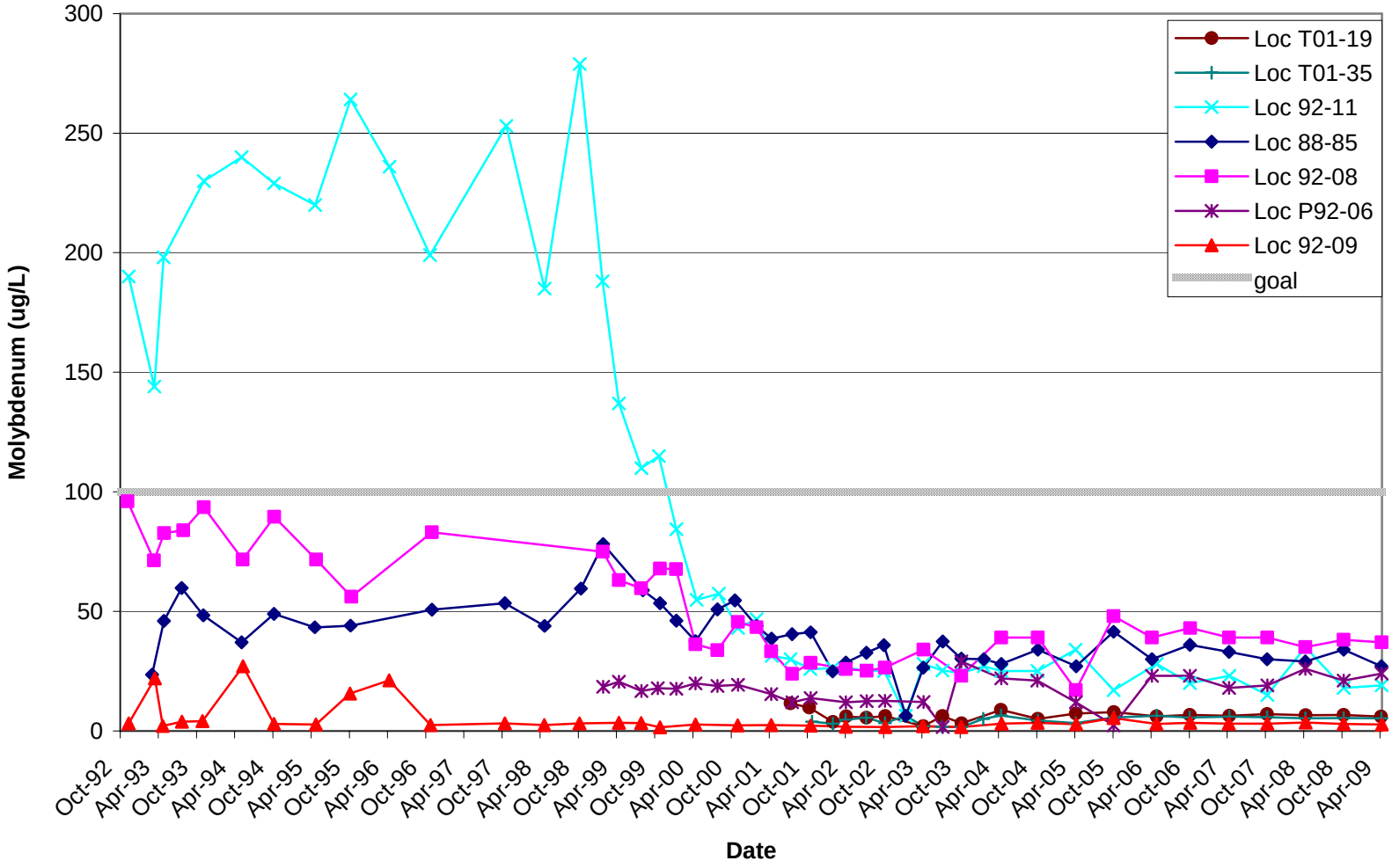

Figure 16. Molybdenum Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

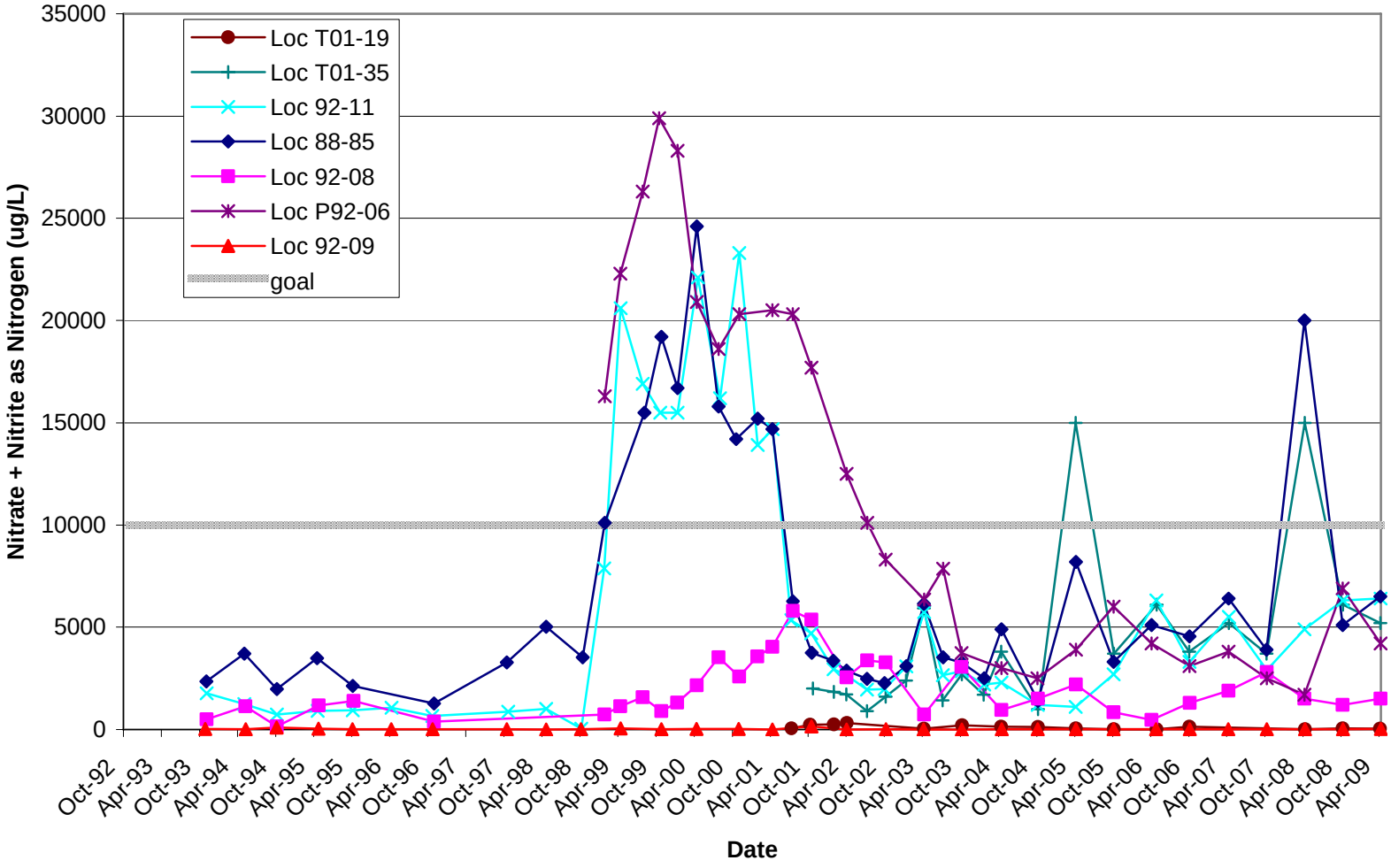

Figure 17. Nitrate (as Nitrogen) Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

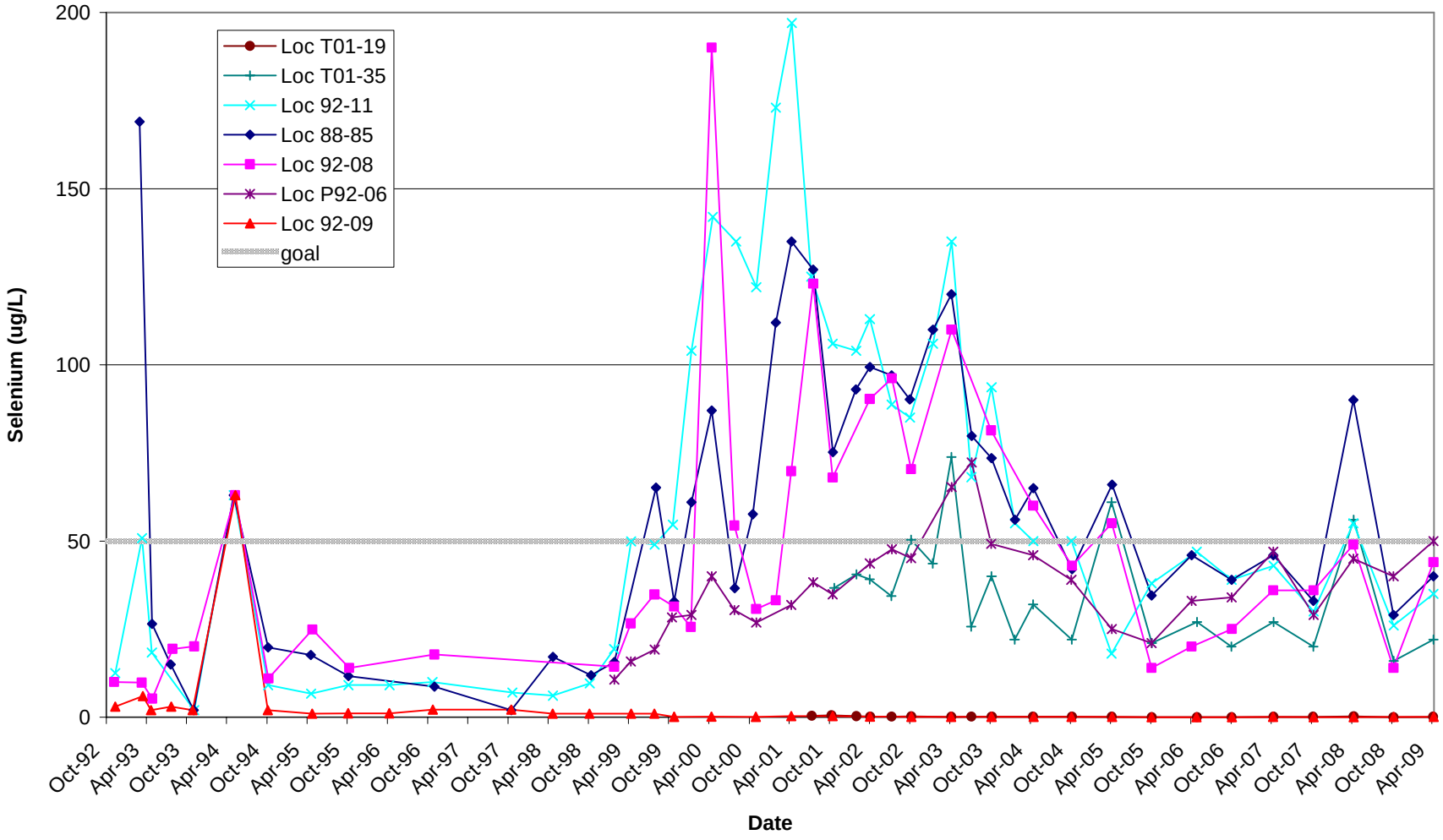

Figure 18. Selenium Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

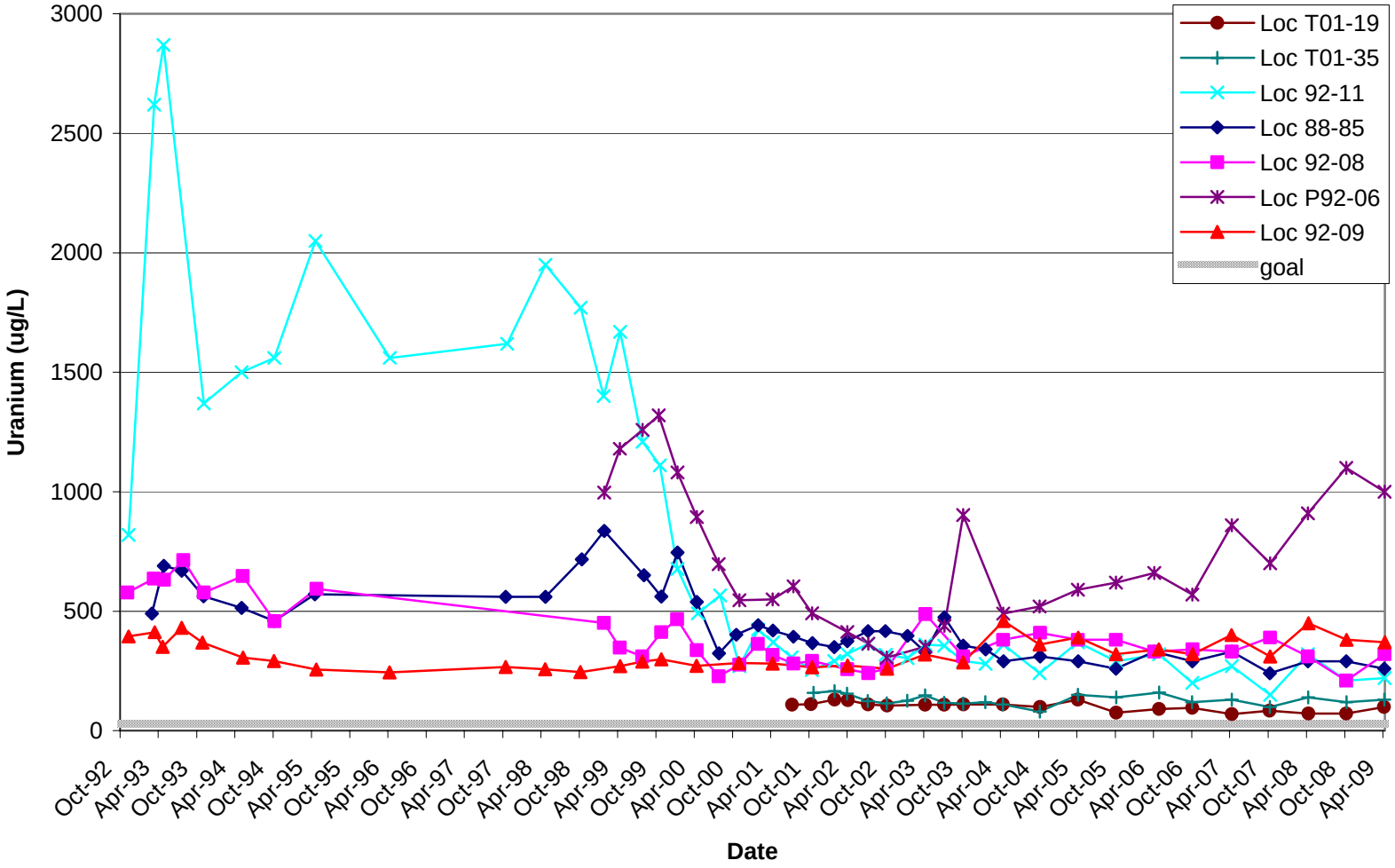

Figure 19. Uranium Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

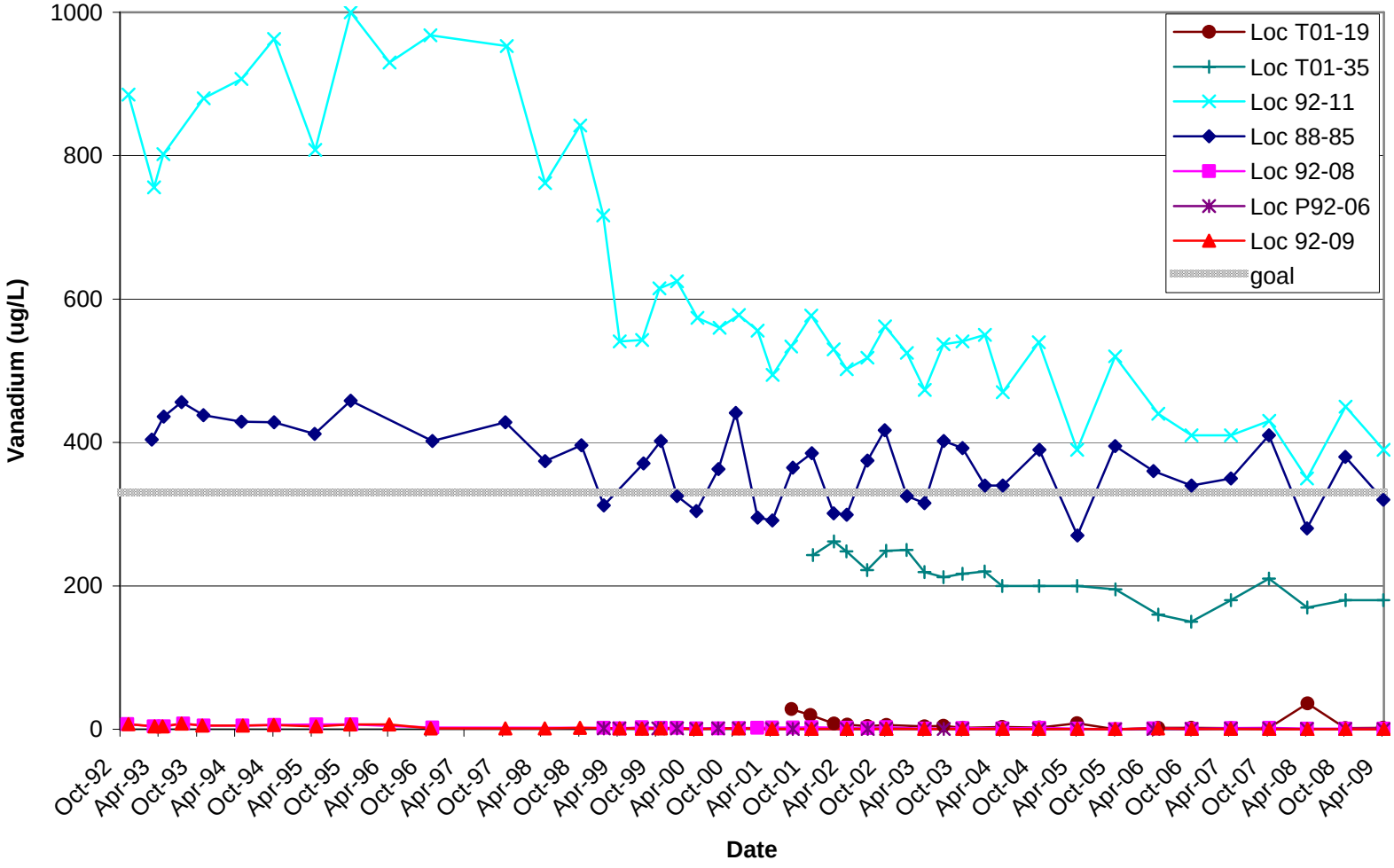

Figure 20. Vanadium Concentration Over Time at Selected Alluvial Aquifer Monitor Wells

