LMS/MNT/S07883

Monticello Mill Tailings Site Operable Unit III Annual Groundwater Report May 2010 Through April 2011

August 2011

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Plate

Plate 1	MMTS OU III Surface Water and Groundwater Monitoring Locations

Abbreviations

BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
FS	Feasibility Study
ft	foot/feet
gpm	gallons per minute
LM	Office of Legacy Management
µg/L	micrograms per liter
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
SOARS	System Operation and Analysis at Remote Sites
UDEQ	Utah Department of Environmental Quality
UDWQ	Utah Division of Water Quality
UMTRA	Uranium Mill Tailings Remedial Action
ZVI	zero-valent iron

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Executive Summary

This report provides the annual update of post-Record of Decision environmental monitoring conducted through April 2011 for Operable Unit III (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 site located in and near the city of Monticello, San Juan County, Utah.

MMTS is comprised of 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. Ore milling generated approximately 2.5 million cubic yards of mill tailings during mill operation from 1942 to 1960. The tailings were hydraulically emplaced and impounded at four locations on the mill site. Groundwater and surface water contamination resulted from the leaching of radioactive and other inorganic constituents contained in the tailings to the underlying valley-fill alluvial aquifer and to Montezuma Creek. Some mill tailings were dispersed by wind and some entered Montezuma Creek which resulted in the contamination of properties surrounding and downstream of the mill site.

Remedial actions to isolate radiologically contaminated soil, sediment, and debris from the environment were completed in 1999 with the encapsulation of these wastes in an engineered repository located on DOE property one mile south of the former mill site. 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. Additional monitoring is conducted monthly to evaluate performance of the groundwater treatment system that was adopted as a component of the OU III remedy under *Explanation of Significant Difference for the Monticello Mill Tailings (USDOE) Site, Operable Unit III, Surface Water and Ground Water, Monticello, Utah* (DOE 2009a).

The current reporting period identified no anomalous monitoring results or unexpected occurrences related to water quality. Similarly, the groundwater treatment system, which uses zero-valent iron as the treatment medium, functioned normally during the period at a sustained rate of approximately10 gallons per minute. However, restoration of the alluvial aquifer and surface water continues to progress more slowly than initial expectations based on groundwater modeling.

Biomonitoring is conducted at OU III to assess the potential risk to ecological receptors from the accumulation of naturally occurring selenium in wetland habitat in OU III. Field investigation for the OU III biomonitoring task was suspended in 2011. The scope of future biomonitoring activities will depend on regulator review of recent data analysis provided by DOE.

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1.0 Introduction

1.1 Scope and Objectives

This report provides the annual update of post-Record of Decision environmental monitoring conducted through April 2011 for Operable Unit III (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 site located in and near the city of Monticello, San Juan County, Utah (Figure 1). The Record of Decision for OU III (ROD) stipulates environmental monitoring and annual review of the progress of the selected remedy (in *Record of Decision for the Monticello Mill Tailings (USDOE) Site Operable Unit III, Surface Water and Ground Water, Monticello, Utah*, May 2004 [DOE 2004a]). The ROD selected monitored natural attenuation with institutional controls as the remedy for OU III.

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 also specifies a phased approach to evaluate potential risk to ecological receptors ("biomonitoring") from selenium accumulation in selected wetland areas. The scope, rationale, and procedures for post-ROD monitoring activities are documented in *Monticello Mill Tailings Site Operable Unit III Post-Record of Decision Monitoring Plan*, Draft Final, August 2004 (DOE 2004b).

As stipulated in Appendix B of the OU III ROD, "Performance Evaluation Plan for Monitored Natural Attenuation at Monticello Mill Tailings Site Operable Unit III," 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
- Biomonitoring results (cumulative) and comparison to established toxicity thresholds

This report includes 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 for the Monticello Mill Tailings (USDOE) Site, Operable Unit III, Surface Water and Ground Water, Monticello, Utah* (DOE 2009a).

This report also includes a summary of recent field investigations that were completed outside of the scope of routine OU III monitoring. These investigations, presented in Section 8.0, were initially identified in *Monticello Mill Tailings Site Operable Unit III Water Quality Compliance Strategy* (DOE 2009b), as possible means to determine the next phase of OU III remedial action. The focus of these activities was to characterize an area of elevated uranium in groundwater located immediately east of the former mill site (see Section 8.1); to evaluate the source of uranium contamination at a seep located on the north side of the former mill site (Seep 6; see Section 8.2); and, to evaluate the source of uranium contamination in Montezuma Creek downstream of the former mill site where the remediation goal is exceeded (Section 8.3).

Section 8.4 of this report summarizes findings of an investigation that is separate from the water quality compliance strategy to evaluate uranium occurrence in an irrigation pond in OU III.

2.0 Historical Information

2.1 Background Information

The MMTS was established as a CERCLA National Priorities List 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. Ore milling generated approximately 2.5 million cubic yards of a sandy waste byproduct, or tailings, during its operation from 1942 to 1960. The tailings were hydraulically emplaced and impounded at four locations on the mill site. 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 to Montezuma Creek. Some mill tailings were dispersed by wind and, some entered into Montezuma Creek, which resulted in the contamination of properties surrounding and downstream of the mill site.

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 LM repository located on DOE property one mile south of the former mill site. 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 (FS).

The RI report was issued in September 1998 (DOE 1998a); however, a companion FS report was not completed beyond draft status because of ongoing OU I and II remedial actions that would significantly and unpredictably impact the groundwater and surface water setting. This condition 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 ROD (DOE 1998b) and to complete the FS later when site conditions had stabilized.

The interim measures included implementing institutional controls to restrict use of contaminated groundwater, expanding and continuing water quality and hydrologic monitoring, characterizing 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. Also, the OU III groundwater model and the OU III human health and ecological risk assessments were updated from those completed under the RI. Results of the interim remedial action 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 the finding of no exposure scenario with significant risk, provided the

technical basis in selecting monitored natural attenuation with institutional controls as the OU III remedy. The ROD did not mandate the PRB as a remedy component.