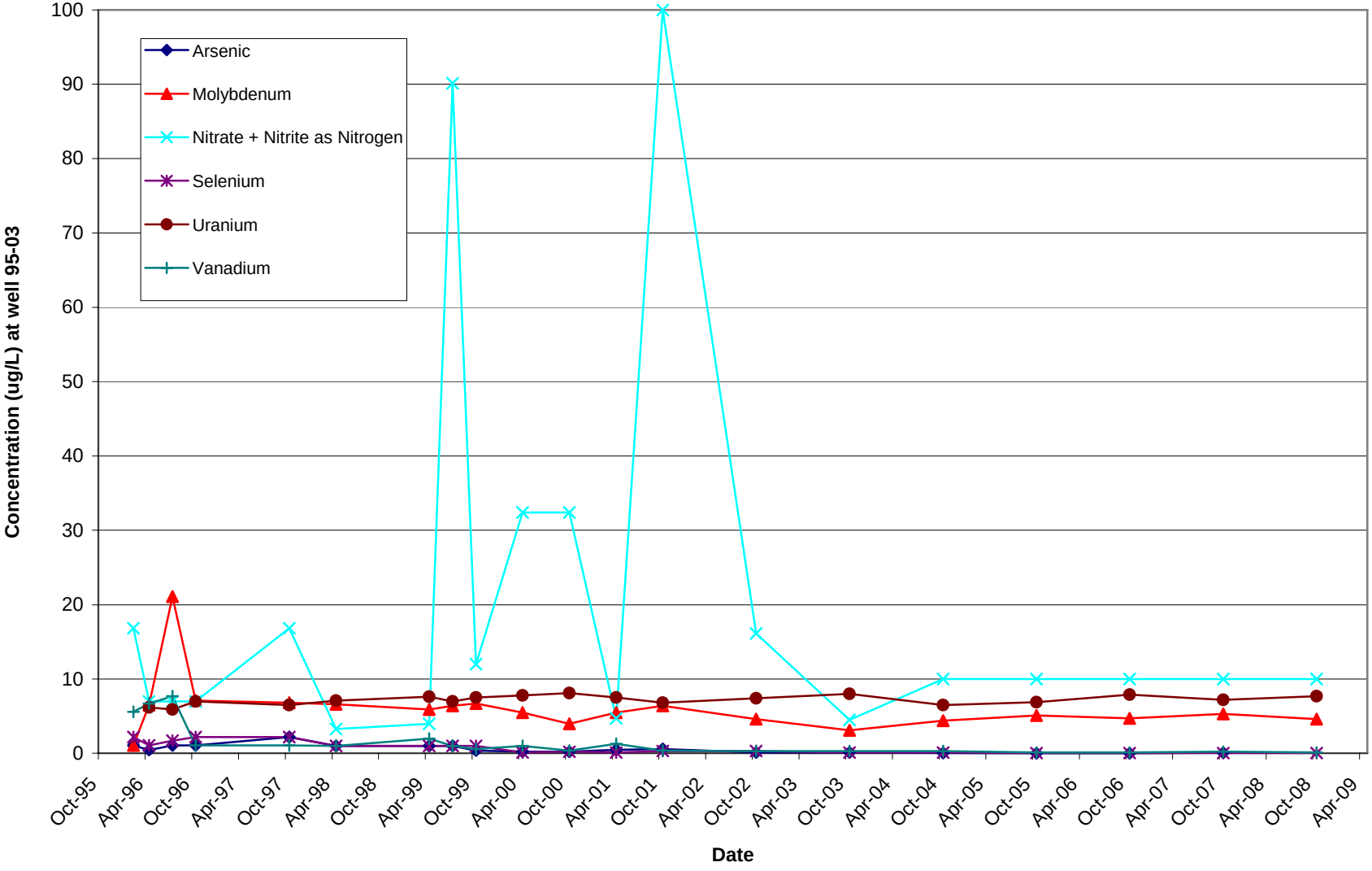

Figure 21. Contaminant Concentrations Over Time at Sentinel Well 95-03

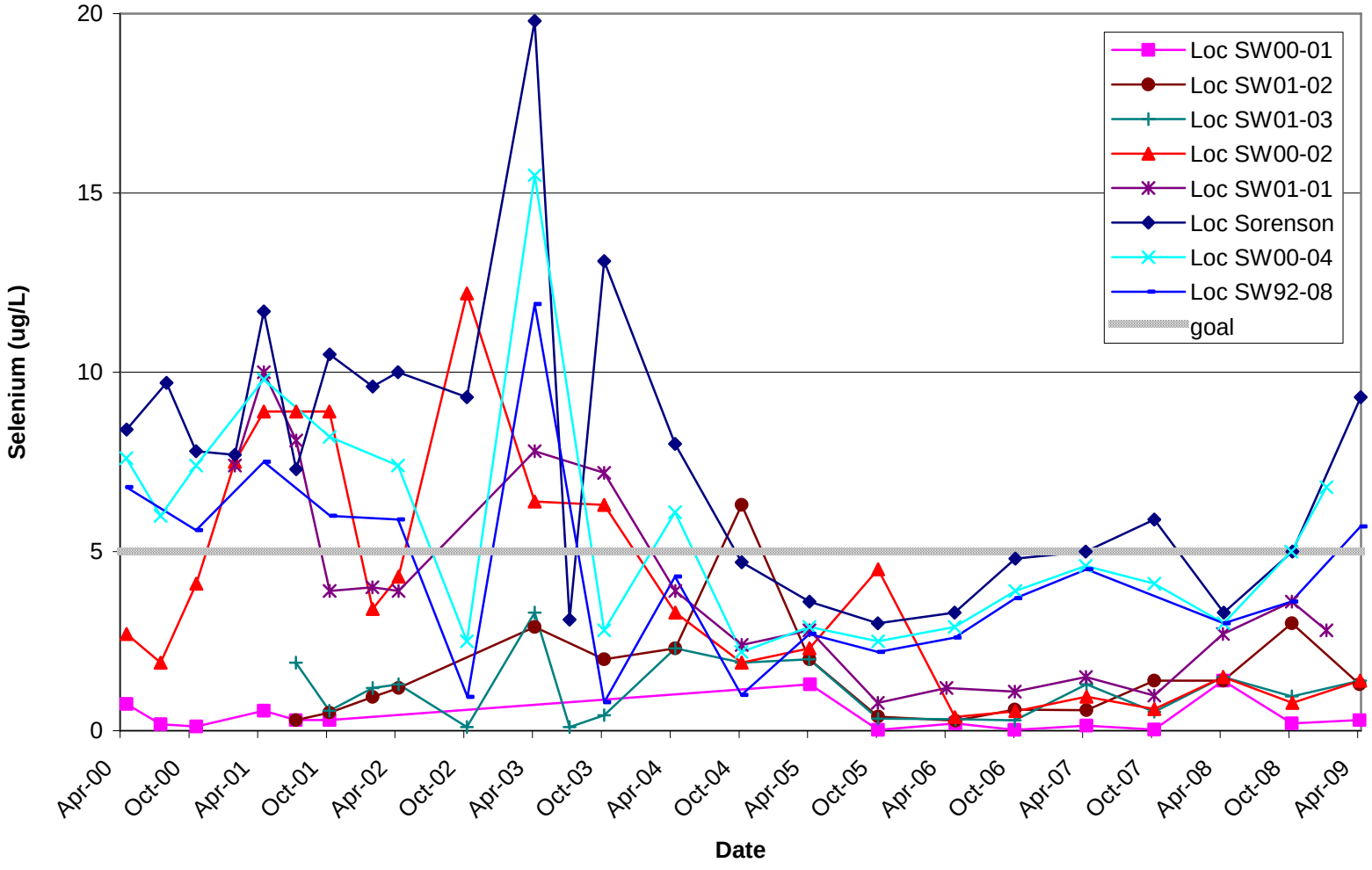

Figure 22. Selenium Concentration Over Time in Montezuma Creek

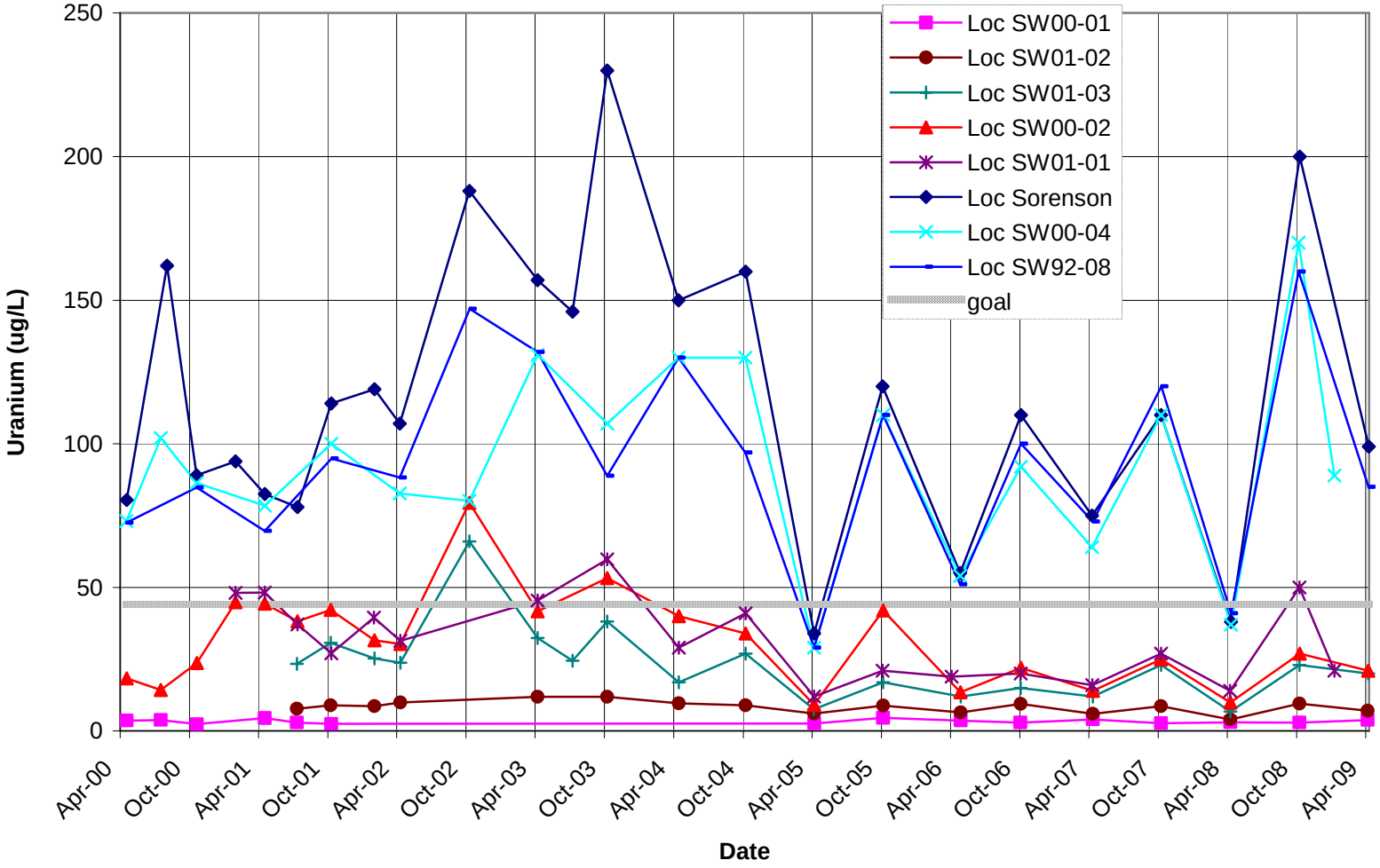

Figure 23. Uranium Concentration Over Time in Montezuma Creek

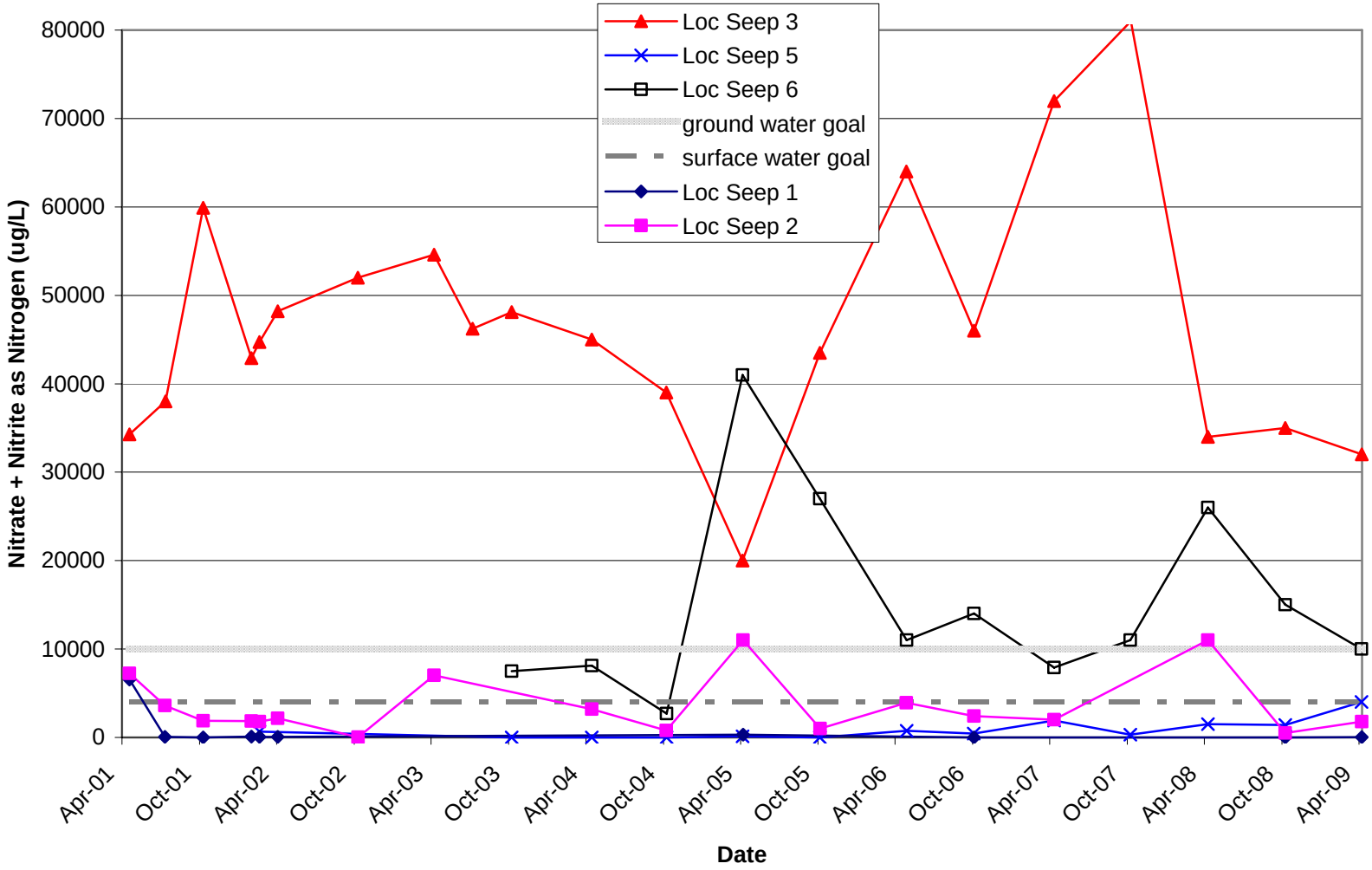

Figure 24. Nitrate (as Nitrogen) Concentration Over Time at Selected Seep Locations