The OU III ROD provided specific criteria to evaluate remedy performance based on a comparison between observed rates of water quality restoration to those predicted by the OU III groundwater model. The ROD also addressed possible response actions should the performance criteria not be met. DOE first recognized in 2006, and later confirmed in 2007 (DOE 2007a), that restoration progress did not meet the performance criteria. DOE also recognized by that time that the effectiveness of the PRB in treating the groundwater was significantly diminished due to mineral fouling. DOE then installed an ex situ pump-and-treat system using ZVI in the area of the PRB in 2007 to further evaluate remediation technology alternatives.

The ex situ system was operated as a technology demonstration project through March 2009. In March 2009, DOE, EPA, and UDEQ concurred in the Explanation of Significant Difference (ESD) to implement a contingency remedy to evaluate the feasibility of pump-and-treat technology for OU III. The ESD formalized the existing pump-and-treat groundwater remediation system as a remedy component. DOE also committed to evaluate options to expand the scope of groundwater capture and treatment. That evaluation is documented in *Monticello Mill Tailings Site Operable Unit III Remedial Design/Remedial Action Work Plan for Groundwater Remediation Expansion* (January 2011). DOE postponed implementing the work plan, in concurrence with EPA and UDEQ, in April 2011 to investigate other options to evaluate the groundwater remedy.

Figure 2 depicts the approximate present extent of uranium contamination in OU III groundwater. The extent of uranium contamination in surface water is similar to that in groundwater, although at much lower concentrations. Uranium is the primary groundwater contaminant in OU III because (1) compared to other site contaminants of concern (COCs), it is most widely distributed at higher concentration relative to restoration goals, and (2) by way of the groundwater ingestion pathway, 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.

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 rabbitbrush. Willow 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 designated and maintained as an 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 rugged 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 flat-lying, 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. Contamination in the alluvial aquifer does not migrate to the deeper Burro Canyon Sandstone aquifer in detectable quantities.

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 on South Creek about 0.5 mile upstream of the mill site, and by municipal diversions from North Creek in the Abajo Mountains. Leakage through the reservoir dam is a main source of base-flow in Montezuma Creek and local recharge to the alluvial aquifer. Leakage from North Creek is also a likely source of local 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 in the mill site reach.

To accommodate placement of the tailings during mill operation, the eastern reach of Montezuma Creek on the mill site was rerouted 200 to 300 ft south from its natural course in the center of the valley. The new channel was about 25 ft above the natural course at the east boundary of the mill site and extended several hundred feet farther east. In an early effort to stabilize the site after milling ceased, an energy dissipater was constructed at that location to prevent headward erosion by the creek into the tailings areas. This structure was removed during later remedial actions, and Montezuma Creek was then restored to its natural position.

Remediation of the mill site required the removal of much of the native alluvium to bedrock. This temporarily exposed deposits of siltstone, shale, and low-grade coal that compose the middle section 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 form a channel several feet wide to contain the creek. This corridor was excavated several feet into bedrock in some areas and occupies the central 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 through an infiltration gallery (cobbles and boulders) built into the upstream banks. The wetlands were excavated into bedrock and fully penetrate the alluvial aquifer. Groundwater discharge from the alluvial aquifer therefore also contributes water to the wetlands as bank seepage. The eastern base of Wetland 3 rests on native alluvium, which allows some leakage from the wetland 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 10 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 sheet-wash colluvium and loess.

A gaining stream condition resumes within about 2,000 to 2,500 ft of the mill site in the area of monitoring wells 82-08, P92-06, and 0200 (see Figure 3 for well locations) as a result of groundwater discharge from the alluvial aquifer. Farther east at the head of the canyon, the alluvial aquifer narrows to about 100 ft and remains thin. This constriction forces additional 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 upward into 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 east where the creek incises the Burro Canyon sandstone (total thickness of the Burro Canyon is approximately 120 ft in this area). 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 lithologic change to 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 (and continues) 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 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 water 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.

3.3 Groundwater Remediation Systems

3.3.1 Permeable Reactive Barrier

The PRB is a subsurface treatment system that was installed to immobilize uranium and other site contaminants as groundwater flows through the reactive media. It was installed in June 1999 on private property about 750 ft east of the former mill site. The PRB measures 103 ft long, north to south (perpendicular to flow) by about 13 ft deep by 8 ft wide (parallel to flow) and is constructed of two treatment zones. The first treatment zone is 2 ft wide and consists of crushed gravel and 13 percent ZVI by volume. 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 aquifer.

The PRB is keyed 1 to 2 ft into low-permeability mudstone bedrock. Low-permeability slurry walls constructed of bentonite-amended soil extend north and south from the PRB to divert groundwater to the treatment zones. 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.

Field and laboratory studies have revealed a progressive loss of hydraulic conductivity of the ZVI, due mainly to the precipitation of calcium carbonate and iron oxide minerals. This has greatly reduced the capacity of the PRB to transmit groundwater and has contributed to groundwater mounding in the area immediately upgradient of the PRB.

3.3.2 Pump and Treat Enhancement System

An ex situ groundwater treatment system was installed in June 2005 and expanded in March 2007 as a technology demonstration alternate to the PRB in evaluating groundwater treatment by ZVI. DOE operates the system since 2009 as directed by the ESD as part of the contingency remedy to enhance natural attenuation.

The ex situ system functions by pumping groundwater through two cylindrical concrete cells that contain the treatment media (ZVI/gravel mixtures). The base of the cell is constructed of

concrete. Each cell, serviceable from ground surface, measures 6 ft in diameter by 6 ft in depth and is set vertically approximately 4½ ft into the ground. Groundwater is extracted at a well located in the groundwater mound upgradient of the PRB (well EW-1 in Figure 3, PRB inset) and is pumped upward, in parallel, through the cells. A third vault (rectangular in outline, see Figure 3, PRB inset) houses monitoring and control devices. The system is designed to discharge treated water to Montezuma Creek through an outfall pipe and to the aquifer by way of an infiltration trench. The treatment capacity of the system is approximately 14 gpm, which is the maximum sustainable pumping rate at EW-1. Each treatment cell can effectively remove uranium at an inflow rate of 5 gpm for about 1 to 1.5 years. The capacity of the infiltration trench to return treated water to the aquifer is about 4 gpm.