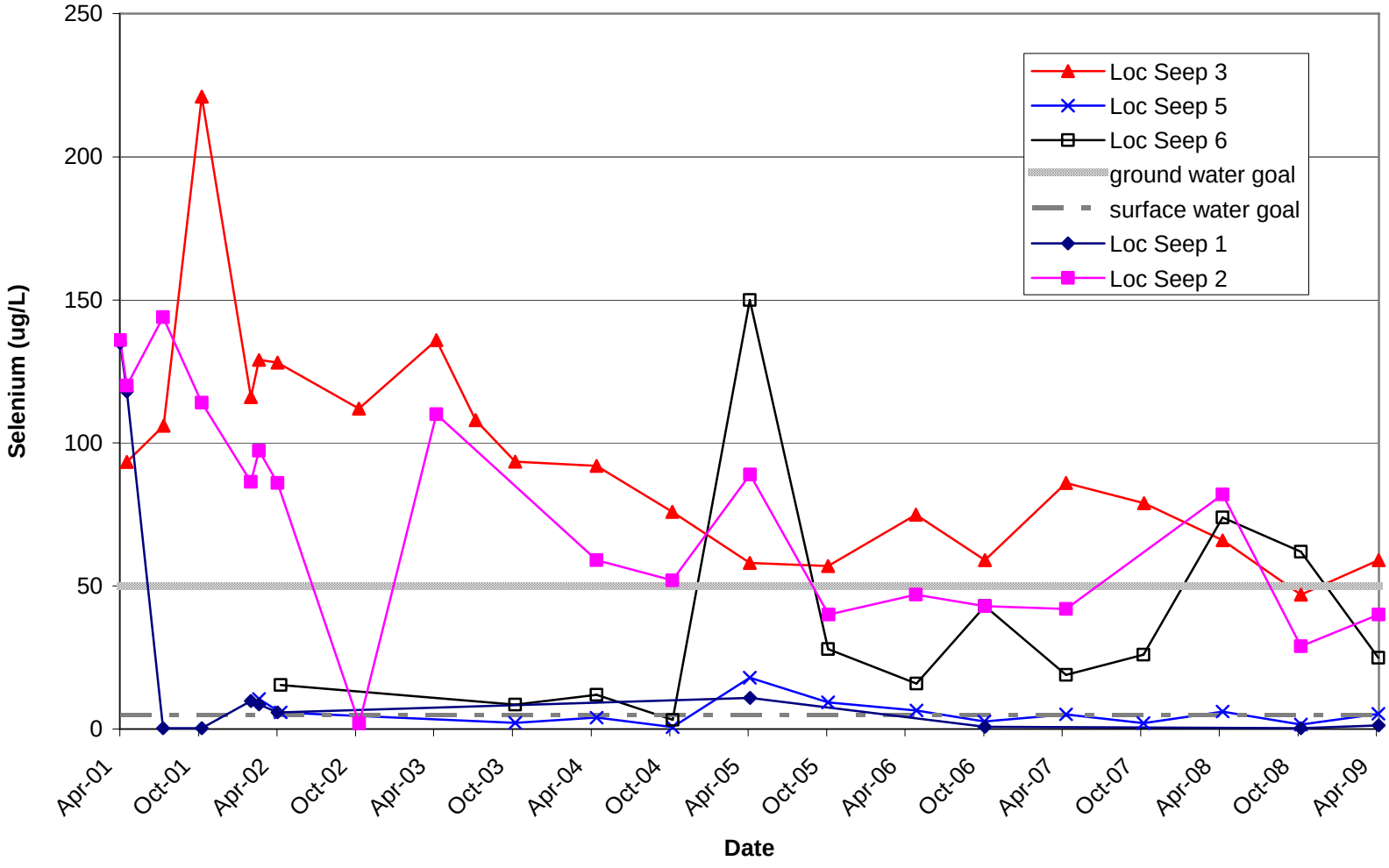

Figure 25. Selenium Concentration Over Time at Selected Seep Locations

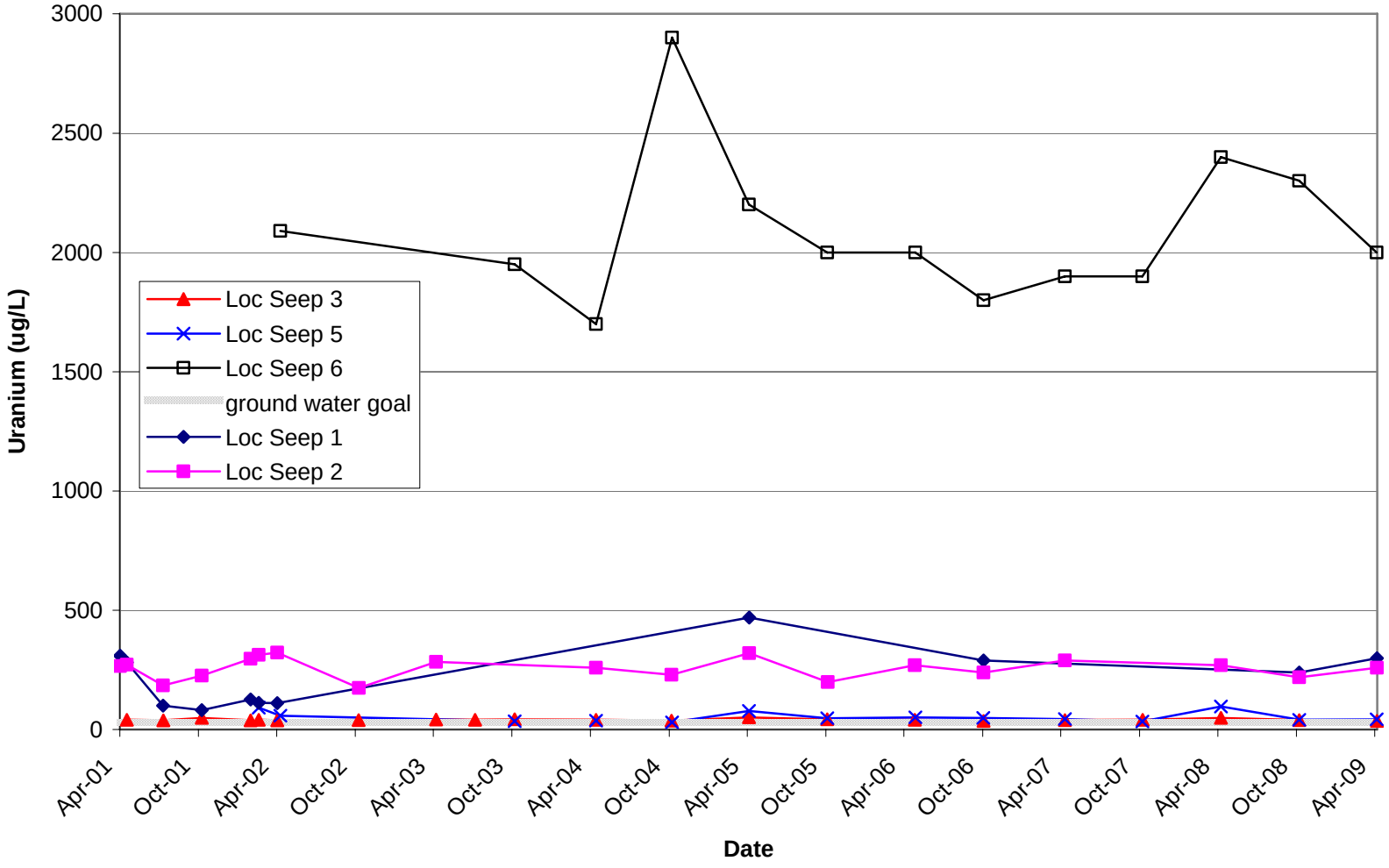

Figure 26. Uranium Concentration Over Time at Selected Seep Locations

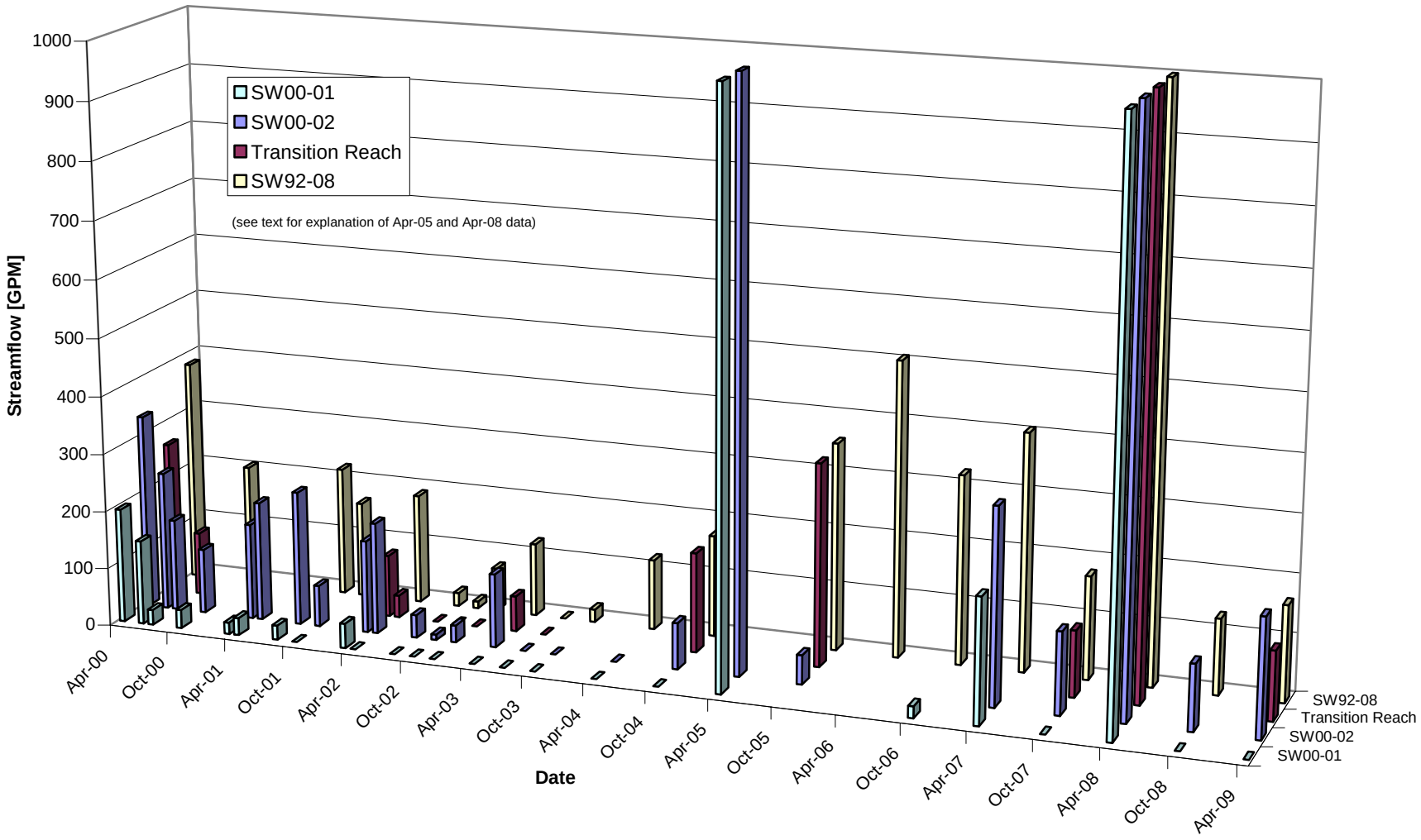

Figure 27. Stream Flow Hydrographs for Selected Sites on Montezuma Creek

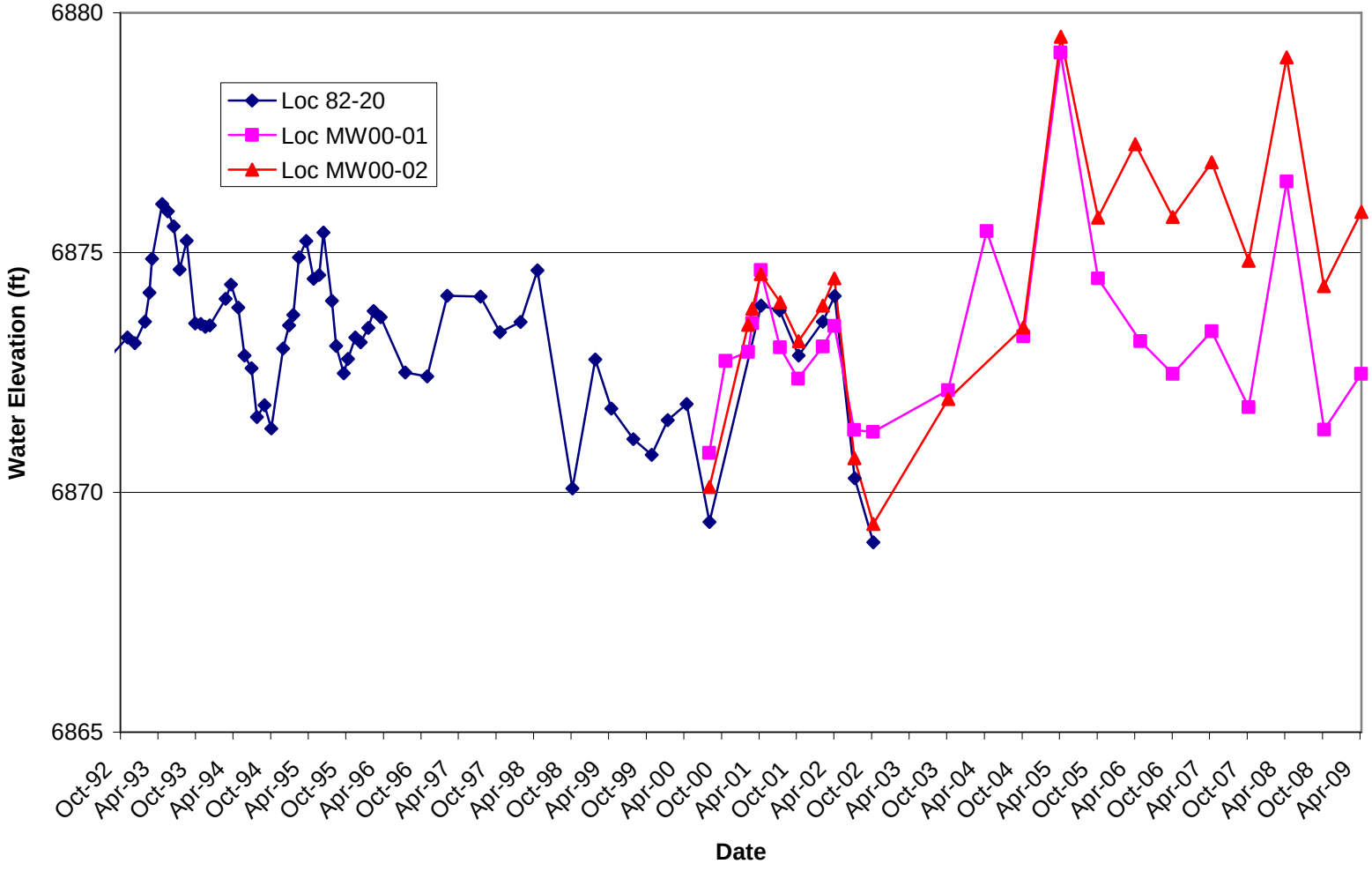

Figure 28. Water Level Hydrographs for Upgradient Alluvial Wells

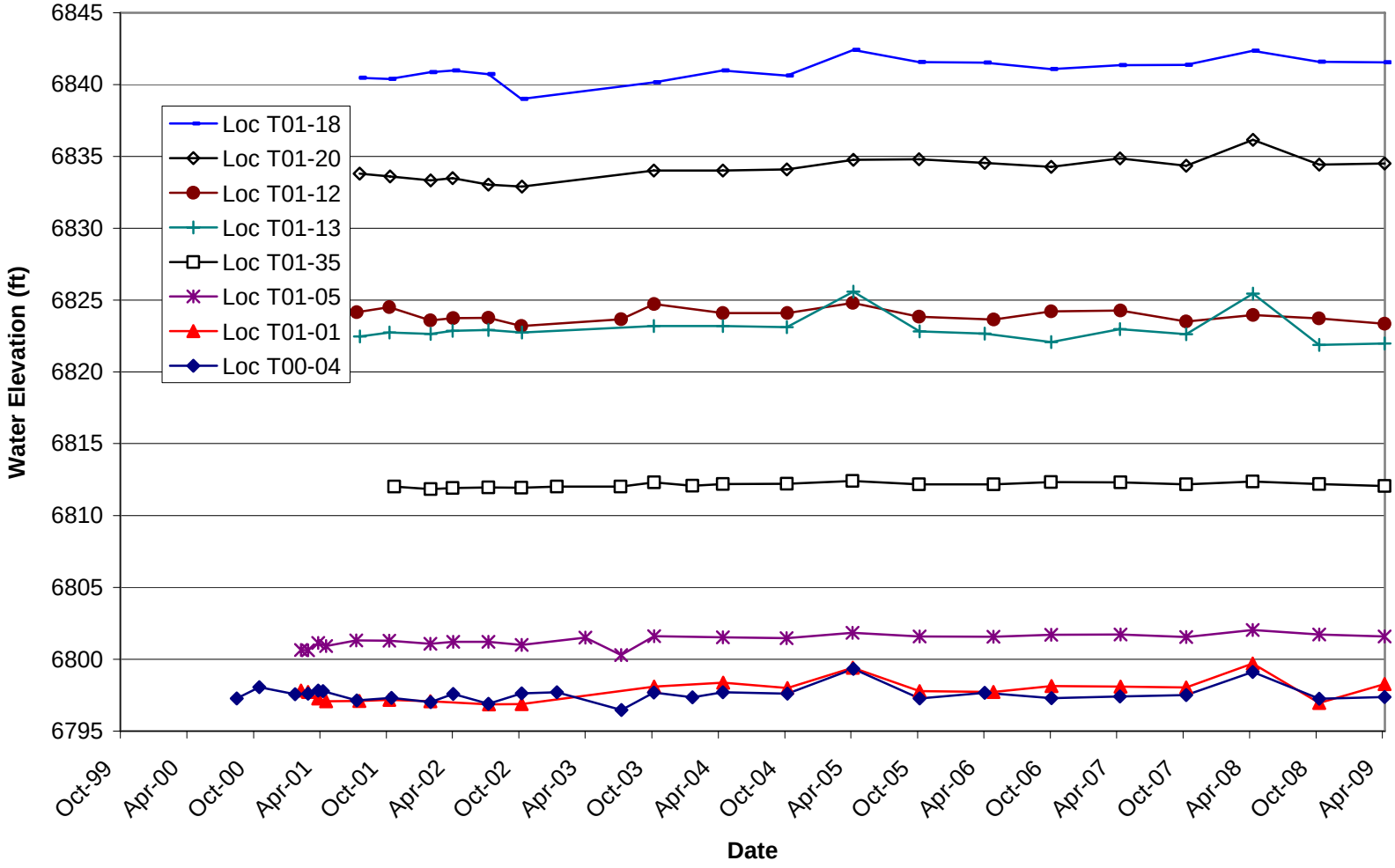

Figure 29. Water Level Hydrographs for Selected Mill site Alluvial Wells

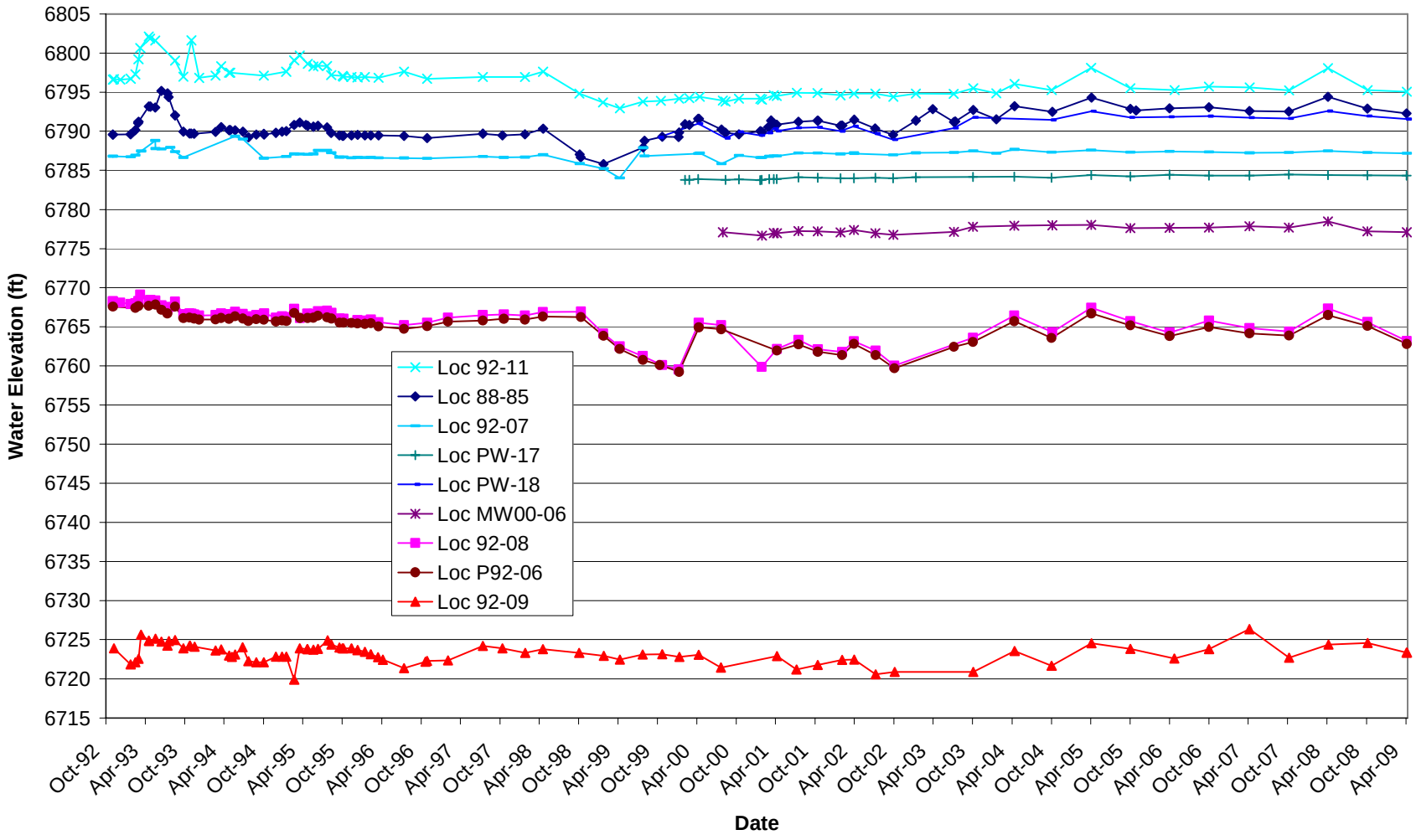

Figure 30. Water Level Hydrographs for Downgradient Wells

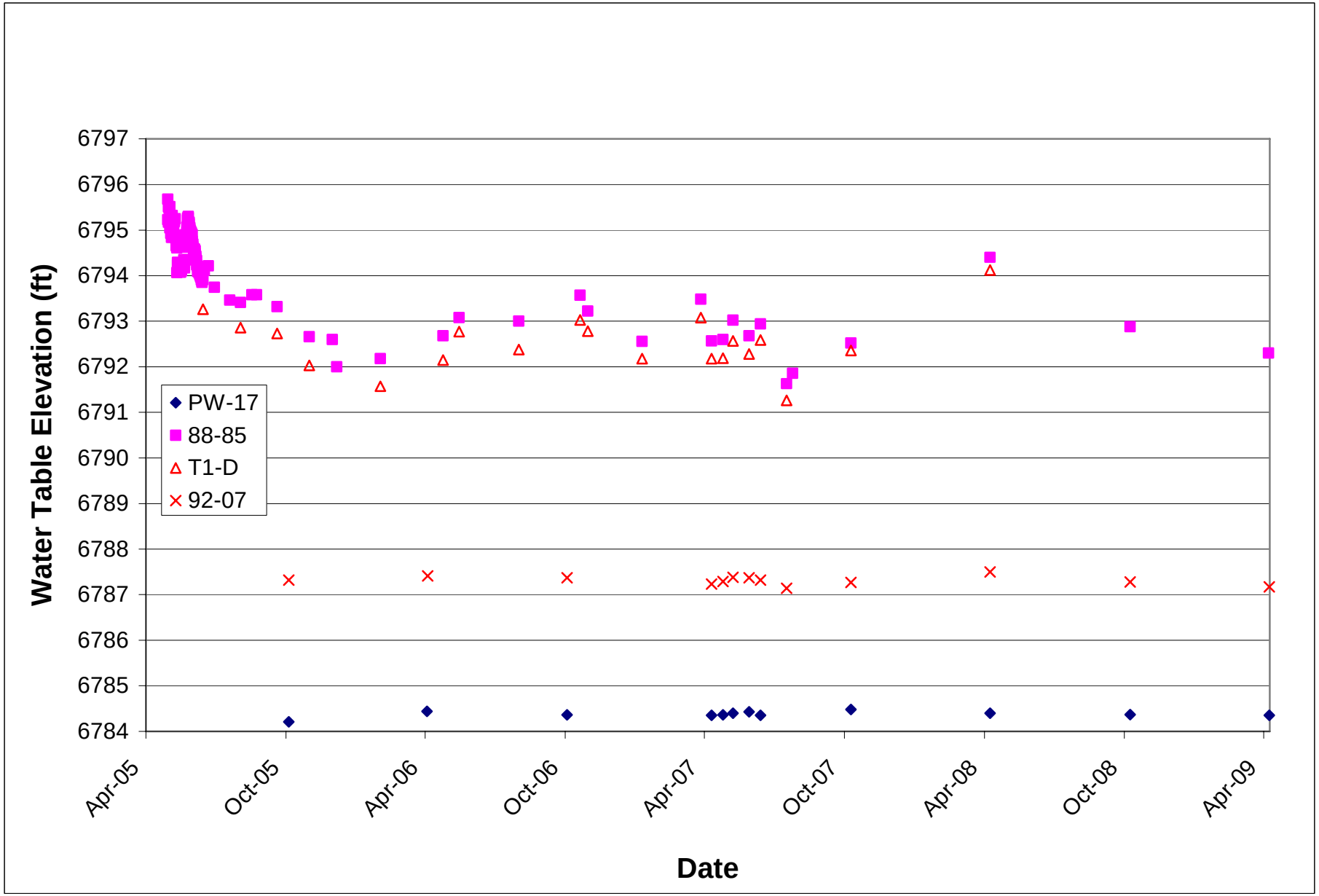

Figure 31. Water Table Trends Near the PRB

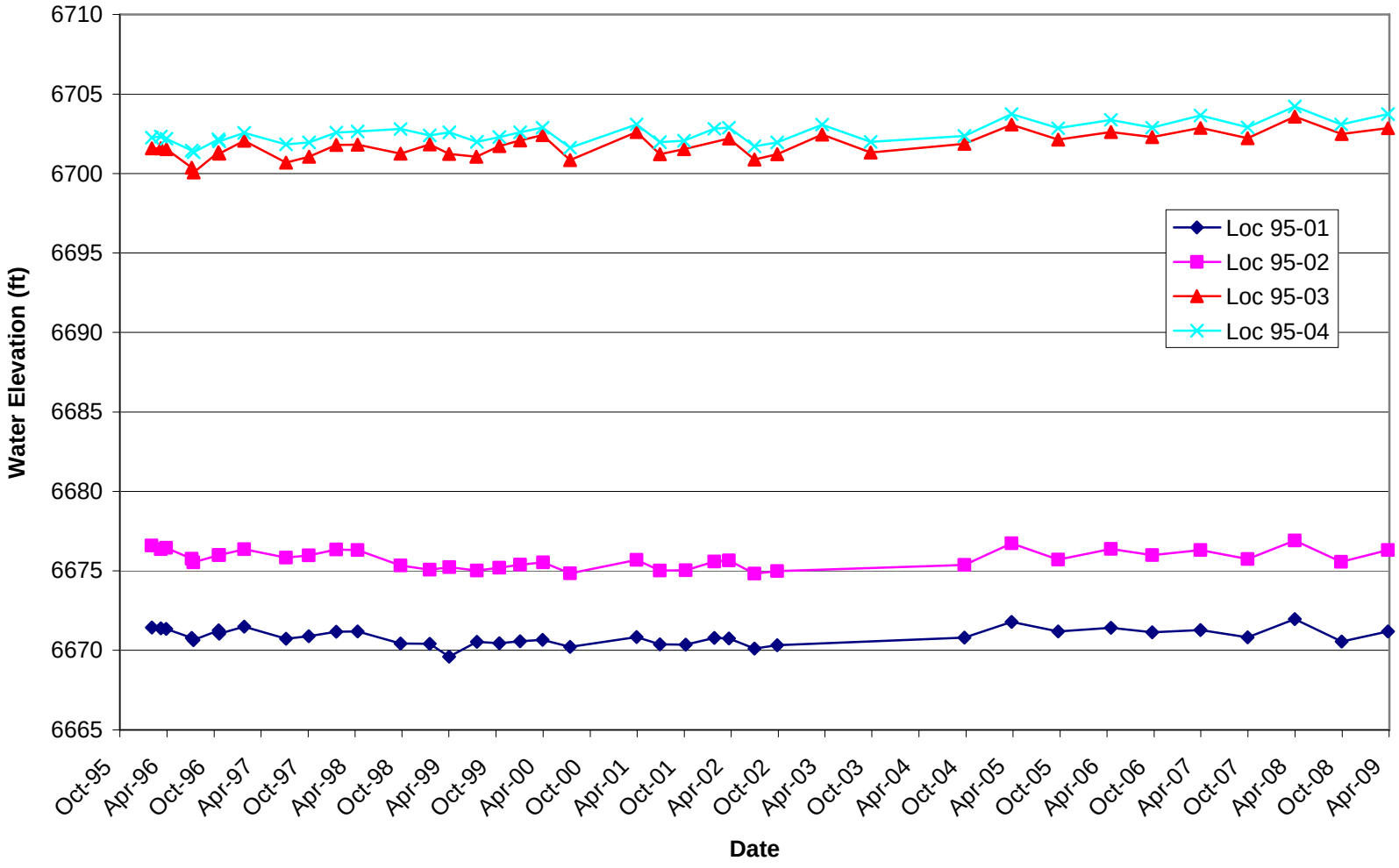

Figure 32. Water Level Hydrographs for Alluvial/Burro Canyon Well Pairs 95-01/95-02 and 95-03/95-04

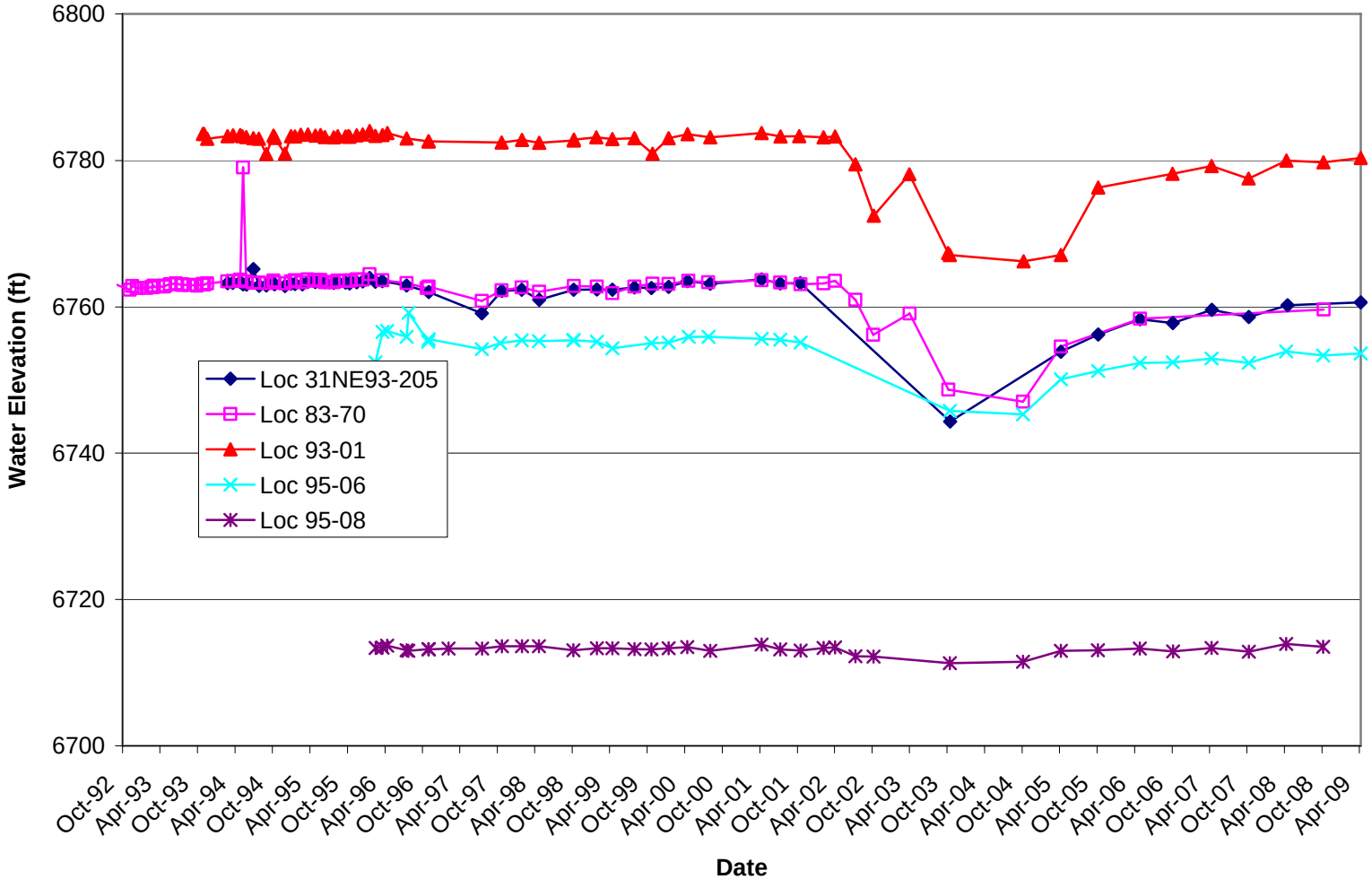

Figure 33. Water Level Hydrographs for Selected Burro Canyon Aquifer Wells

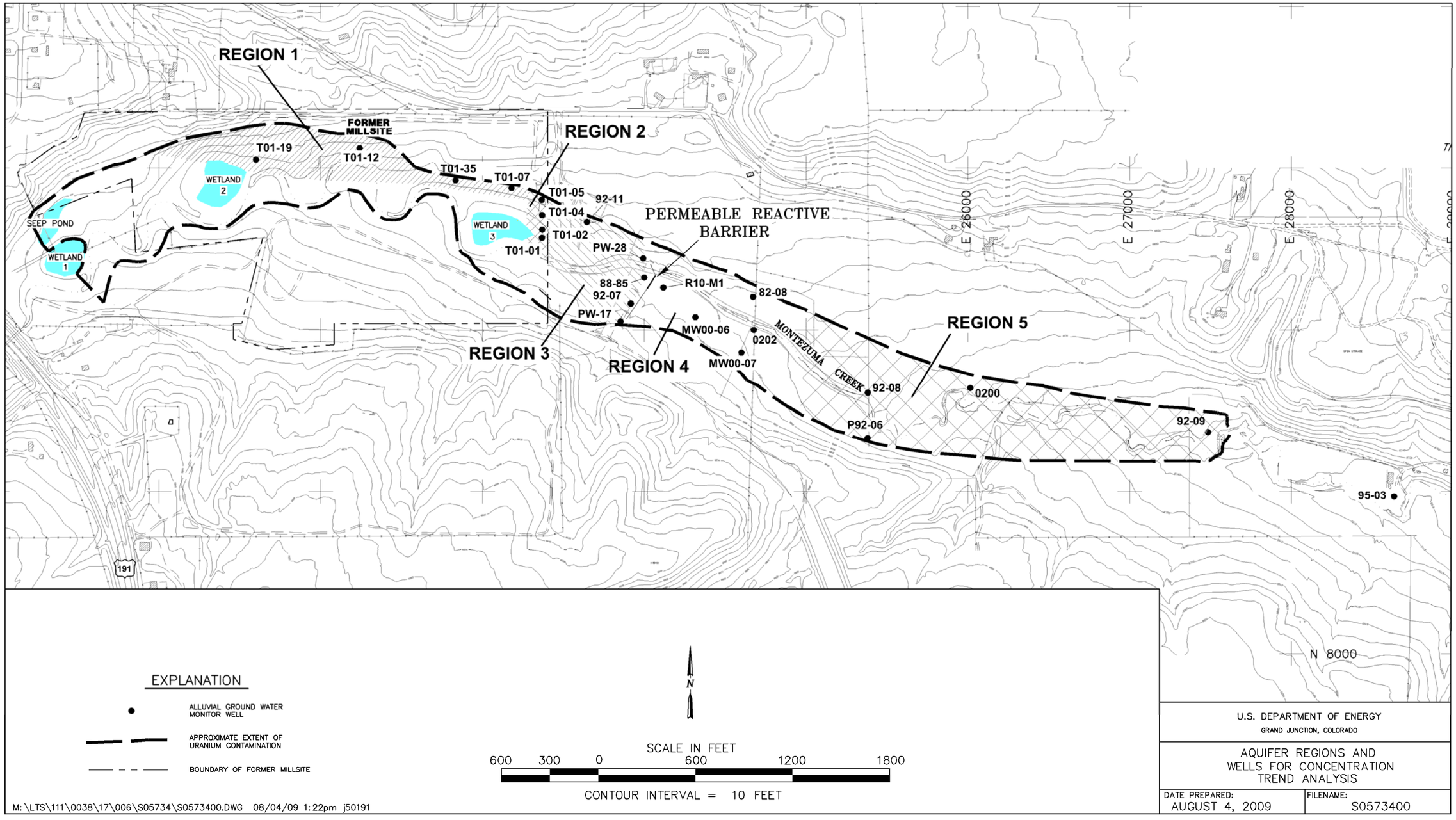

Figure 34. Aquifer Regions and Monitor Wells Selected for Concentration Trend Analysis

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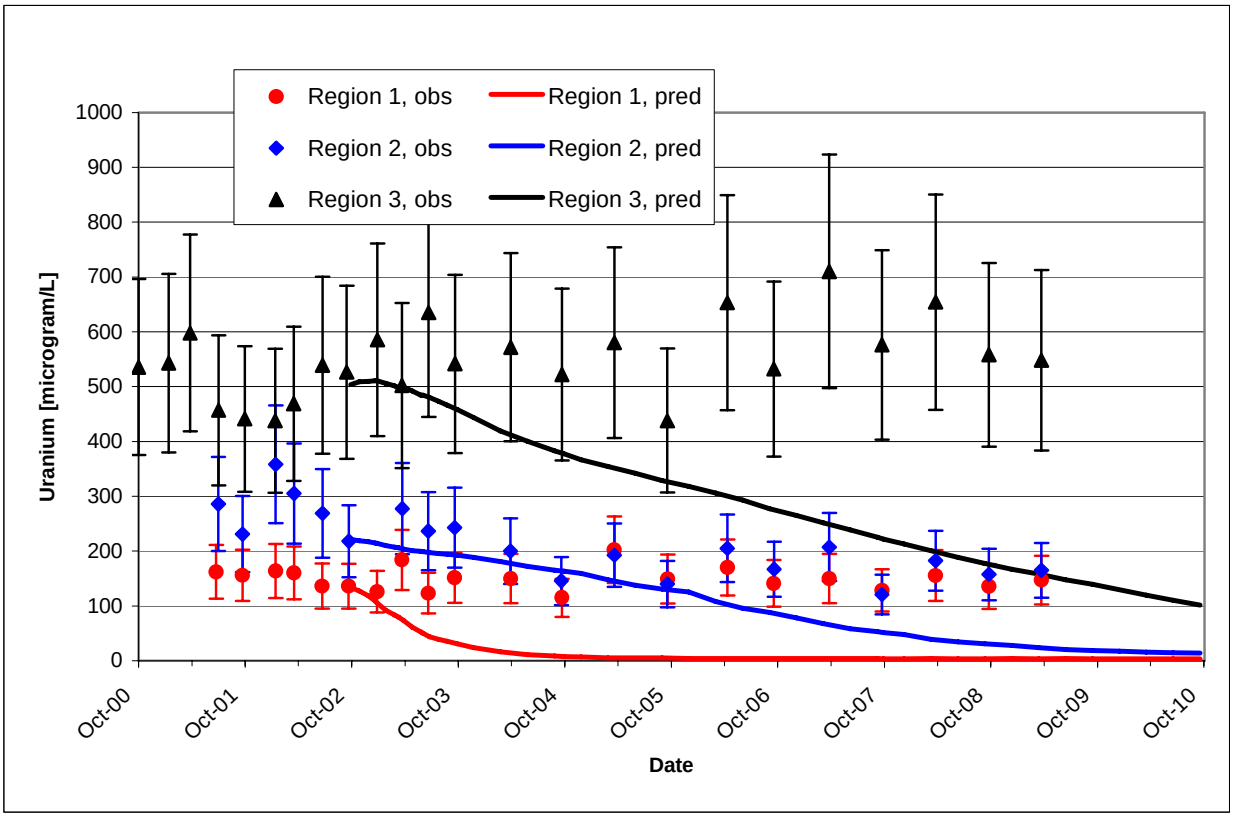


Figure 35. Comparison of Model Prediction to Observed Restoration Progress—Aquifer Regions 1 to 3

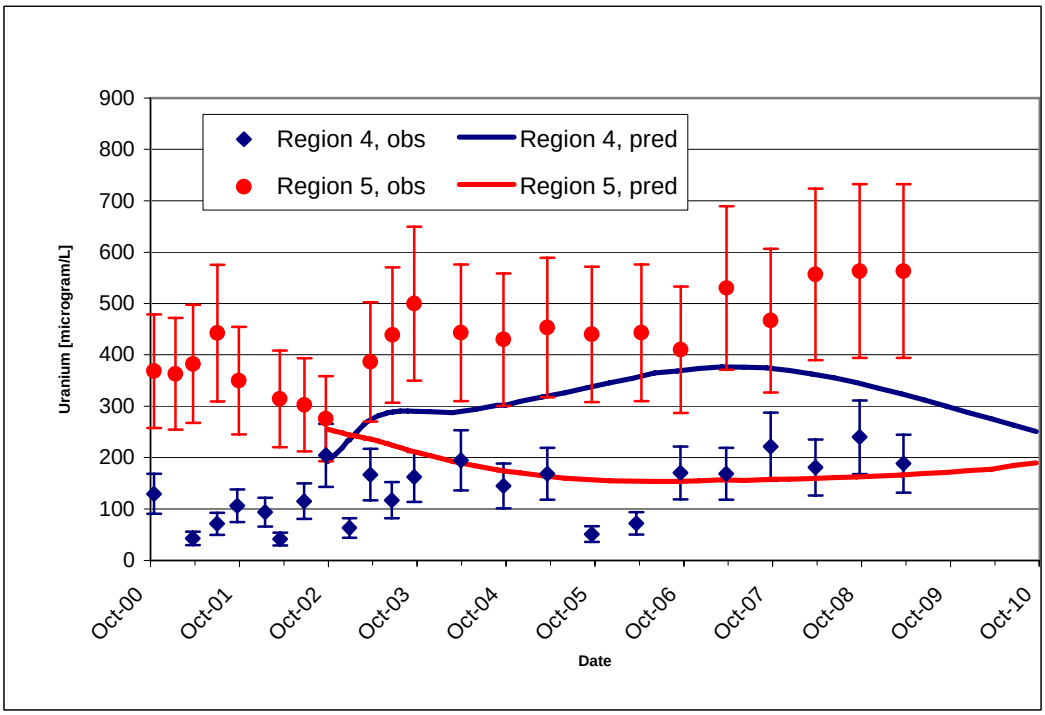


Figure 36. Comparison of Model Prediction to Observed Restoration Progress—Aquifer Regions 4 and 5