3.3.3 Telemetry System

The treatment system is equipped to monitor influent line pressure to each treatment cell; flow rate through each treatment cell; discharge rate to Montezuma Creek and the infiltration trench; and water levels in the extraction well, the treatment cells, and infiltration trench. Data are collected on closely spaced time intervals (usually every 2 hours) and downloaded (usually every day) via cellular telephone service to the LM Systems Operation and Analysis at Remote Sites (SOARS) administered in Grand Junction, Colorado. Monitoring data are available for remote real-time and historical viewing and processing. The components of the automated data collection, transmission, and display system are collectively referred to as the telemetry system.

Each treatment cell is instrumented to prevent overfilling. Automated alarms are transmitted by cellular telephone to SOARS when the well pump is deactivated by pump failure, overfill prevention, or by power failure. The water level in the infiltration trench is monitored and regulated to prevent groundwater saturation at land surface. The telemetry system allows for remote activation and deactivation of the pump. Flow rate adjustments are performed manually in the field.

3.3.4 Operating Parameters

The treatment system is currently operated to maximize the rate of groundwater treatment within the established allowances for discharging the effluent. These allowances are:

- A maximum discharge rate of 10 gpm of treated water to Montezuma Creek.
- Treated water discharged to the creek is not to exceed 45.4 milligrams per liter (mg/L) total iron and is to have a pH of not less than 6.5 and not greater than 9.0.
- Treated water can be discharged to the alluvial aquifer by way of the infiltration trench.

The discharge allowances to Montezuma Creek were negotiated between DOE, EPA, UDEQ, and Utah Division of Water Quality (UDWQ) in May 2008. These allowances are based on the Utah standard for acute iron toxicity to aquatic wildlife (1 mg/L) and the in-stream standard for pH for all water-use categories. The default perennial flow rate for the receiving surface water (Montezuma Creek) is 2 cubic ft per second, as communicated by UDWQ. Discharge of treated water to the infiltration trench was negotiated with the UDEQ Underground Injection Control Program in June 2005 while the system was operated as a technology demonstration project.

Water samples are collected monthly at influent and effluent locations to monitor the performance of the treatment system in removing uranium and to monitor compliance with the pH and iron discharge allowances. The monitoring data are also used to determine when media change-out is needed and for estimating the mass of uranium removed from the aquifer. The telemetry system monitors flow rates to ensure compliance with the discharge allowance, to recognize non-normal operating conditions, and to monitor the volume of groundwater treated.

Additional descriptions of the operating parameters, performance monitoring, media change-out criteria, and reporting requirements are provided in the treatment system operating plan that was issued in December 2009 under Program Directive MNT-2010-02. Past performance of the treatment system indicates that replacement of the treatment cell media will occur every 1 to 1.5 years.

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 and Remediation Goals

COCs for OU III surface water and groundwater are arsenic, manganese, molybdenum, nitrate, selenium, uranium, vanadium, and gross alpha and gross 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 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; however, 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.

Analyses to determine activities of uranium-234 and uranium-238 in groundwater and surface water were discontinued in 2006 in concurrence with EPA and UDEQ. 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 of 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. Analyses for gross alpha and gross beta activity were also discontinued in 2006 with concurrence from EPA and UDEQ.

Table 1. Contaminants of Concern and 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.

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 more comprehensive than in April; in April, several alluvial wells located beyond the extent of contamination and several bedrock wells are omitted from sample collection. Three other 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 in response to revised data objectives or changing field conditions as the project has progressed (see Plate 1 for all locations that have been monitored on one or more occasions since January 2000 and Appendix D for monitoring wells decommissioned since that time).

Hydrologic monitoring, conducted concurrently with semiannual water quality sampling, consists of water level measurement at all monitoring 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 2000 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 the discussion of hydrologic monitoring results in 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 2011 samples; the several results for wells sampled in October 2010 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 except vanadium was present in alluvial groundwater at one or more location in excess of the respective remediation goal. Except for uranium, current monitoring data indicate only minor contamination by COCs with respect to spatial distribution and magnitude relative to remediation goals: concentrations generally do not exceed the remediation goal by more than a factor of 2, and contamination is generally limited to the small area between the former mill site and the PRB. 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.

- Arsenic contamination is limited to the area between the mill site and the PRB; the maximum concentration (19 µg/L; Figure 4) is less than two times the remediation goal.
- Manganese contamination is limited to one location in the central are of the mill site and one location immediately downgradient of the PRB (Figure 5). Elevated manganese immediately downgradient of the PRB is likely a remnant of ZVI corrosion that occurred early in the operation of the PRB (see Section 4.4.1). Manganese distribution in groundwater otherwise does fit the pattern of a conventional plume emanating from a source or former source area.
- Molybdenum contamination is limited to a small area of the aquifer at the south end of the PRB slurry wall (Figure 6). The maximum concentration was 140 µg/L. Molybdenum concentrations in recent years have often been less than the remediation goal (100 µg/L) at all monitoring locations.
- Nitrate contamination is limited to one location on the north side of the aquifer, upgradient of the PRB (Figure 7). Nitrate contamination at low levels in this area is not uncommon and likely originates from livestock feedlots immediately north of the mill site. The current maximum nitrate concentration (11,600 µg/L) only marginally exceeds the remediation goal (10,000 µg/L).
- Selenium contamination is limited to a single location at a concentration of 86.1 µg/L (Figure 8). The isolated location of contamination (well 0200; Figure 3) is downgradient of the PRB. The minor selenium contamination at this location is attributed to natural bedrock sources (shale deposits within the Dakota Sandstone that were disturbed during mill site remedial actions). Selenium contamination is absent in groundwater downgradient of the contact of the Dakota Sandstone and Burro Canyon Formation.
- Vanadium contamination is currently absent in OU III groundwater. Vanadium concentrations at one or two locations (at the east boundary of the mill site) remained close to the remediation goal (330 µg/L) over the past several years but have since decreased to less than the remediation goal.
- 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.