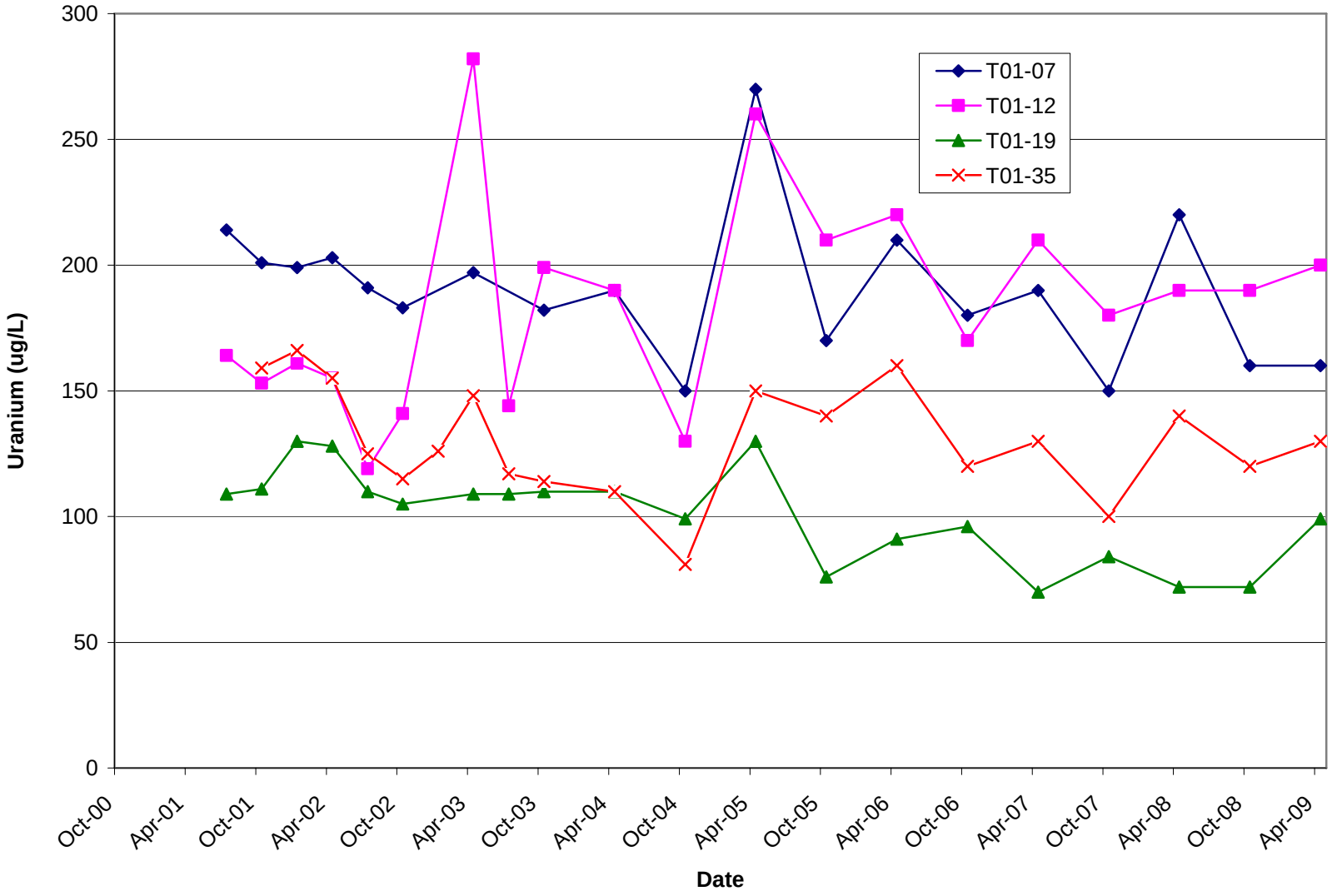


Figure 37. Region 1 Uranium Concentration Trends in Groundwater

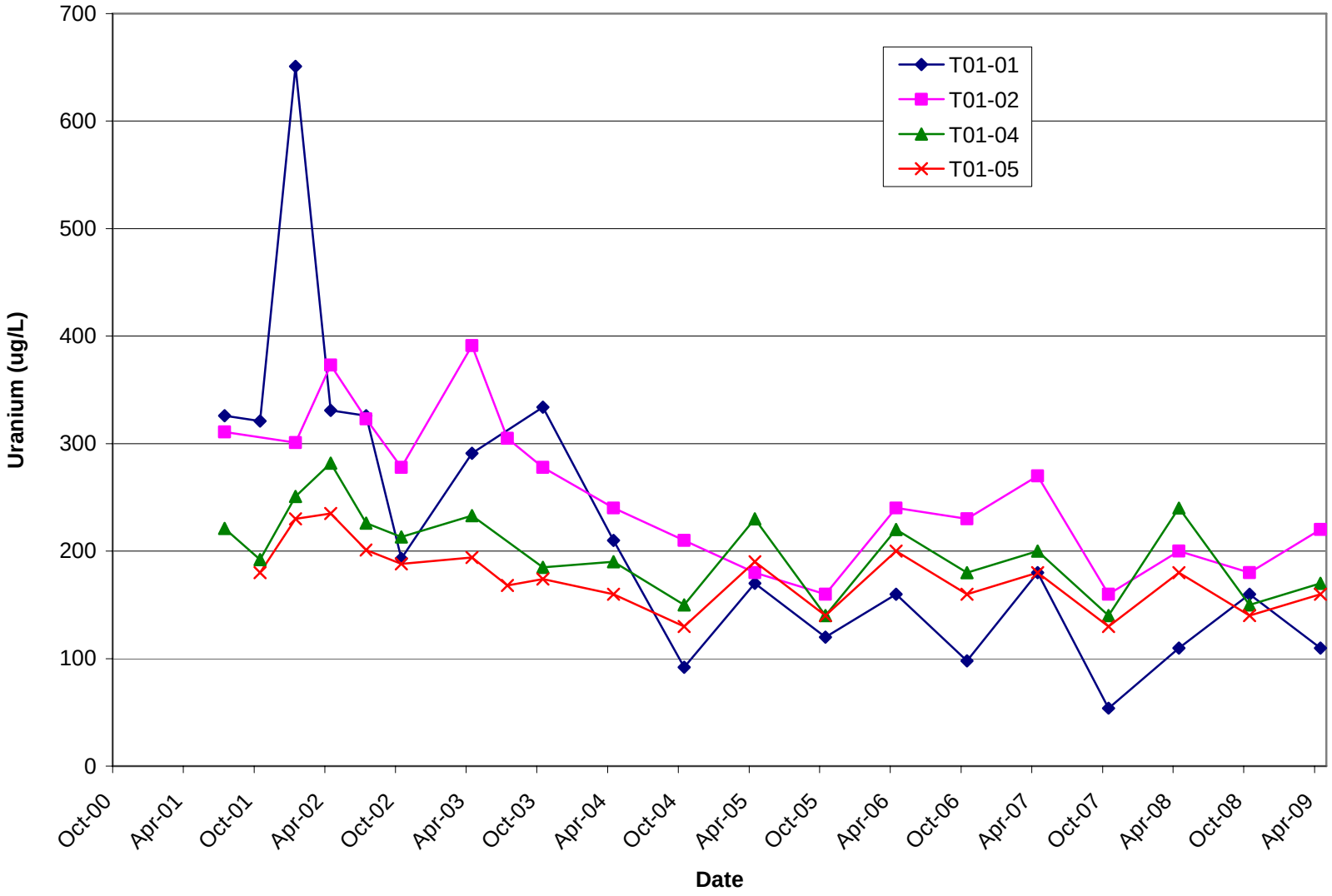


Figure 38. Region 2 Uranium Concentration

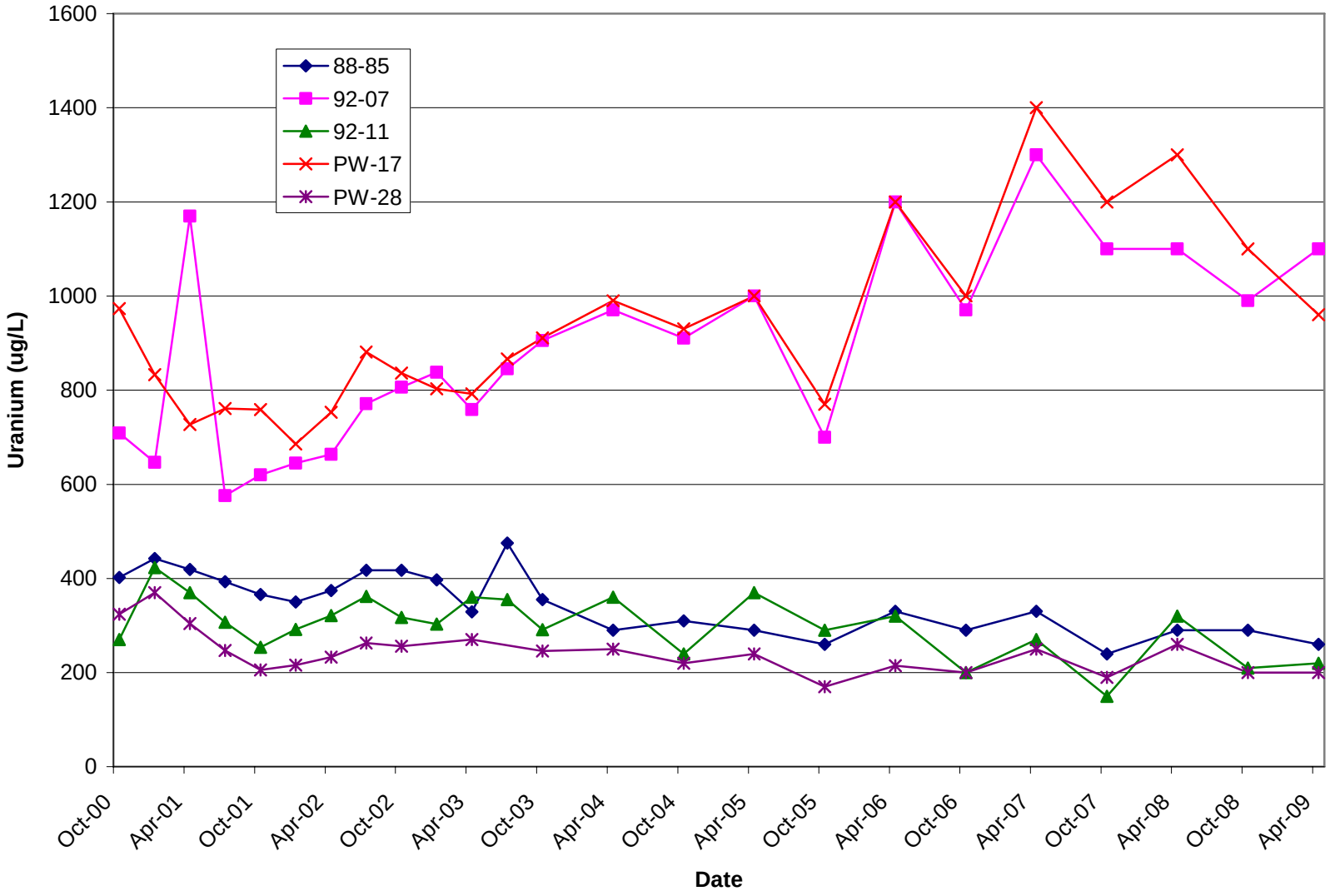


Figure 39. Region 3 Uranium Concentration

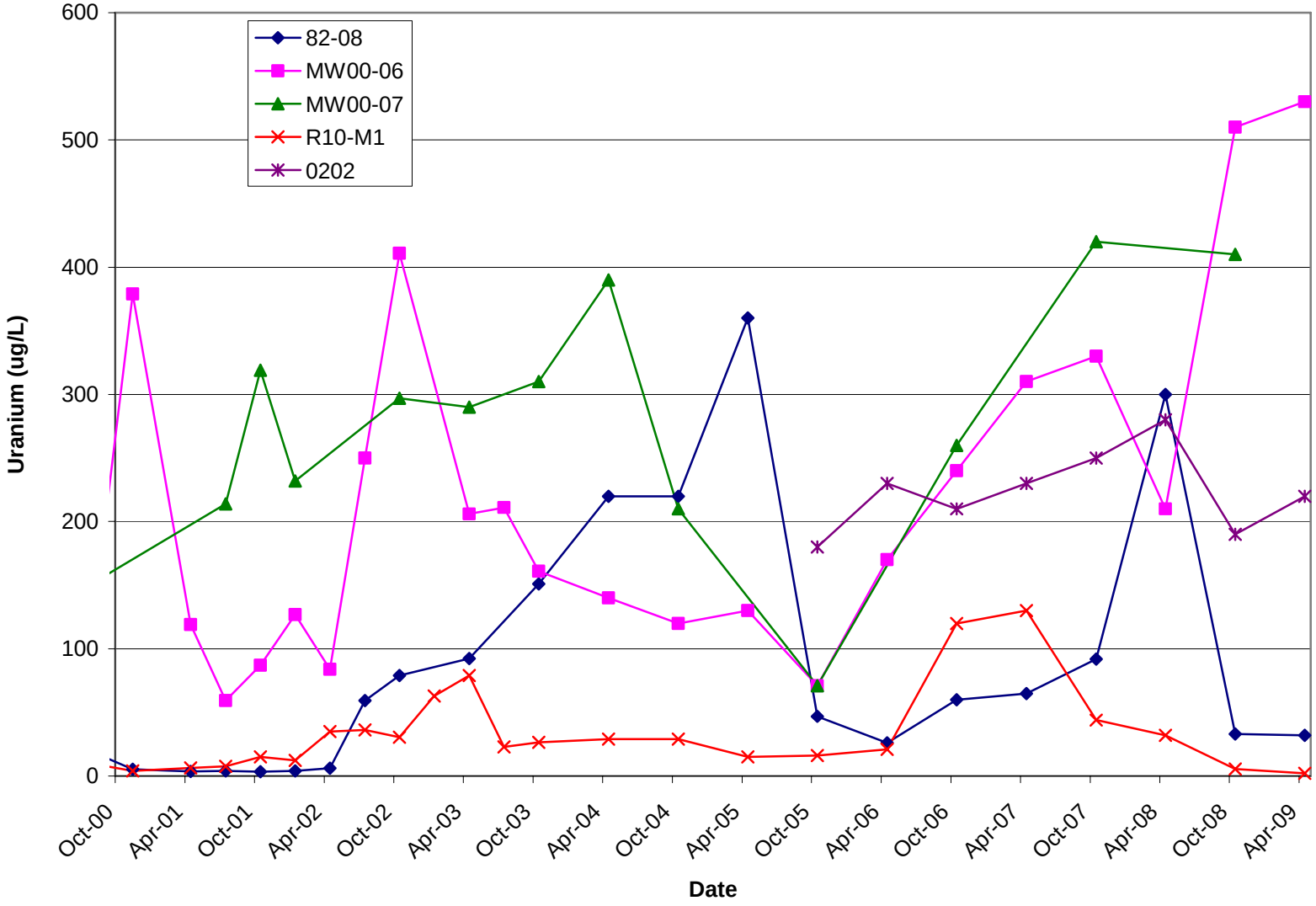


Figure 40. Region 4 Uranium Concentration

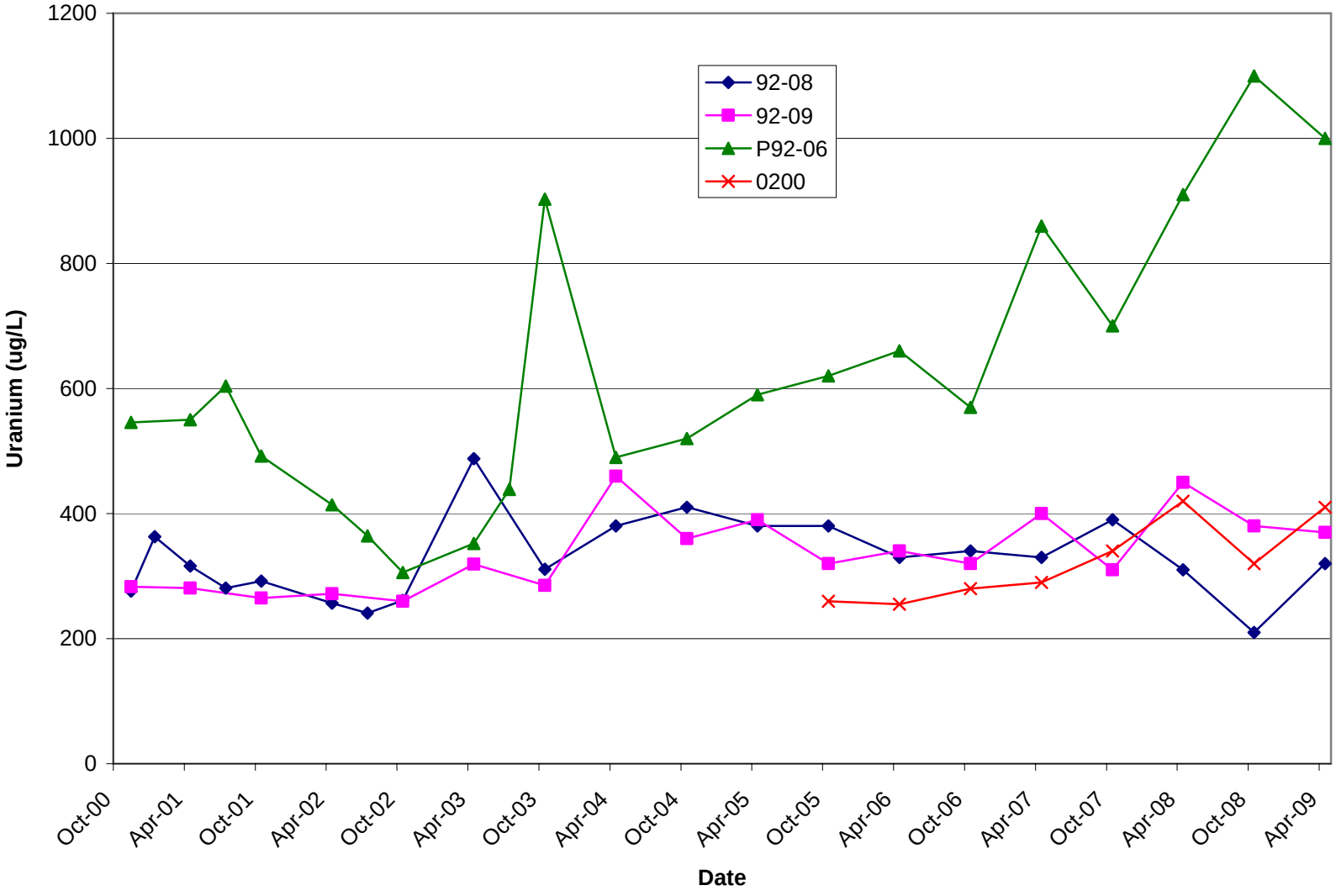


Figure 41. Region 5 Uranium Concentration

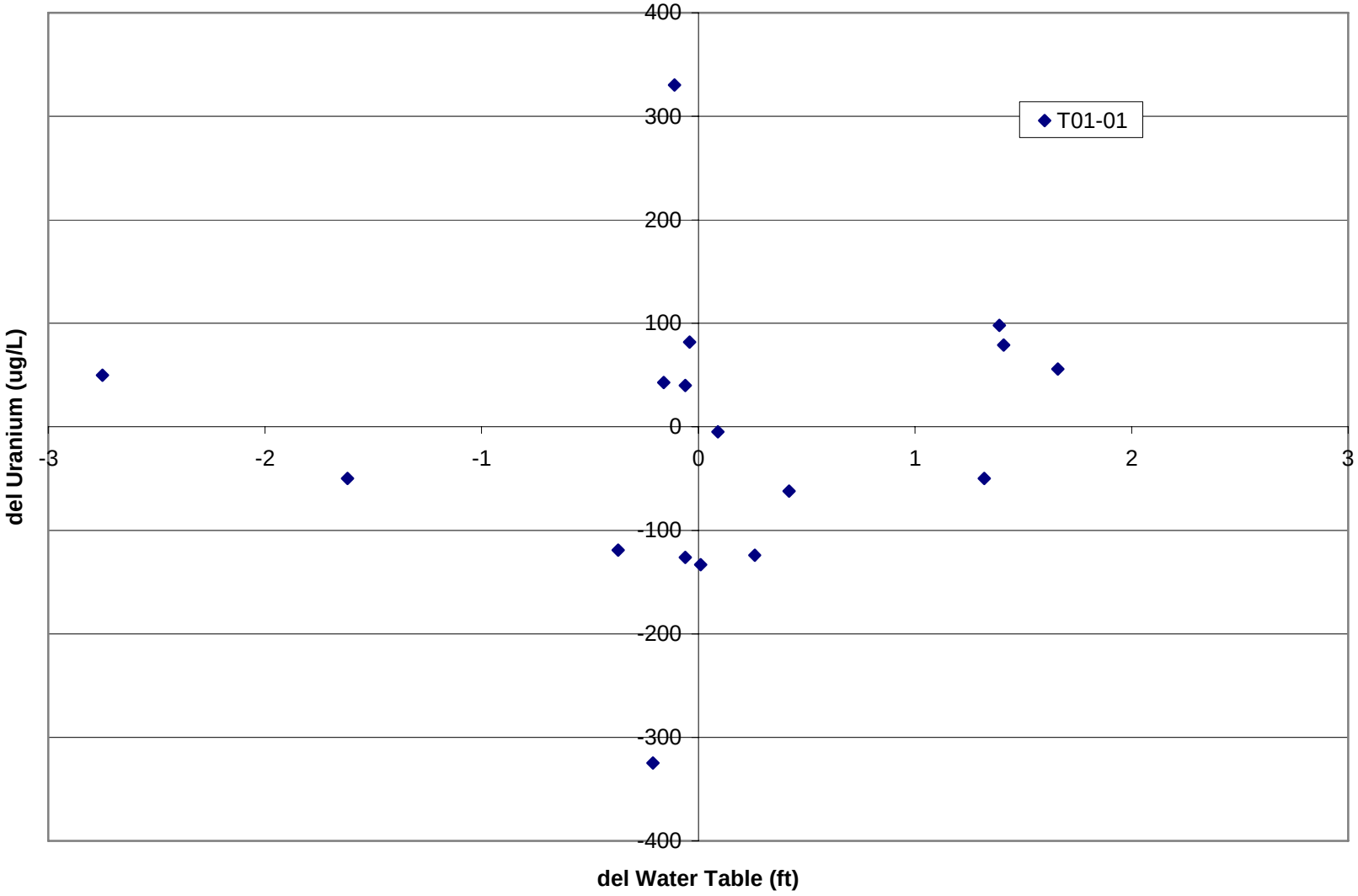


Figure 42. Uranium Concentration vs. Water Table Elevation, Well T01-01

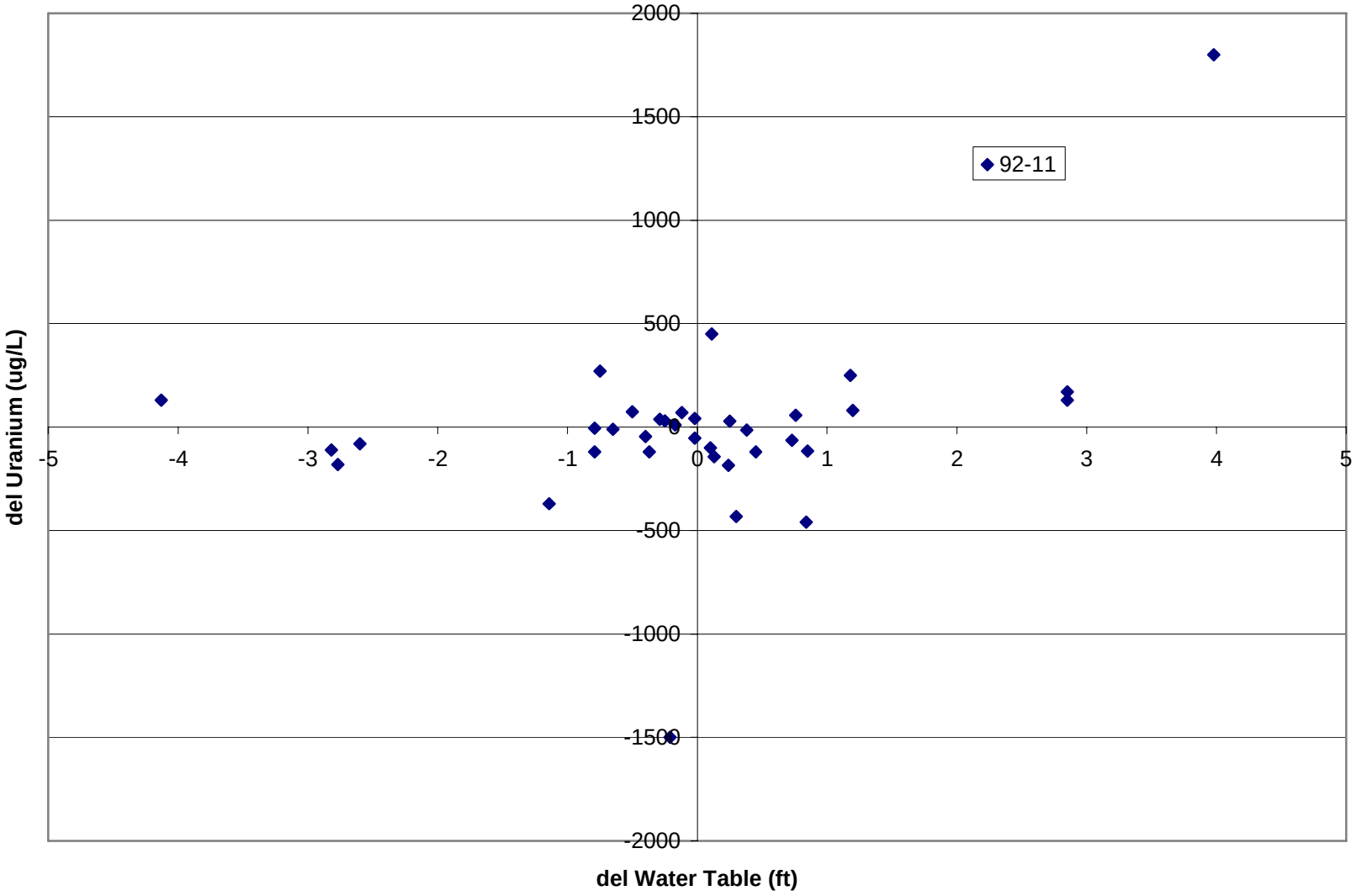


Figure 43. Uranium Concentration vs. Water Table Elevation, Well 92-11

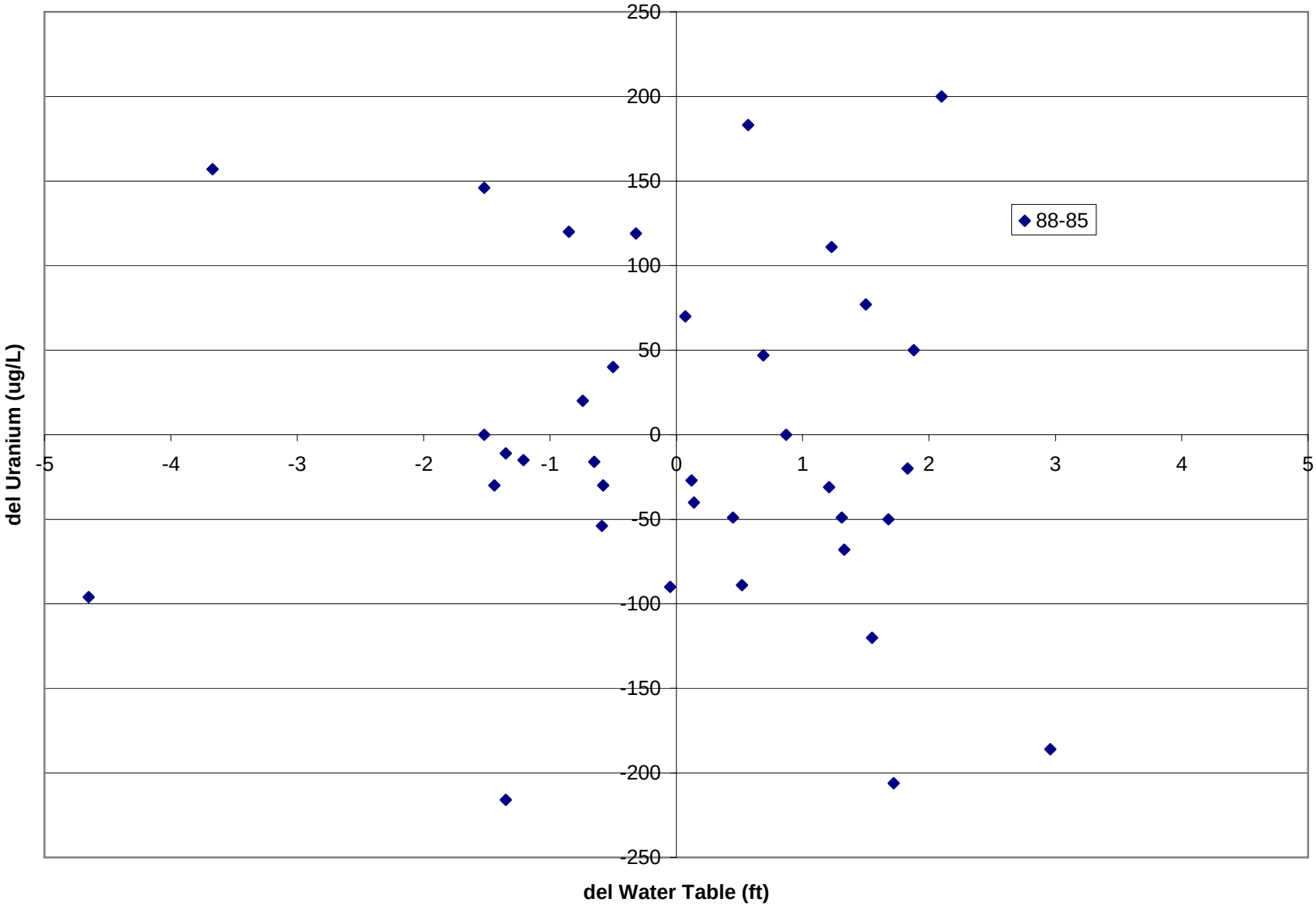


Figure 44. Uranium Concentration vs. Water Table Elevation, Well 88-85

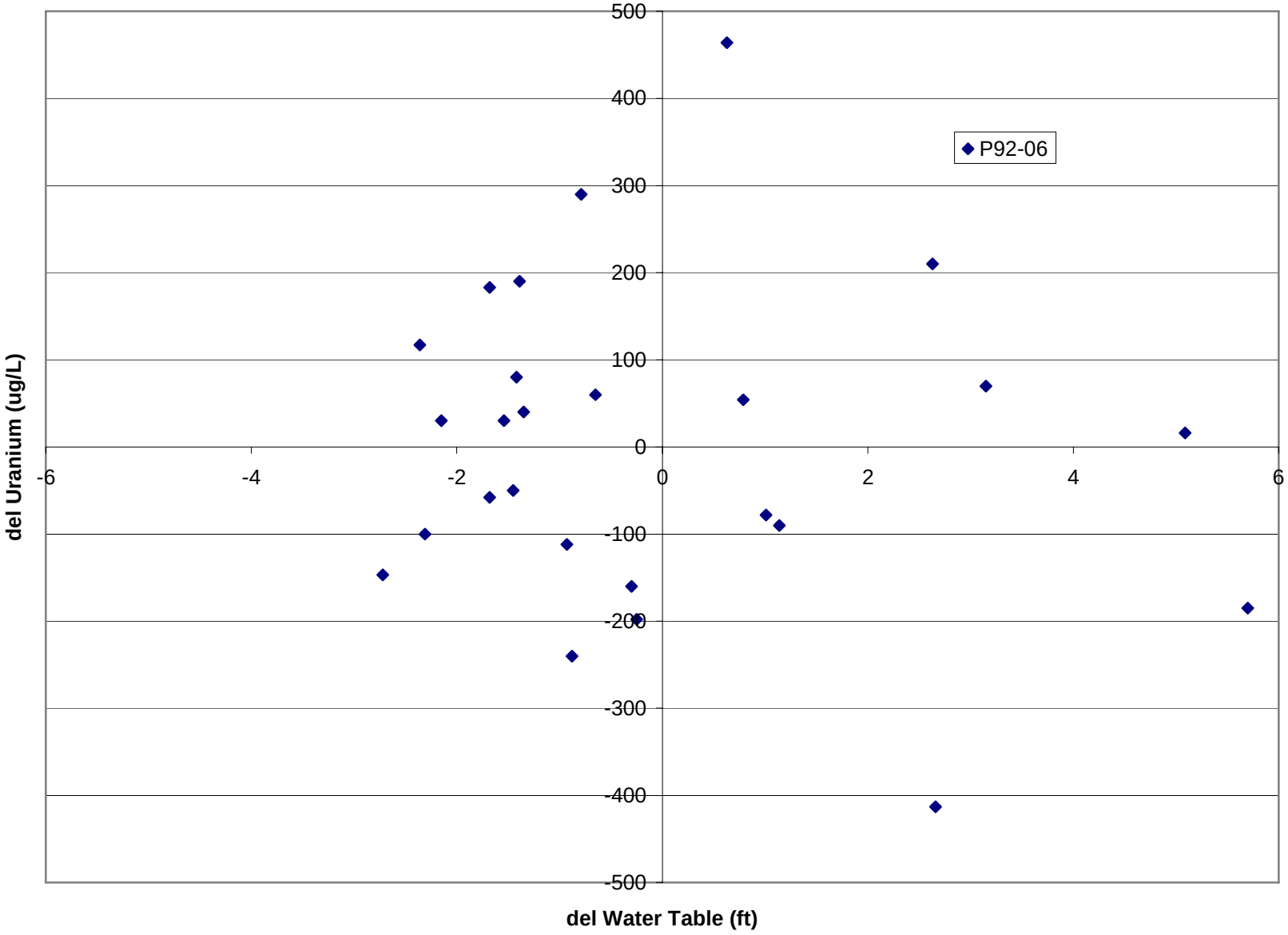


Figure 45. Uranium Concentration vs. Water Table Elevation, Well P92-06

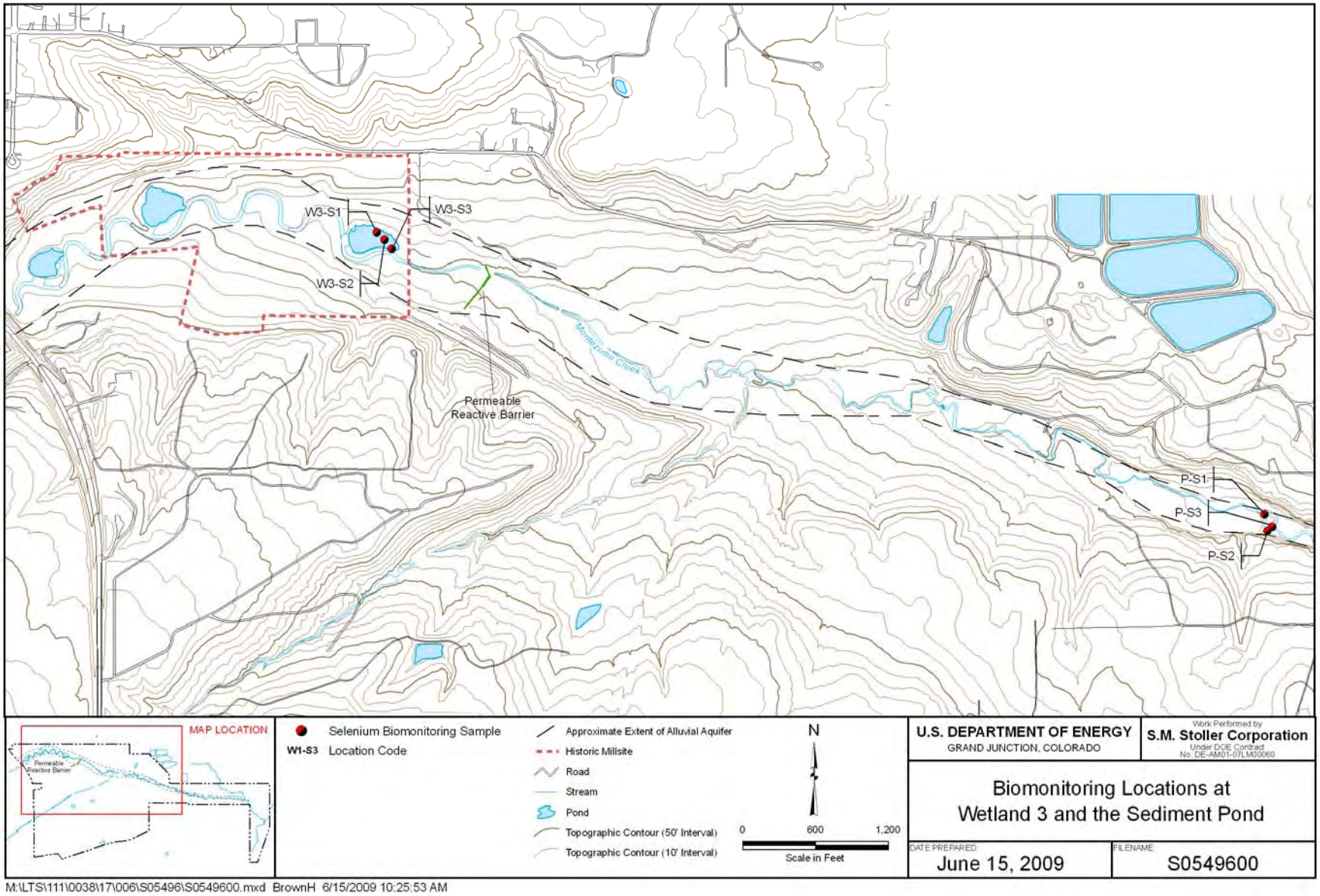


Figure 46. Biomonitoring Locations at Wetland 3 and the Sediment Pond

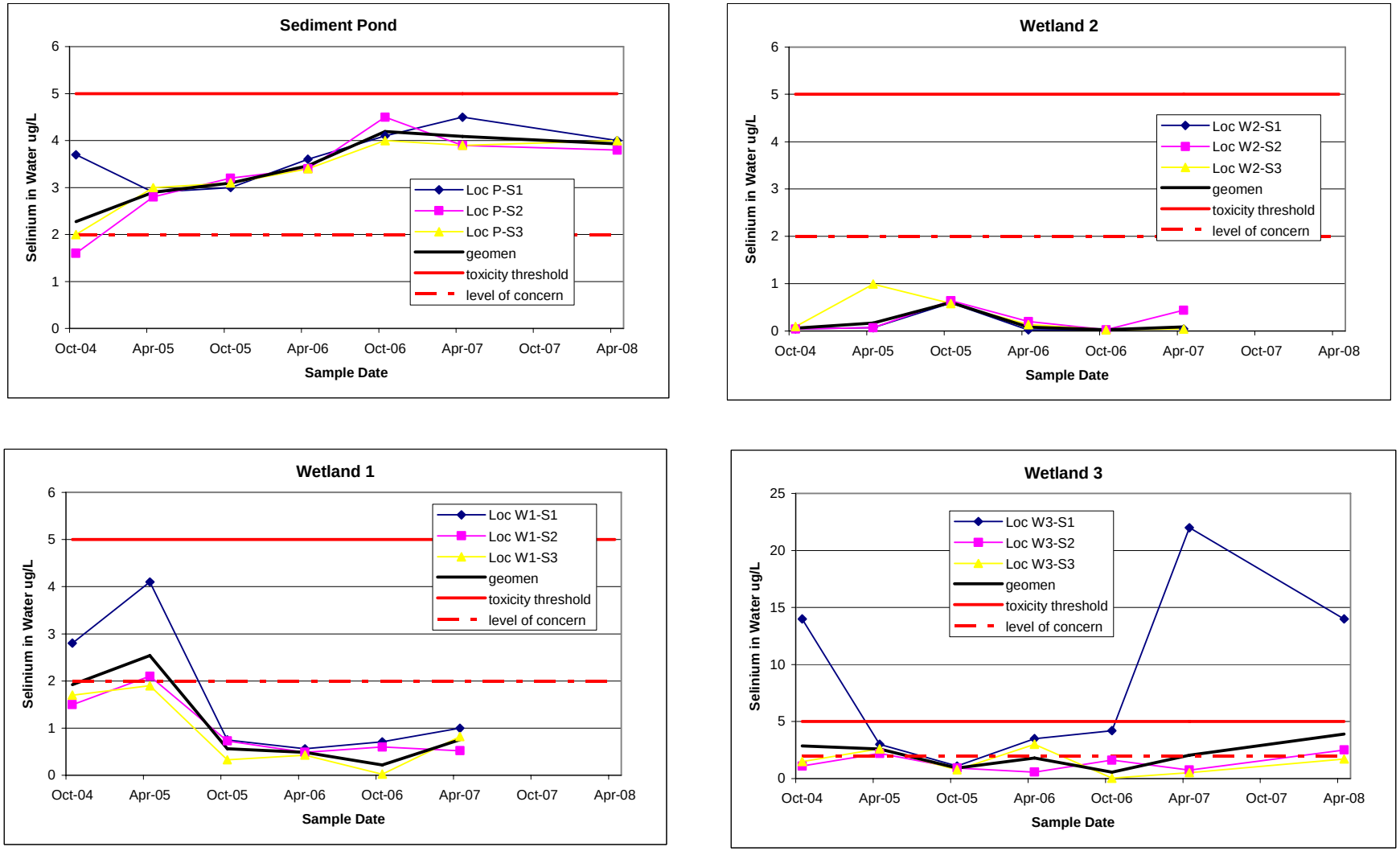
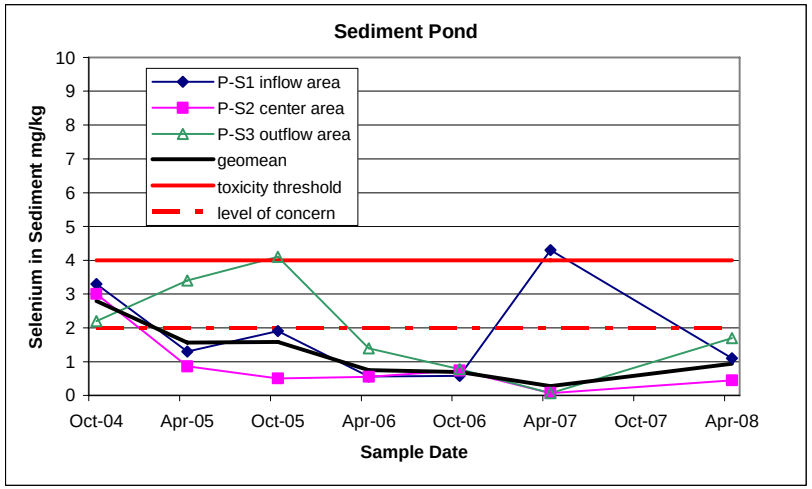
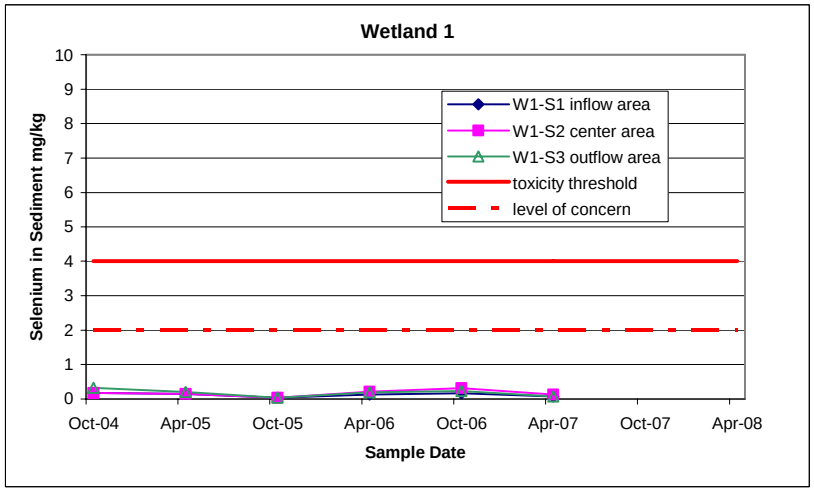
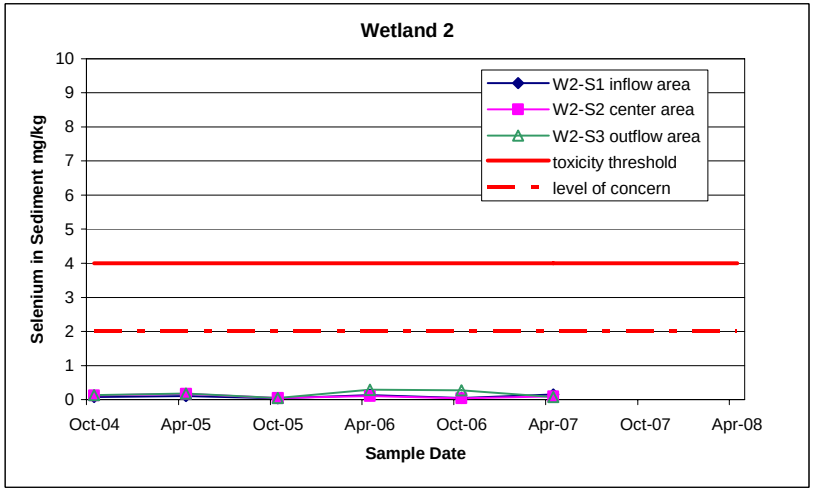


Figure 47. Selenium Concentrations in Surface Water







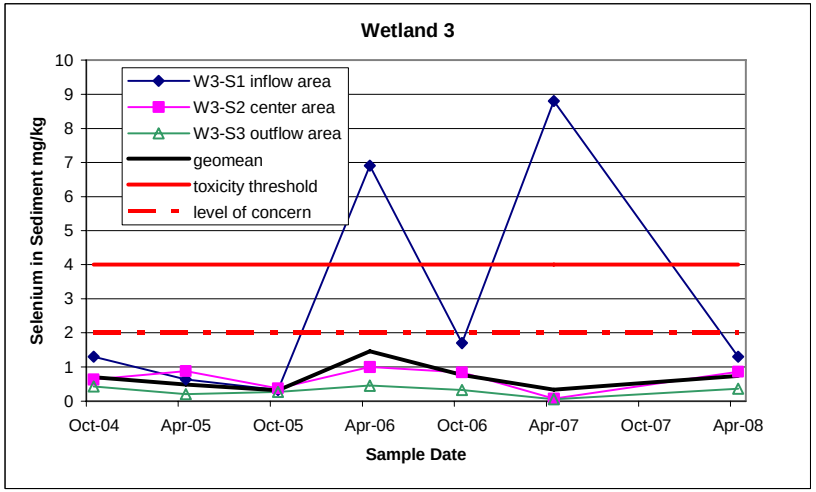
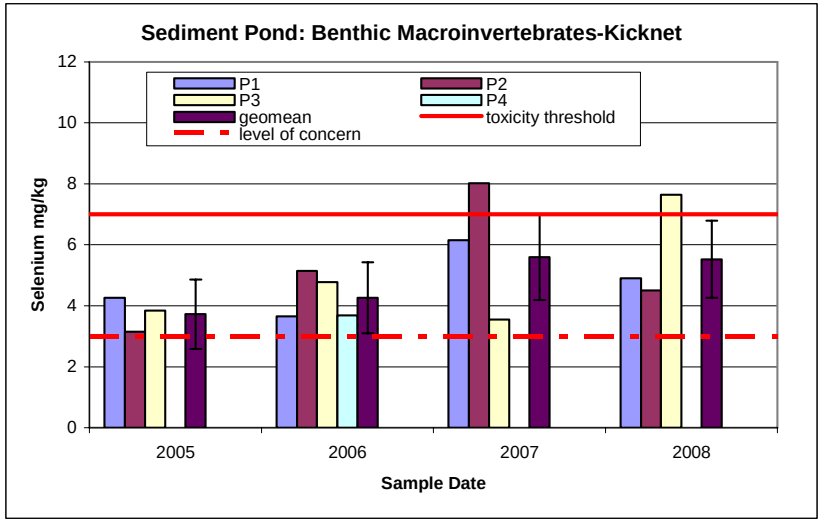
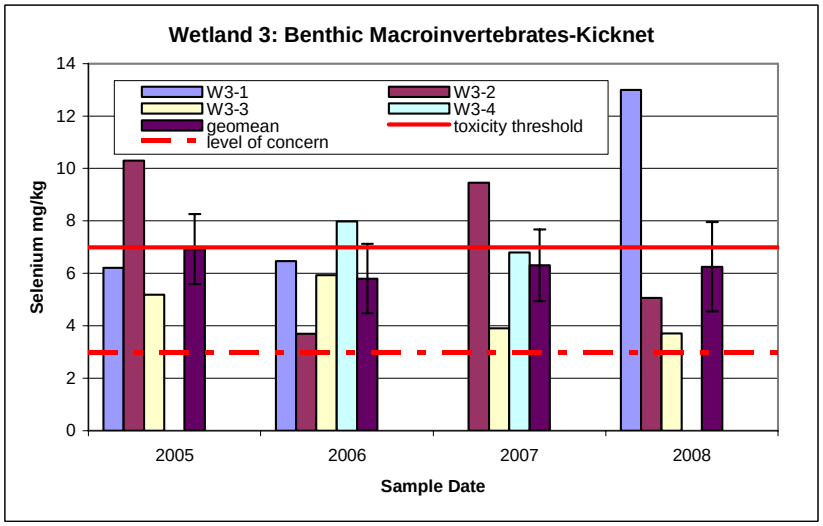
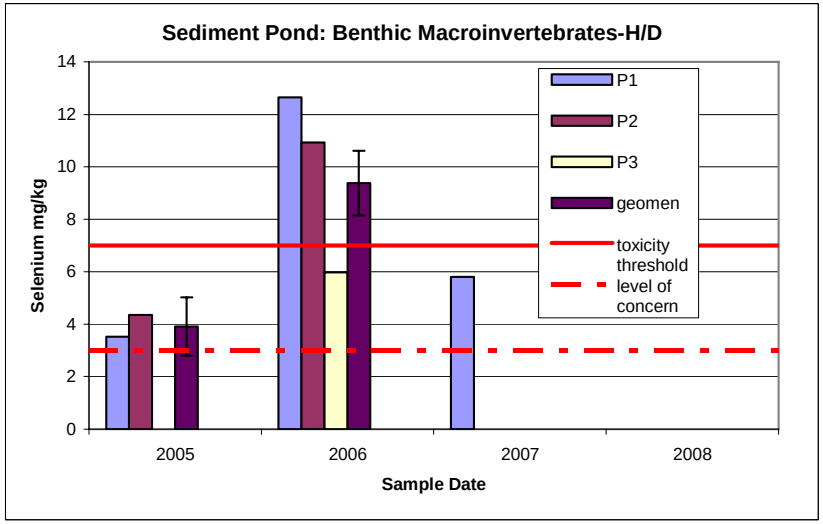