In summary, contamination of the alluvial aquifer by site COCs excepting uranium is very minor with respect to spatial distribution and magnitude relative to established restoration goals. Source removal and natural attenuation have shown noticeable progress in water quality restoration for these COCs. Uranium contamination has also decreased in some areas of the aquifer. Discussion of concentration trending is addressed in Section 4.4.1; additional discussion of uranium fate and transport in the alluvial aquifer is addressed in Section 6.0.

4.4.1 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 monitoring 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 (source removal), 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. At the few locations where arsenic contamination remains in the groundwater, concentrations are less than twice the remediation goal.

Figure 15 shows that manganese concentrations at most wells remain below the remediation goal. Manganese concentrations at well 92-11, located several hundred feet downgradient of the former mill site, show a steep decline to levels below the remediation goal following source removal. Concentrations at that location prior to source removal were erratic and often exceeded the remediation goal by a factor of 4 to 5. At well T01-19, the only location where manganese concentration exceeds the remediation goal (see Figure 5), obvious trending is not evident, with concentrations ranging between about 4,000 and 8,000 µg/L, or about 4.5 to 9 times the restoration goal (880 µg/L).

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 in column studies to be relatively rapid (DOE 2001). Molybdenum contamination is very limited in distribution and magnitude, as described in Section 4.4.

The sharp increase in nitrate concentrations 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. In April 2005, 2008, and 2010, order-of-magnitude increases again occurred at some locations, including the upgradient monitoring well (data for MW00-01 is 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 coincidence of elevated nitrate concentrations

downgradient of livestock operations on the north side of the mill site 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 excavation freshly exposed an extensive area of carbonaceous, pyritic shale of the Dakota Sandstone. Naturally occurring selenium in these deposits is presumed to have been mobilized by oxygenated groundwater within the newly reconstructed alluvial aquifer. Selenium concentrations in groundwater have generally decreased significantly since this effect of the bedrock exposure (Figure 18). Locations where selenium concentrations increased in April 2005 and April 2008 coincide with those of increased nitrate (Figure 17). This correlation, also apparent with the nitrate release in 1999, may be associated with the ability of nitrate to oxidize and mobilize naturally occurring selenium (Wright 1999; Wright and Butler 1993; Weres et al. 1990; see also DOE 2001); however, increased selenium concentrations at several wells in April 2010 were not accompanied by increased nitrate concentration. Selenium concentrations since April 2010 have decreased to levels below the remediation goal except at well 0200, as discussed in Section 4.4.

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 not exceeded at any monitoring location. 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 extends over a much greater region of the aquifer. Because of the greater extent of uranium contamination and as the greatest contributor to potential human health risk, analysis of concentration trending for uranium in groundwater is provided in greater detail in Section 6.0.

4.4.2 Plume Expansion in the Alluvial Aquifer

The uranium contamination plume terminates between monitoring wells 92-09 and 95-03; therefore, well 95-03 is regarded as a sentinel well to detect if the plume is advancing past the current downgradient extent of contamination (see Figure 3 for well locations and Figure 9 for uranium concentrations). The uranium concentration shown in Figure 9 corresponding to well 95-03 is from October 2010; as indicated in Section 4.3, well 95-03 is not sampled in April sampling events.

The OU III groundwater model predicted only slight increases in uranium concentrations east of the current extent of contamination but not 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 (well 95-03 is sampled annually in October). Plume expansion into this area is prevented by the hydrologic discharge boundary described in Section 3.0 (alluvial aquifer discharge to Montezuma Creek and Burro Canyon aquifer groundwater discharge to the alluvial aquifer and creek).

Manganese concentrations at sentinel well 95-03 plot off-scale 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.

4.4.3 PRB and Ex Situ Treatment System Performance

Figures 4 through 10 (see PRB insets) show that the PRB continues to effectively reduce contaminant concentrations to acceptable levels; however, the ability of the PRB to transmit water has been compromised by internal mineralization. Relatively high manganese concentrations immediately downgradient of the PRB may be remnants of early PRB operation when manganese, as a trace constituent of ZVI, dissolved from the ZVI and was then deposited in the aquifer matrix immediately downgradient of the PRB. 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 March 2011, the ex situ treatment system had treated about 18 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 cell had treated an additional 3.1 million gallons. On the basis of monthly inflow and outflow sampling, approximately 43.5 pounds of uranium have been removed by the treatment system from the alluvial aquifer cumulatively through March 2011. Additional information on treatment system performance, including influent and effluent water quality, is provided in quarterly reports distributed by DOE to EPA and UDEQ.

4.4.3.1 Effluent 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 in the effluent to protect water quality in Montezuma Creek although there is no discharge compliance standard. 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 (location 0301 in Figures 3, 11, 12, and 13). 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 of SW00-02).

The allowable concentration of total iron in the effluent is 45.4 mg/L at the maximum allowable discharge rate of 10 gpm. The pH of the effluent is to be within the range of 6.5 to 9.0 (see Section 3.3.4 for derivation of discharge allowances). Operation of the treatment has complied with the discharge allowances to date. The highest concentrations of iron in the effluent typically are associated with change-out of the reactive media. Uranium concentrations at the upstream and downstream sample locations (SW00-02 and 0301, respectively) are very similar. Discharge monitoring and performance assessment of the treatment system are provided quarterly in Federal Facilities Agreement reports.

4.5 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 background water 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 2009. 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 2009

Well	COC Concentration October 2010[a]						
	Arsenic	Manganese	Molybdenum	Nitrate[b]	Selenium	Uranium	Vanadium
83-70	0.1	250	0.95	10U[c]	0.03	0.09	0.03
92-10	0.05	480	1.5	10U	0.03U	0.04	0.01
93-01	0.34	79	0.16	10U	0.03U	0.07	0.14
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. The next sampling of these wells will therefore be in October 2011. Prior to 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. The occurrence of these analytes at the respective concentrations is attributed localized natural sources (DOE 1998a). The cumulative monitoring data to date for Burro Canyon monitoring wells indicates that the Burro Canyon aquifer is not contaminated by site-related constituents.

4.6 Surface Water Quality

Results for the surface water samples collected in April 2011 at the routine OU III sampling locations are shown in Figures 4 through 10. Surface water sites sampled in October 2010 and April 2011 are identified in Figure 3. The April 2011 sampling event was conducted during a period when dilution by high spring runoff did not bias sample results.

Uranium and selenium are the only COCs to exceed the respective remediation goal among the April 2011 samples collected from within Montezuma Creek (seeps and wetlands are addressed below in Section 4.7.1). 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 the concentration then increases. A relatively constant concentration of uranium then persists through the remainder of OU III, although some dilution in the creek is evident. The increase in selenium in

the creek at the Sorenson location results in only a very slight excess of the surface water restoration goal. Increased concentrations of uranium and selenium at the Sorenson location is a common pattern within OU III. The source of the contamination increases at the Sorenson location was investigated in 2009 and reported in the 2009 (DOE 2009c) and 2010 (DOE 2010) OU III annual reports and so is not repeated in this report in detail (see Section 8.3 of this report). COCs for which there are no surface water standards (manganese, molybdenum, and vanadium) are present in Montezuma Creek at concentrations that are consistent with background levels or are much less than the respective groundwater standard.

4.7 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 Section 4.7.1). Ordering of the sampling sites in the legend of these figures is from west to east in the direction of creek flow. Selenium and uranium were selected for presentation because selenium in surface water is particularly relevant to OU III biomonitoring (OU III biomonitoring is described in Section 7.0) and because uranium contamination is most extensive in OU III groundwater and surface water.

Selenium concentrations trended downward for about 5 years following OU I remedial actions (see also Section 4.4.1). In April and October 2009 sample results showed an increase in selenium concentration at several locations downstream of the mill site, where concentrations exceeded the remediation goal (locations Sorenson, SW00-04, and SW92-08; Figure 22) by a factor of about 2 to 3. Uranium concentrations coincidently increased at those locations (Figure 23). Selenium and uranium concentrations at these locations have since decreased sharply (Figures 22 and 23).

4.7.1 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 that are above the valley of Montezuma Creek. The seeps are topographically higher than the alluvial aquifer. COCs that historically have occurred at one or more of these seeps in excess of a surface water remediation goal are nitrate, selenium, and uranium. The typically high nitrate levels at Seeps 3 and 6 are attributed to livestock operations located hydraulically upgradient of the seeps. 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 by livestock waste.

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 high levels (Figure 25) that coincide with high nitrate at that location. Despite similar bedrock geology at Seep 3, selenium concentrations do not appear to correlate with nitrate. Selenium concentrations at the two seeps where selenium levels most frequently exceed the surface water goal (Seep 2 and Seep 3) have continued to decline since monitoring began at these locations in 2001.

Uranium concentrations at Seep 6 during the reporting period (approximately 1,600 µg/L; [Figure 26]) are consistent with observations since monitoring began at that location in 2002. DOE recently evaluated the possible source of water and uranium contamination expressed at

Seep 6. The results of that investigation were reported in detail in the 2009 annual groundwater report for OU III and so are not repeated in this report.

4.7.1.1 Wetland 3

Concentration trending at seeps at Wetland 3 is of particular importance to OU III biomonitoring because the seep water often contains levels of selenium that are potentially toxic to ecological receptors. Groundwater from the alluvial aquifer discharges to Wetland 3 at Seeps 1 and 2 near its northwest corner. Since monitoring began in 2001 at these locations, 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 monitoring wells. Moderate levels of COCs discharge from the alluvial aquifer to the wetland at these seeps. Only uranium had concentrations in April 2011 that exceeded the remediation goal at the routine sampling locations within Wetland 3 (locations W3-03 and W3-04 in Figure 3; see Figure 9 for uranium distribution in Wetland 3). 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 is observed (Figure 25), similar to that at Seep 3. Section 7.0 includes additional discussion of selenium concentrations in Wetland 3 (and the Sediment Pond) with respect to OU III biomonitoring.

5.0 Hydrologic Monitoring Assessment

5.1 Surface Water 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 sandstone of the Burro Canyon, and the valley begins to narrow into a steep-walled canyon. Flow measurements for that reach were taken near former sampling locations SW00-03, 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 in the Dakota/Burro Canyon transition reach.

Figure 27 also shows the effect of recent drought on flow in Montezuma Creek, 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 base-flow from the reservoir and North Creek, but it 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.

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. Measurement of stream flow in April 2010 was not possible because of very high flows and over-bank conditions. Figure 27 therefore depicts an estimated flow of greater than 1,000 gpm for April 2010. High creek flow in spring results in diluted COC concentrations in Montezuma Creek samples collected in the April sampling event.

Stream flow measured in October 2010 typified "normal" baseflow conditions. Despite normal to above normal snowpack in the Abajo Mountains through the past winter, a significant spring runoff did not occur according to local observers. It is assumed that high spring runoff was moderated by slow melting and the predominance of infiltration of the snowmelt into soil and rock instead of direct surface runoff. The runoff that did occur was before the April 5, 2011, OU III monitoring event.

5.2 Alluvial Aquifer Water Levels

Leakage through the dam at the municipal reservoir and seepage from North Creek are the primary sources of 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 monitoring wells (wells 82-20, MW00-01, and MW00-02; Figure 28), this area is subject to seasonal water table fluctuations of 5 ft or more, indicating sensitivity to 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. Water level measurements recorded in October 2010 and April 2011 are slightly above historical values. Elevation of the water table at the upgradient monitoring wells does not appear to show an upward or downward trend since 1992 (Figure 28).