Figure 48. Selenium Concentrations in Sediment







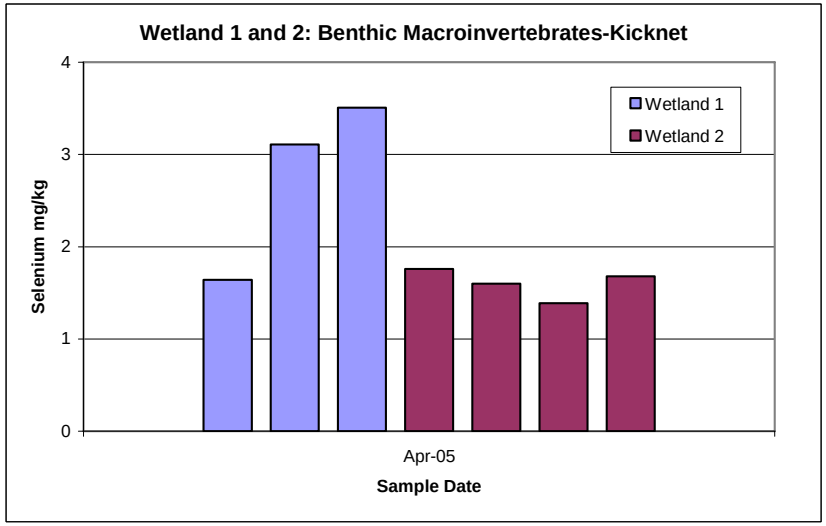


Figure 49. Selenium Concentrations in Aquatic Macroinvertebrate Tissue

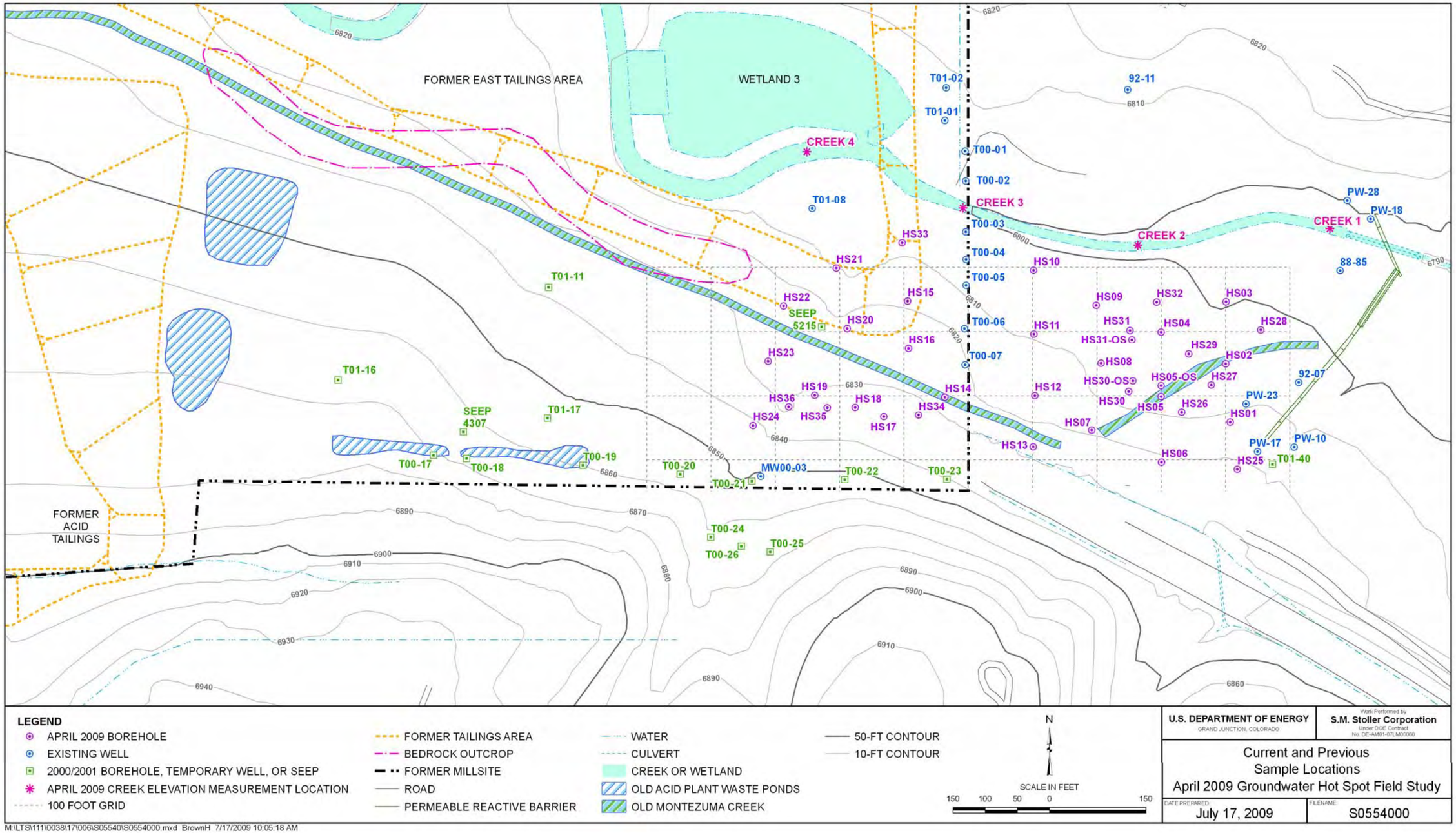


Figure 50. Current and Previous Sample Locations, April 2009 Hot Spot Study

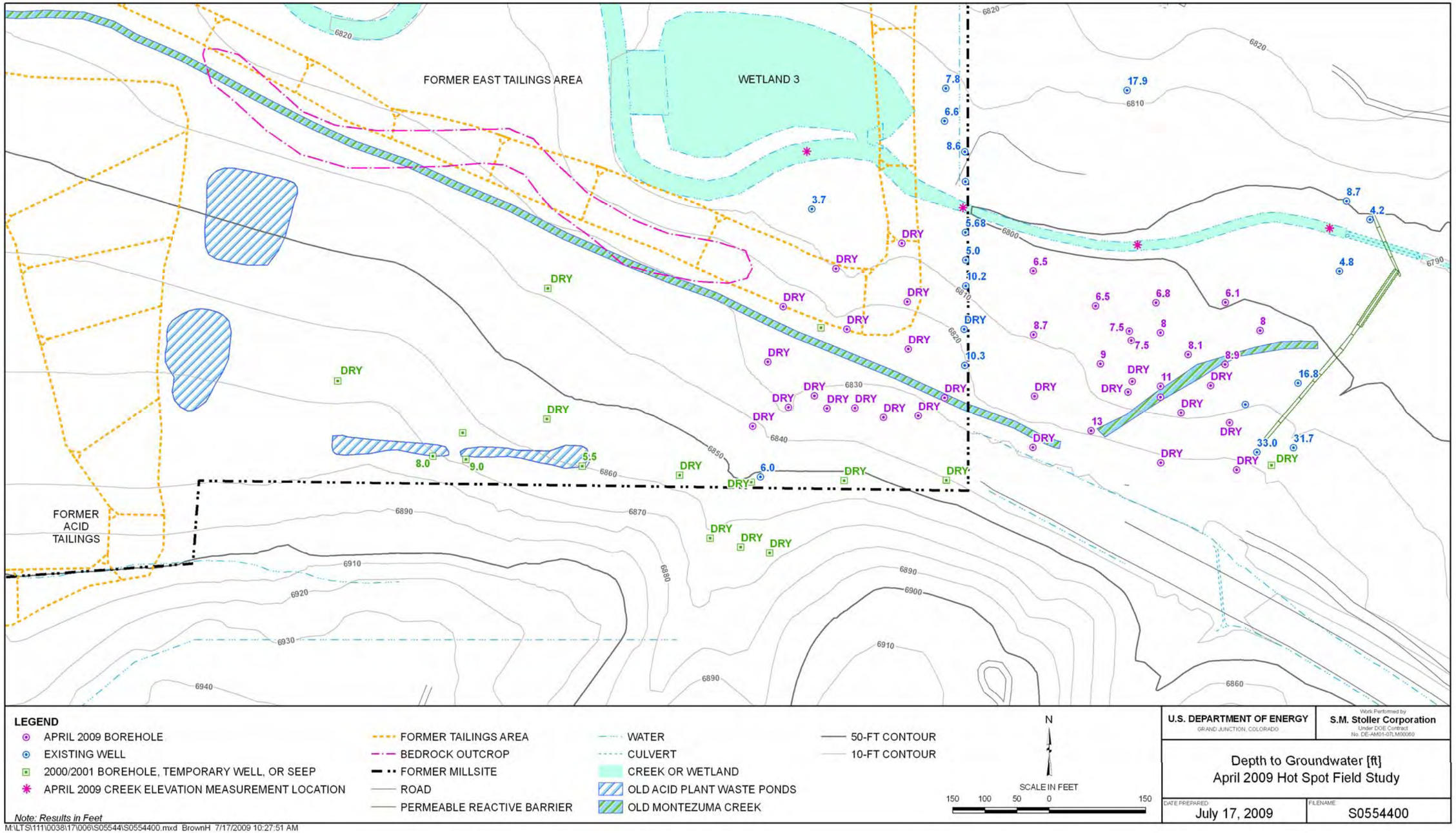


Figure 51. Depth to Groundwater, April 2009 Hot Spot Study

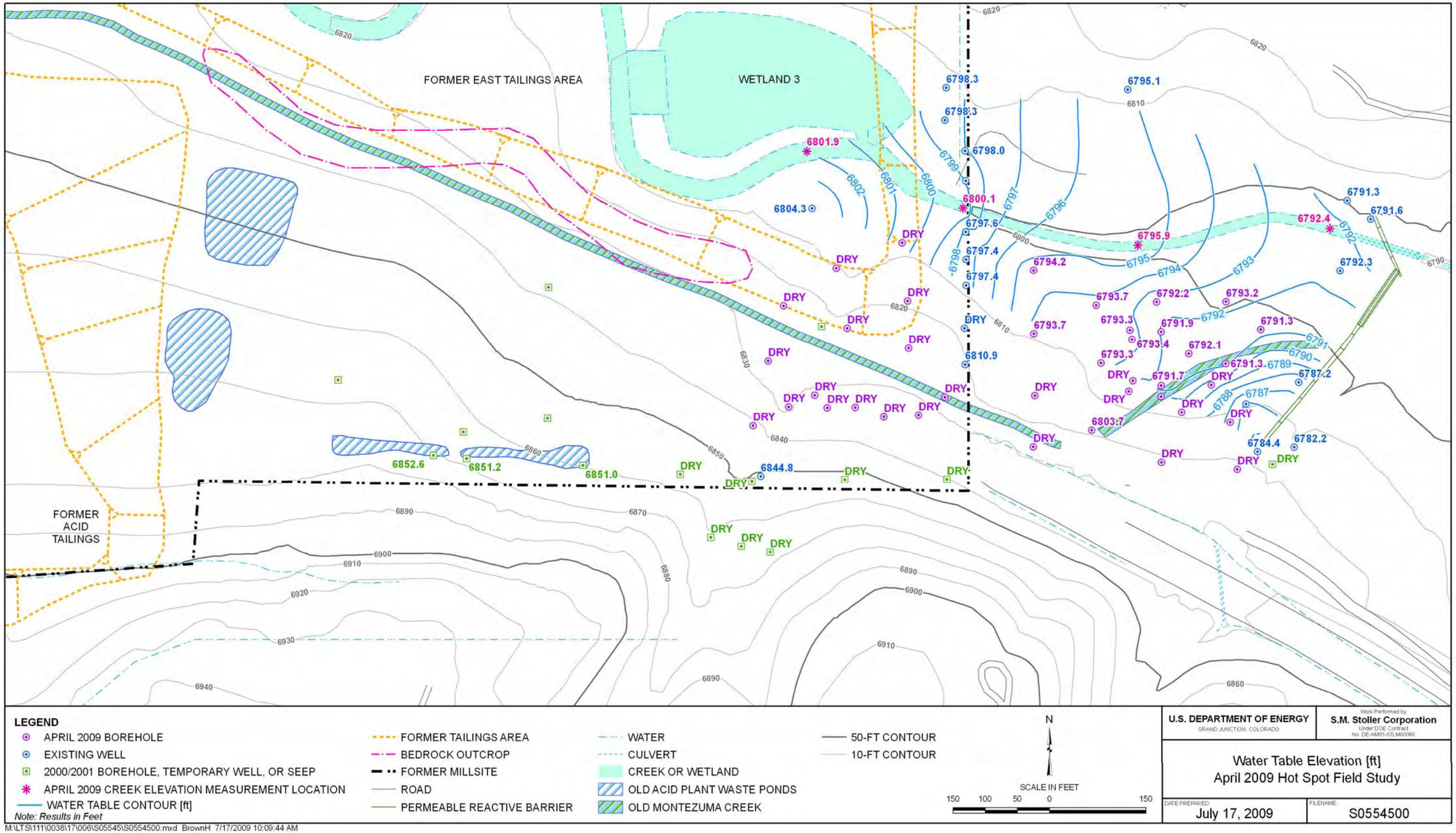


Figure 52. Water Table Elevation, April 2009 Hot Spot Study

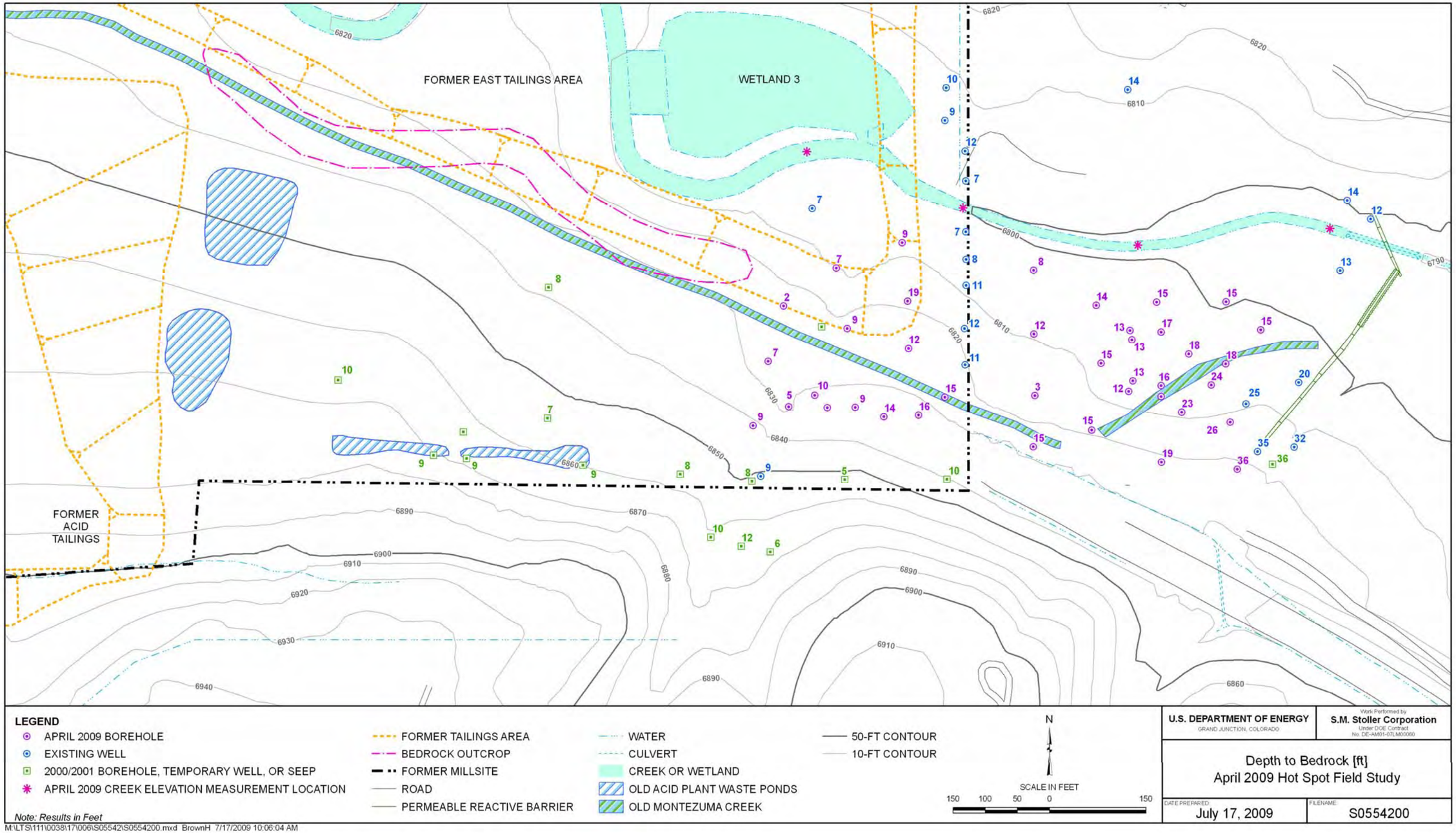


Figure 53. Depth to Bedrock, April 2009 Hot Spot Study

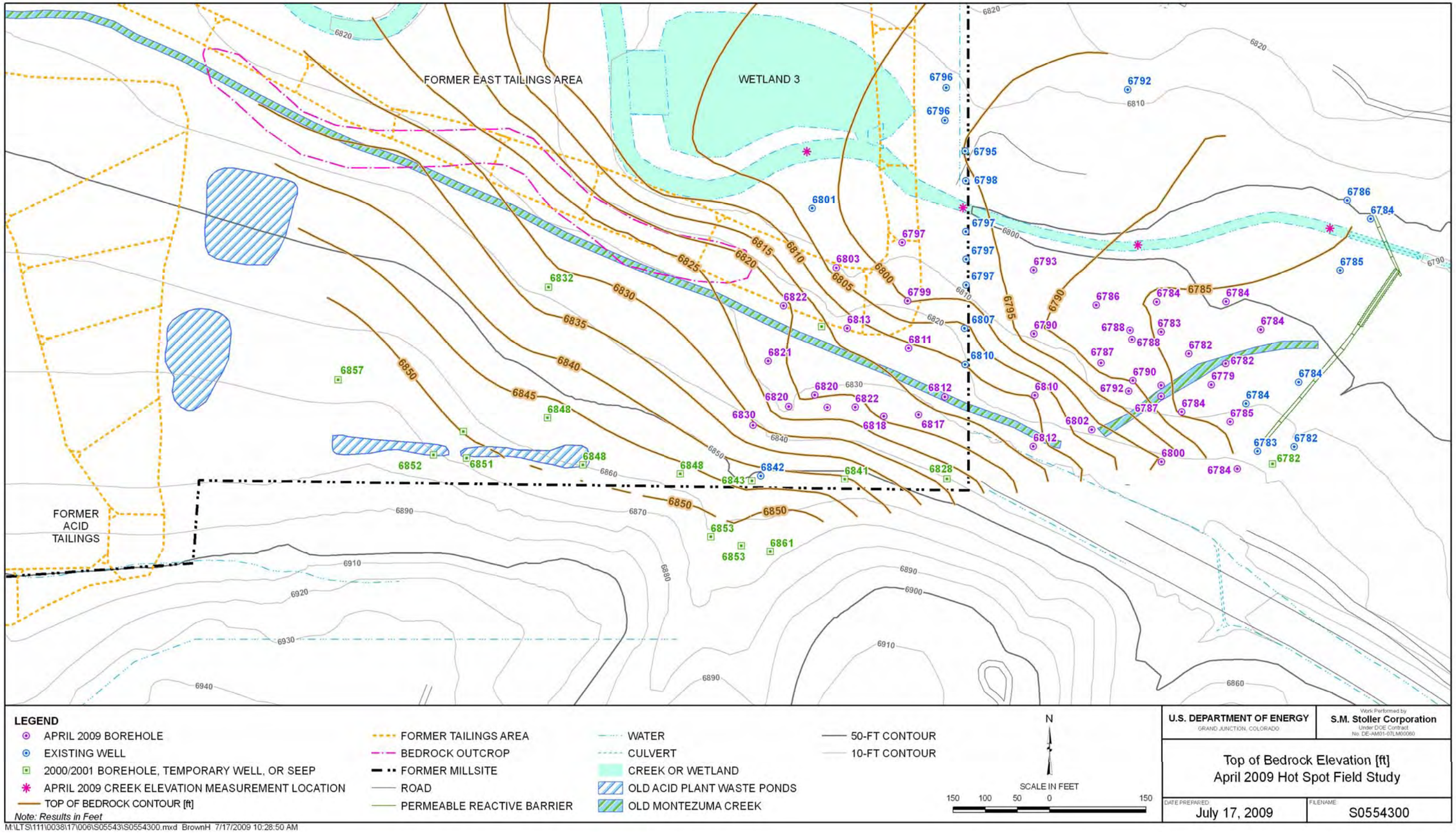


Figure 54. Top of Bedrock Elevation, April 2009 Hot Spot Study

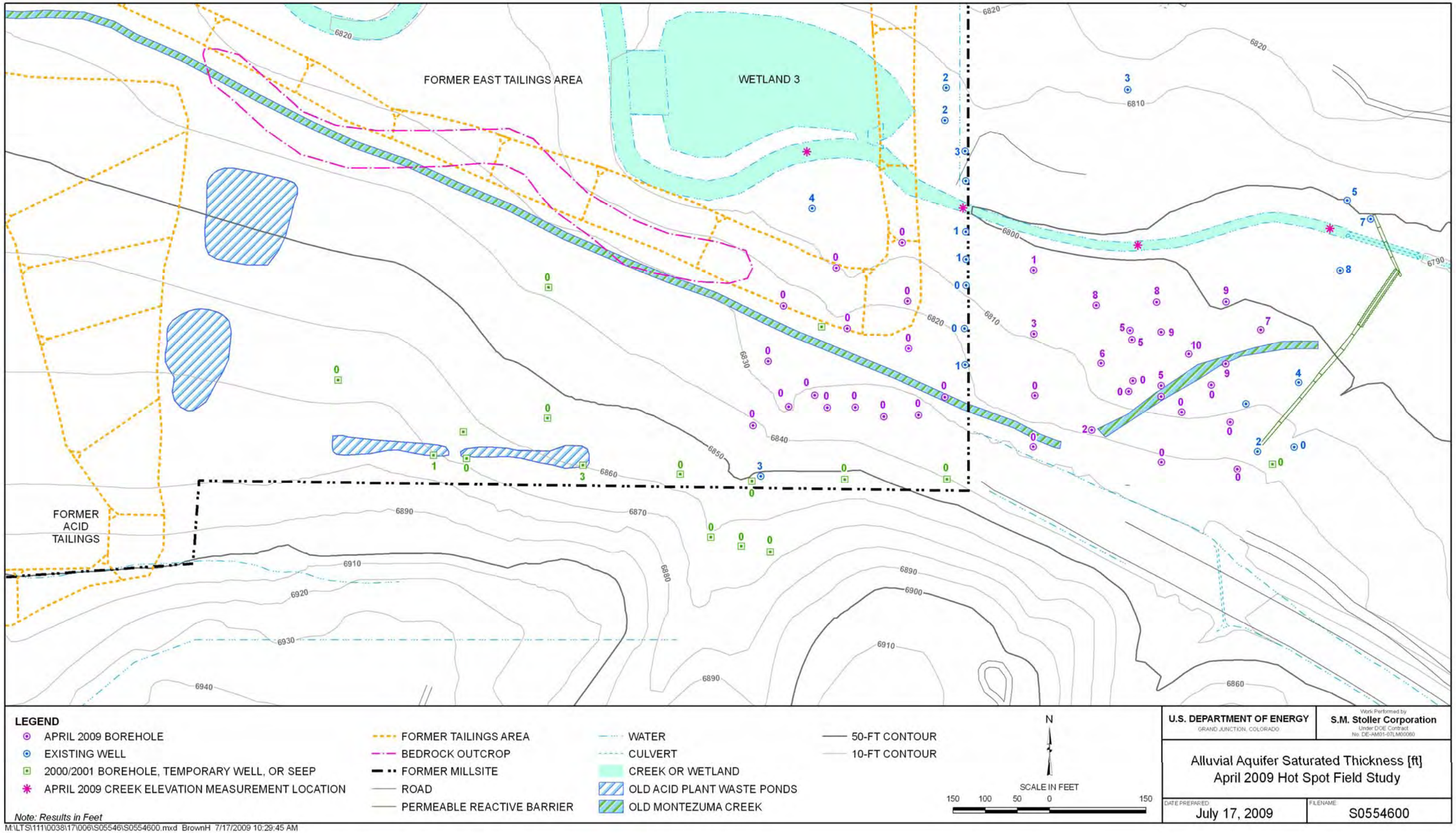


Figure 55. Alluvial Aquifer Saturated Thickness, April 2009 Hot Spot Study

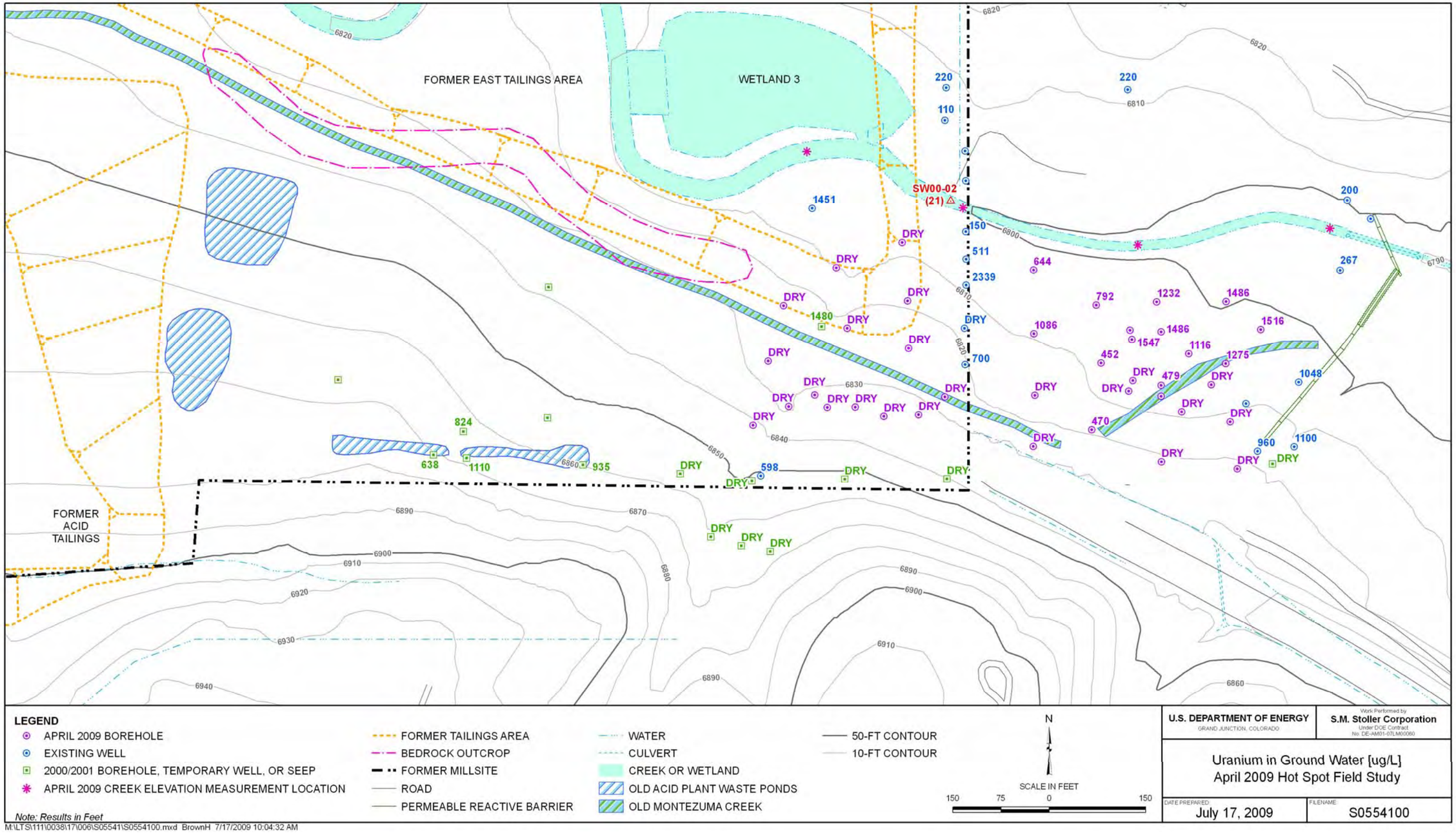


Figure 56. Uranium in Groundwater, April 2009 Hot Spot Study

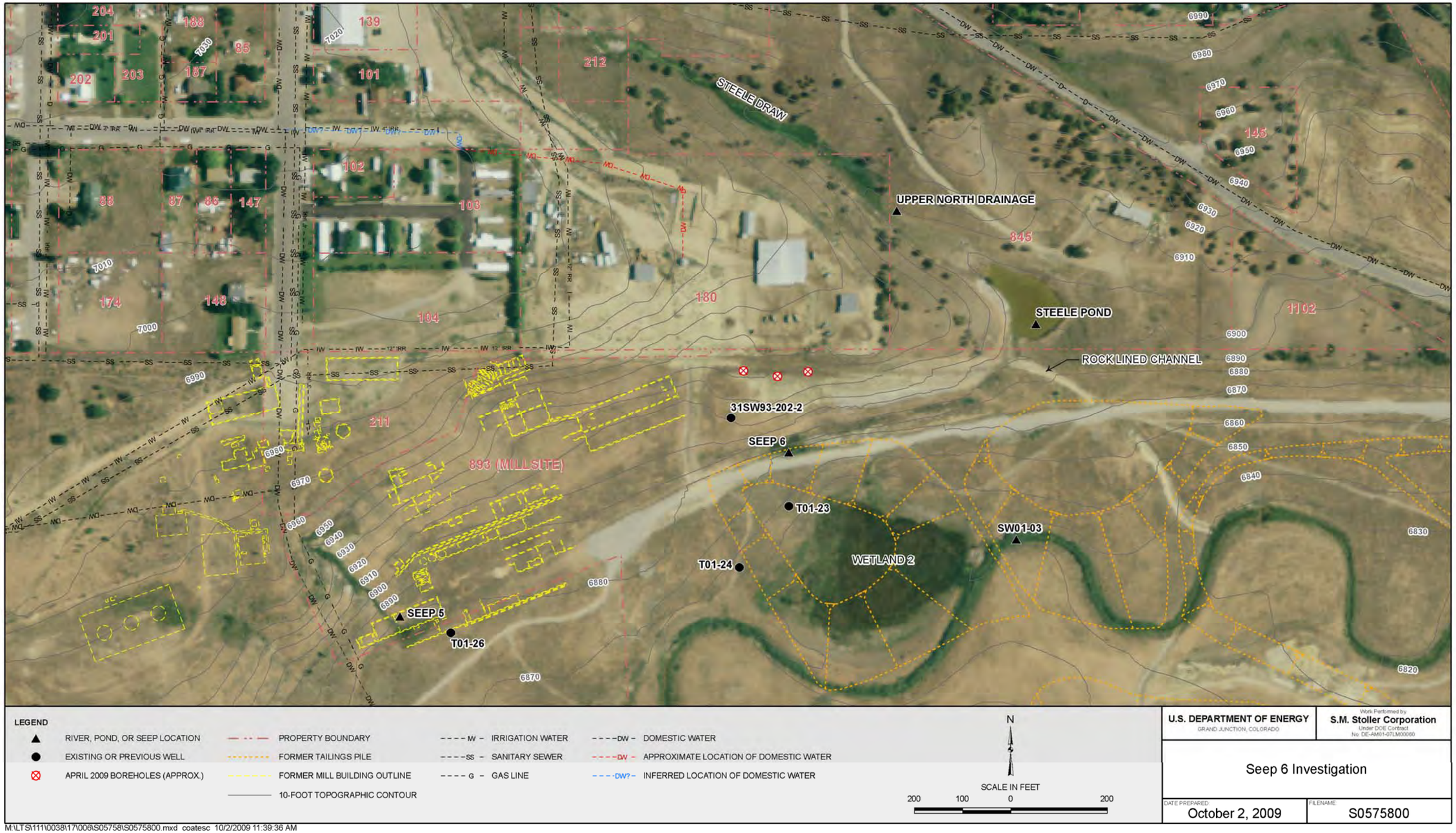


Figure 57. Seep 6 Investigation, General Features Map

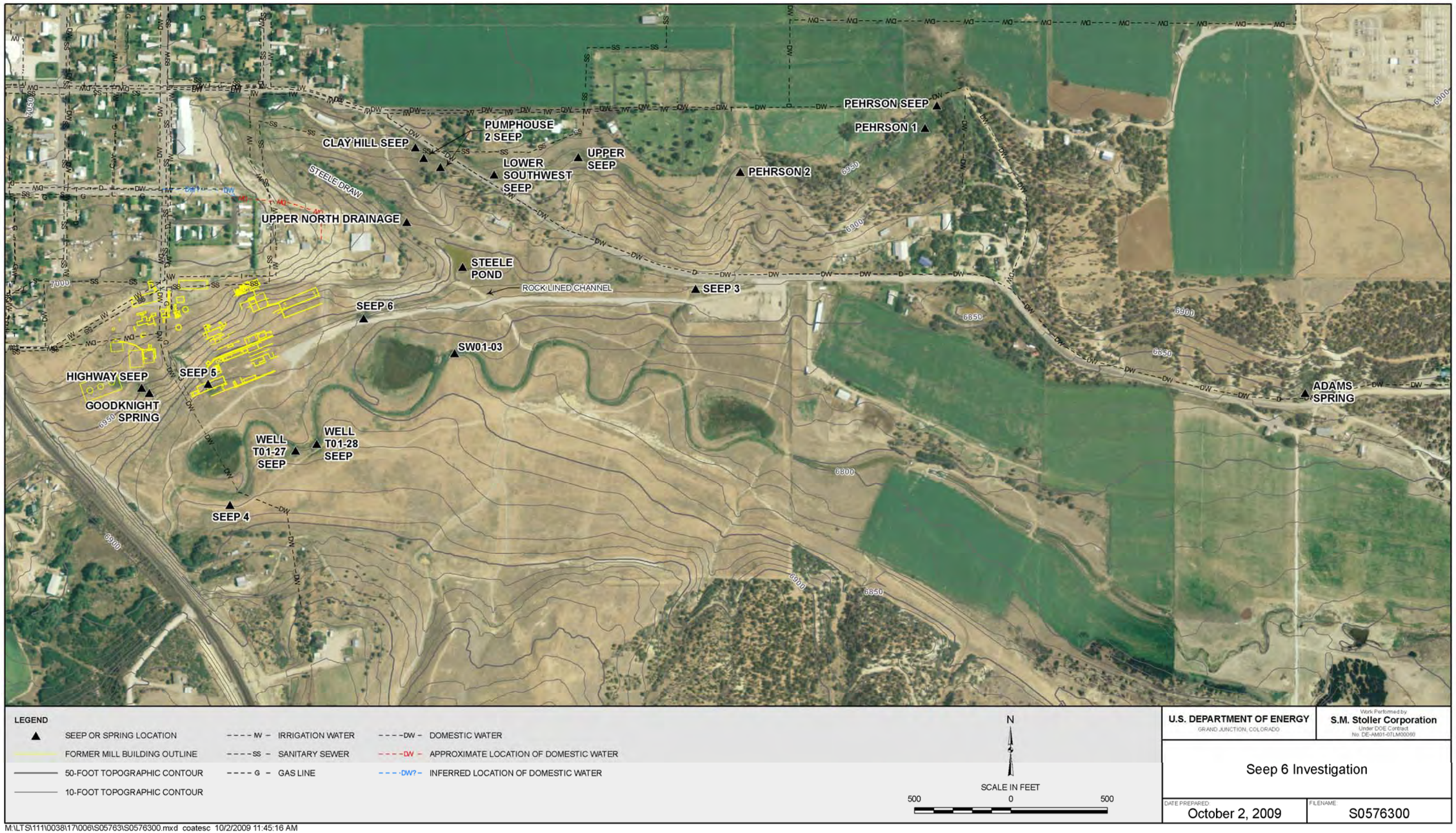