On the mill site, the water table does not fluctuate as widely as observed at upgradient wells MW00-01 and MW00-02. For example, the dry years of 2002 and 2003 produced only minor variation, 1 ft or less, in the water table elevation (Figure 29). Similarly, the wide fluctuations observed at upgradient wells since 2004 (Figure 28) are not evident at the mill site wells (Figure 29). The effect of the creek as a groundwater sink (drain) may dampen water fluctuations in this area through abundant groundwater discharge to the creek. Water levels at many wells on the mill site exhibit a net increase of about 1 ft since 2000 (Figure 29).

Water level hydrographs for selected monitoring 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 in about 6 months to levels that approach 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). Higher water levels in this area by 2 or 3 ft in April 2010 likely

reflect the rapid runoff of an above-average high-mountain snowpack and deliberate releases from the reservoir in spring 2010.

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 2010, water levels in the aquifer downgradient of the PRB also increased by 2 to 3 ft.

5.2.1 Groundwater Mound at the PRB

Water level hydrographs for wells nearest the PRB (Figure 31) indicate no apparent trending. This suggests that groundwater extraction from well EW-1 does not significantly reduce the groundwater mound, centered at well 88-85, associated with the PRB (the apparent water table decline in 2005 at wells 88-85 and T1-D is a regional effect unrelated to groundwater extraction). Groundwater extraction also has had no apparent effect on water levels at monitoring wells 92-07 and PW-17 (Figure 31), located about 200 ft and 300 ft from the extraction well, respectively. This suggests that groundwater withdrawal at EW-1 has not significantly reduced the flow of groundwater around the south slurry wall (the quantity of groundwater flow around the south slurry wall was estimated to be minimal prior to the start of pumping). The water table in the mounded area was about 2 ft below ground surface in April 2011.

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 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 the location of these two well pairs. 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). Abundant groundwater withdrawal from the Burro Canyon aquifer by the city of Monticello during 2001 to 2004 during drought 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 (well 95-08) is located on the mesa above well pair 95-03/95-04. The much greater static water level at well 95-08 as compared to that at wells 95-02 and 95-04 is a measure of the hydraulic potential for groundwater discharge from the Burro Canyon aquifer in the floor of the canyon.

At Burro Canyon monitoring 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 seasonally by a private landowner for limited irrigation since about 2006, but this use has had no significant drawdown at this location

based on semiannual water level measurements (measurement data for April 2011 is considered unreliable and inconsistent with previous measurement data; down-hole pump equipment interferes with water level measurement).

6.0 Groundwater Restoration Assessment

6.1 Uranium Trending Compared to Model Prediction

The ROD for OU III stipulates that observed concentrations for uranium are to 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) distinguishable by contaminant distribution and by geographic and hydrologic factors. Beginning with the October 2004 monitoring results, the arithmetic mean of uranium concentration is computed for each of these regions from a selected group of monitoring wells. The means 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 for the corresponding wells (see Appendix G) are similarly averaged, normalized to calendar date (model time zero is October 2002), and graphed with the observed averages, as shown in Figures 35 and 36. In these figures, solid lines represent mean model-predicted concentration; 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 for a given region 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, the rate of aquifer restoration as of April 2008 is significantly less than the model prediction in Regions 1, 2, 3, and 5. 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 deviated significantly lower than the model prediction through 2009, but have since risen to be consistent with the model prediction (Figure 36).

6.2 Nonparametric Trend Analysis

The OU III ROD stipulates that an additional statistical analysis of time-varying uranium concentrations would be performed if the acceptance criterion defined above was not met for any aquifer region. DOE met this requirement in August 2007 (in DOE 2007a) 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, as described by EPA (1994) and 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. The conclusion of the nonparametric trend analysis was that aquifer restoration within the 42-year period was not likely based on current trends under any of the test conditions (DOE 2007a).

6.3 Summary of Restoration Progress

Region 1 Obvious trending is not evident overall at the wells in this region (Figure 37). This implies a cleanup time that exceeds the established 42-year period. Uranium persists at concentrations between about 100 and 200 µg/L. Only at well T01-19 is a downward trend apparent (Figure 37).

Region 2 All wells exhibit downward trending (Figure 38) at rates that project cleanup of this region within the 42-year period, assuming the linear trend continues. 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. Uranium concentrations in Region 2 are likely decreasing because the aquifer is locally recharged by uncontaminated water at the eastern end of Wetland 3 and by a losing-stream condition in the reach above the PRB.

Region 3 Three of five wells exhibit a downward trend (wells 92-11, 88-85, and PW-28); the remaining two wells (92-07 and PW-17) show apparent upward trends (Figure 39). The area encompassing wells 92-07 and PW-17 was investigated in April 2009 to evaluate lack of restoration progress in this area (see DOE 2009c). A significant area of uranium contamination was identified in this area south of the creek between the PRB and mill site. Increasing concentration trends at wells 92-07 and PW-17 may reflect downgradient movement of the uranium plume in this area and not continued source input.

Trends at wells 92-11, 88-85, and PW-28, which are located north of the creek, suggest that at current rates this portion of the aquifer will attain cleanup within the 42-year period.

Regions 4 Consistent trending is not evident at monitoring locations in this region (Figure 40); instead, concentrations are highly variable over time. Localized upward trending may be expected as groundwater bypass occurs from Region 3 at the south slurry wall of the PRB. Variable concentration trending in this area is also expected because of local irrigation practices and the discharge of treated groundwater from the PRB.

Region 5 Upward trending at well P92-06 (Figure 41) may indicate movement of a localized hot spot of groundwater contamination. This result is not unexpected and is due to normal groundwater flow and natural attenuation processes. 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.

As described in Section 3.2, plume containment is maintained by natural hydrologic boundaries. Primarily, downgradient migration of the uranium plume beyond the current extent of contamination is prevented by the discharge of groundwater from the alluvial and Burro Canyon aquifers to Montezuma Creek.

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 any of the locations, 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 monitoring 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 that were conducted under the interim record of decision (DOE 1998b) to evaluate COC mobility in OU III groundwater. In these tests, 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 (see 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. The focus of biomonitoring is on avian receptors in wetland habitat. Biomonitoring activities are conducted in accordance with the ROD and the Post-ROD Monitoring Plan (DOE 2004a and DOE 2004b, respectively), and in consultation with the Biological Technical Assistance Group (BTAG), which consists of representatives from the U.S. Fish and Wildlife Service, EPA, UDEQ, and DOE. Biomonitoring focuses on wetland habitat in OU III and has been implemented in phases since 2004; the scope is determined annually following BTAG review of the previous year's results. Sample media are sediment, surface water, and benthic macroinvertebrates. Surveys have also been conducted to identify potential avian receptors to selenium accumulation in the wetlands habitat.

Between 2004 and 2007, biomonitoring focused on three constructed wetland areas on the former mill site (Wetlands 1, 2, and 3) and the sediment retention pond (Sediment Pond) located on Montezuma Creek about 1 mile downstream of the mill site (see Figure 3 for wetland and pond locations). The sediment retention pond and wetlands were constructed in 1999 and 2001, respectively. Wetland 1 and 2 were excluded from biomonitoring after 2006 because selenium concentrations were low in all media. Biomonitoring was not conducted in 2009 but resumed in June 2010 for collection of benthic macroinvertebrates and surface water at Wetland 3, the Sediment Pond, and background location on Montezuma Creek and Verdure Creek. Biomonitoring sample collection was suspended in 2011 in concurrence with the BTAG.

7.1.1 Description of Wetland 3 and the Sediment Pond

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 growth of cattails and rushes. Water flow through the wetland is not rapid and is commonly stagnant or nearly so. About 1 ft of black organic muck and decaying vegetation covers the base of the wetland. 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 bank of the pond is 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 muck covers the base of the pond.

7.2 Results Summary

Cumulative evaluation of results for all biomonitoring sample media and avian surveys are documented in DOE 2005a, 2005b, 2006, 2007b, 2007c, 2008b, 2008c, and *Monticello Mill Tailings Site Operable Unit III Biomonitoring Program Status and Analytical Update* (DOE 2011). Results have also been presented each annual groundwater report since 2005 (see DOE 2010 for example). The BTAG has determined that surface water and sediment sample data are of relatively minor significance in assessing potential risk to ecological receptors at OU III. Therefore, the following sections focus on results of benthic macroinvertebrates as the primary media of concern to assess potential risk to avian receptors.

Results of selenium concentration in benthic macroinvertebrate samples collected at Wetland 3 and the Sediment Pond are shown in Figure 47. In the Biomonitoring Program Status and Analytical Update (DOE 2011), statistical analysis of macroinvertebrate sample data indicated no significant trending. Sample results for the Sediment Pond indicated that mean (arithmetic) values are below the adopted toxicity threshold for OU III (7 mg/kg). Sample results for Wetland 3 were shown to not be significantly greater than the threshold. DOE 2011 provides a comprehensive analysis of the biomonitoring sample data.

7.3 Avian Survey Results

Avian surveys were conducted in 2005, 2006, and 2008. The 2005 survey (see 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 (DOE 2006).

The main purpose of the 2008 surveys was to confirm that no federally protected, State-listed, or other avian species of concern not identified in previous surveys are present on or near Wetland 3 or the Sediment Pond. 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. A migrating bobolink, a state-listed species, was observed once near Wetland 3. Two Birds of Conservation Concern (listed by U.S. Fish and Wildlife Service) were each observed once: a black-throated grey warbler, and a Virginia's warbler. A nesting pair of northern harriers, also a Bird of Conservation Concern, was observed throughout the summer at Wetland 3. 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 (see DOE 2008c).

7.4 Future Scope of Biomonitoring

BTAG members are scheduled to determine the future scope of OU III biomonitoring in 2011/2012 following review of *Monticello Mill Tailings Site Operable Unit III Biomonitoring Program Status and Analytical Update* (DOE 2011). The report presents formal statistical analysis of biomonitoring results in comparison to ROD-specified performance criteria and to background conditions. The report also summarizes ecological concepts related to potential receptors of selenium at OU III. The report concludes that DOE has fulfilled biomonitoring requirements as specified in the OU III ROD and that selenium accumulation associated with DOE activities does not pose significant risk to ecological receptors. Following the BTAG conducted on June 27, 2011, the scope of future biomonitoring is yet to be determined.

8.0 Post-ROD Water Quality Investigations (2009−2012)

DOE conducted several water quality investigations in 2009 that are outside of the routine OU III water quality monitoring program. The investigations were conducted to (1) characterize an area of elevated uranium in groundwater east of the former mill site to the PRB (Section 8.1), (2) evaluate the source of uranium contamination at a groundwater seep (Seep 6) located on the north side of the former mill site (Section 8.2), and (3) evaluate the source of uranium contamination in Montezuma Creek downstream of the former mill site where the surface water remediation goal is exceeded (Section 8.3). The results of these activities are briefly summarized in the following sections and are documented in detail in DOE 2009c and DOE 2010.

These water quality investigations were conducted in accordance with *Monticello Mill Tailings Site Operable Unit III Water Quality Compliance Strategy* (DOE 2009b), as partly summarized in Table 3. A plan to expand groundwater remediation was documented in *Monticello Mill Tailings Site Operable Unit III Remedial Design/Remedial Action Work Plan for Groundwater Remediation Expansion* (January 2011; not issued). DOE postponed implementing that work plan, in concurrence with EPA and UDEQ, in April 2011 to investigate other options to evaluate the groundwater remedy.