Figure 58. Seep 6 Investigation, Local Seep Locations

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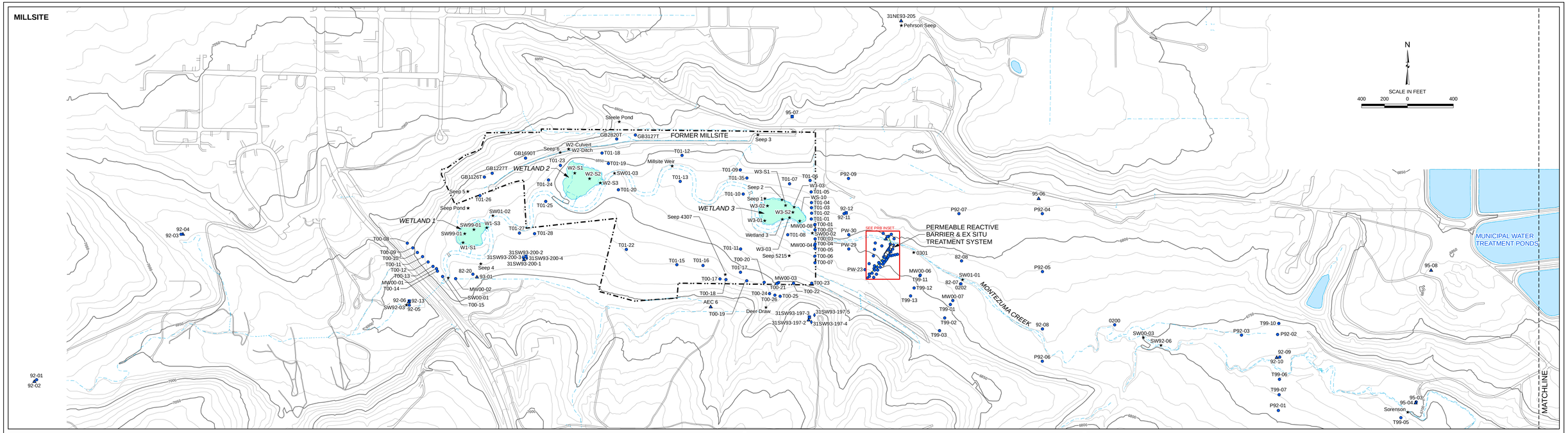

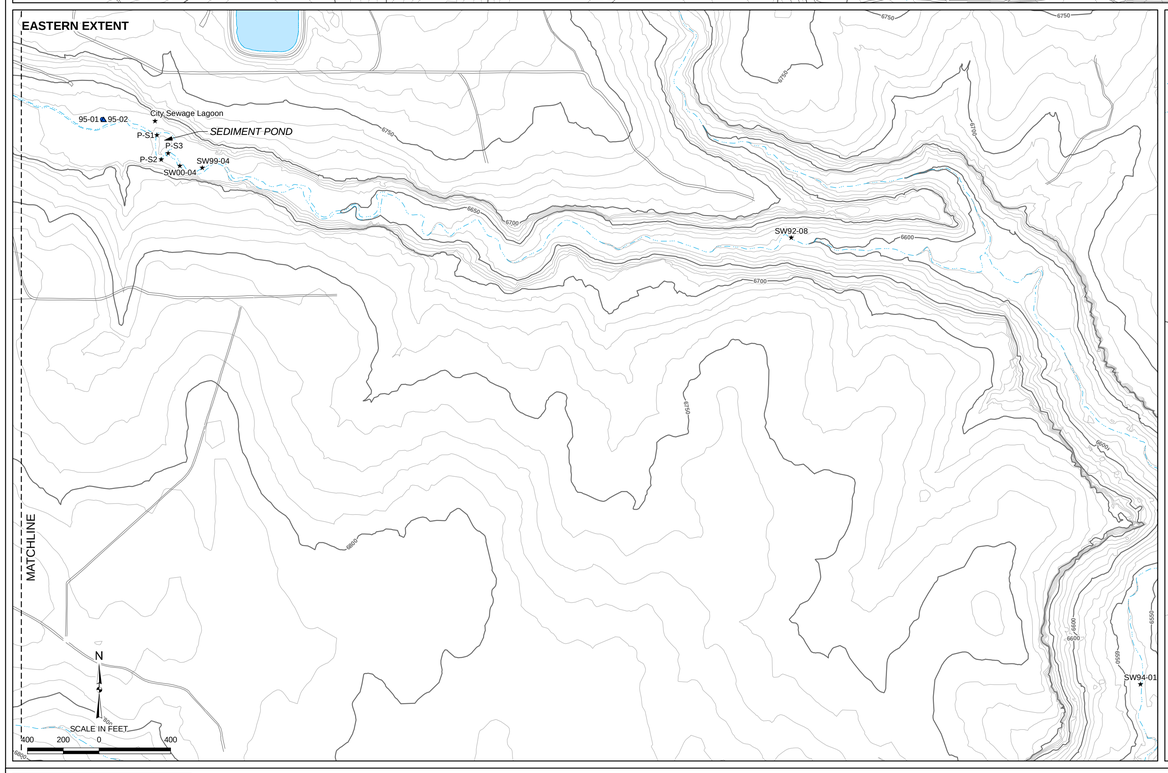

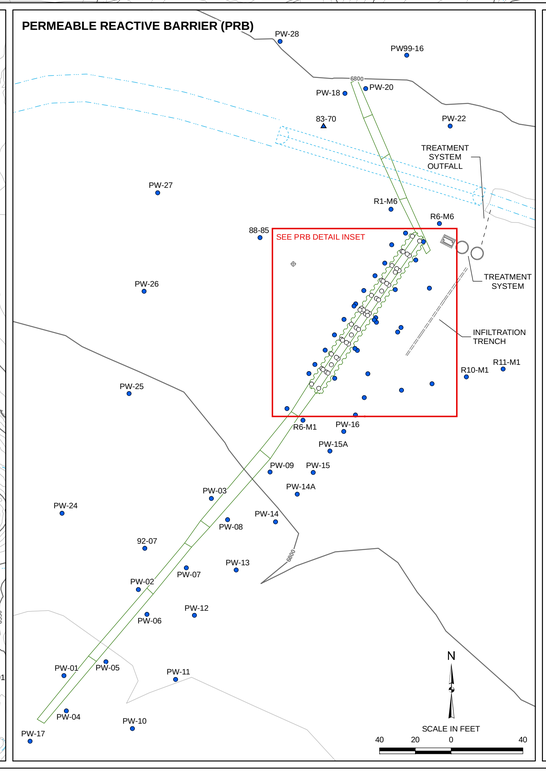

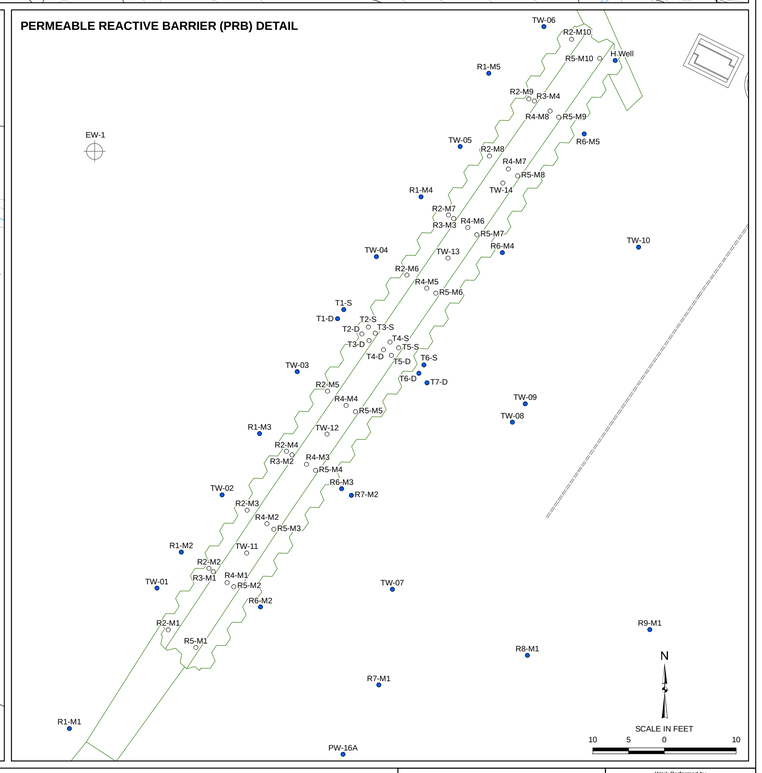

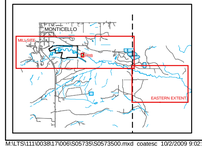

LEGEND

- ALLUVIAL GROUNDWATER MONITORING WELL
- MANCOS SHALE GROUNDWATER MONITORING WELL
- LOWER DAKOTA SANDSTONE GROUNDWATER MONITORING WELL
- BURRO CANYON AQUIFER GROUNDWATER MONITORING WELL
- REACTIVE MEDIA MONITORING WELL
- SURFACE WATER CHEMISTRY LOCATION
- FORMER MILLSITE
- ROAD
- PERMEABLE REACTIVE BARRIER
- WATER
- CULVERT
- INFILTRATION TRENCH
- TREATMENT SYSTEM
- 50-FT CONTOUR
- 10-FT CONTOUR
- POND
- WETLAND AREA

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO

Work Performed by
S.M. Stoller Corporation
Under DOE Contract
No. DE-AM01-07LM00060

PLATE 1
MMTS OU III SURFACE WATER AND GROUNDWATER MONITORING LOCATIONS

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FILENAME: S0573500

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