An additional investigation (Section 8.4) was conducted independently of the water quality compliance strategy and ESD to address use of surface water to irrigate crops in OU III as a potential environmental risk. The potential risk was first identified in 2008 following a land and water use change by a property owner.

Table 3. Compliance Strategy Key Work Elements

Work Element	Scope of Work	Data Use Objective	Schedule
Evaluate Pump-and-Treat Remediation	(1) Operate the groundwater treatment as currently configured. (2) Expand the treatment system. (3) Monitor and evaluate the performance of the treatment system.	Determine if pump-and-treat technology is feasible in meeting cleanup objectives in a reasonable time.	(1) Operate the current treatment system as is. (2) Design and install the expanded treatment system in 2010 and 2011. (3) A termination date for active groundwater treatment will be determined at a later date.
Evaluate Natural Attenuation Factors at OU III	Conduct review of existing OU III site characterization data and literature sources, and implement field study to: (1) Evaluate the extent of uranium contamination in a groundwater hot-spot area. (2) Evaluate flow stagnation at the PRB. (3) Evaluate uranium mobility in the alluvial aquifer. (4) Evaluate effects of surface seepage on groundwater quality. (5) Evaluate climate effects on restoration progress.	Refine the understanding of hydrogeochemical factors that affect aquifer restoration at OU III and that may account for slow restoration progress compared to OU III model predictions.	(1) Continuous throughout the contingency remedy evaluation. (2) Communicate and document progress through FFA meetings, annual groundwater reports, and CERCLA 5-year reviews.
Evaluate Surface Water Restoration	(1) Use existing water quality and surface flow data to evaluate the impact to surface water by discharge of the contaminant plume to Montezuma Creek. (2) Conduct field sampling to evaluate the contribution of residual mill tailings in stream bank sediments on water quality in Montezuma Creek. (3) Use existing data and field reconnaissance to evaluate the off-site source of contamination at a prominent groundwater seep.	(1) Determine if restoration goals are attainable in an identified reach of Montezuma Creek where uranium concentrations exceed the standard. (2) Determine if restoration goals are attainable at an identified seep where residual contamination is known.	Field investigation and data review to be completed in 2010 and reported in the 2010 annual groundwater report.
Groundwater Modeling	Scope to be determined as information on the progress of active treatment is evaluated.	Modeling (numerical or analytical) could be employed to estimate the groundwater remediation time.	To be determined as information on the progress of active treatment is evaluated.

8.1 Groundwater Contamination Investigation

The April 2009 investigation indicates that uranium contamination in the region between the mill site and PRB is greater than previously characterized and so may account for the lack of restoration progress in this region (Region 3 of the aquifer). The results indicated that expansion of the groundwater treatment system, as proposed in DOE 2011, in this region is feasible with regard to hydrogeologic conditions and uranium distribution. Results of the April 2009 study

also indicate that the southeast portion of the former mill site is not a continuing source of contamination to the alluvial aquifer.

8.2 Seep 6 Investigation

Seep 6 is located on the steep south-facing hillside in the northwest portion of the former mill site (see Figure 3 for location). Uranium concentration in the water expressed at Seep 6 remains at about 2,000 µg/L since monitoring at the location began after the completion of mill site remediation in 1998. DOE reported that the likely source of contamination is mill tailings or ore present in the backfill of a nearby buried irrigation water line (about 7 ft deep) or an adjacent, more deeply buried (about 20 ft) sanitary sewer line. The source of water expressed at Seep 6 is suspected to be leakage from the sewer line or the irrigation line.

Flow of water at Seep 6 is low, probably less than 250 mL/min. The water does not flow directly into Montezuma Creek or Wetland 2 but instead seeps into the soil cover immediately down-slope of the seep. The seep is generally perennial and supports a small growth of cattails. Significant wildlife habitat is not supported at Seep 6 because the seep area is less than about 100 ft by 100 ft and the topography is steep.

Radiological contamination in this water utility corridor was left in place during OU II remediation, in consultation with EPA and UDEQ, to be managed by DOE as supplemental standards material consistent with the practices described in *Long-Term Surveillance and Maintenance Plan for the Monticello NPL Sites* (DOE 2007d).

8.3 Uranium Distribution in Montezuma Creek

The 2009 ESD adopted the recently enacted State standard for uranium (30 pCi/L) in surface water as an OU III remediation goal. Following remediation of the mill site, uranium concentration in Montezuma Creek has not exceeded this standard at the established monitoring locations on and downstream of the mill site until the Sorenson location is reached. At this location, approximately 0.75 mile downstream of the former mill site, uranium concentrations typically increase from less than the standard at upstream locations to between about 75 and 150 µg/L, depending on the season. Concentrations of uranium in Montezuma Creek prior to OU I and OU II remediation (source removal) exceeded the standard upstream of the Sorenson location but were also observed to similarly rise at the Sorenson location.

With the recent adoption of the water quality protection standard for uranium, DOE increased the scope of surface water monitoring for the October 2009 event to further evaluate the location of uranium influx to Montezuma Creek downstream of the mill site. The October 2009 results, reported in DOE 2010, indicate that there is no correlation apparent between uranium concentrations in Montezuma Creek and localized residual soil contamination in the reaches of the creek where supplemental standards were applied for soil remediation. Some contribution of uranium to Montezuma Creek from stream side deposits containing residual mill tailings cannot be excluded; however, the primary source of contamination to the creek downgradient of the mill site is attributed to the discharge of contaminated groundwater from the alluvial aquifer in the uppermost reach of Upper Montezuma Creek. The concentration of uranium in Montezuma Creek at the affected locations is therefore expected to gradually decrease as the uranium plume in groundwater attenuates.

8.4 Surface Water Diversion to Irrigation Pond

DOE, in consultation with EPA and UDEQ, collected two water samples on October 6, 2009, from the irrigation pond on peripheral property MP-00990-CS, located downstream of the mill site, for laboratory analysis of uranium. The pond (Adams Pond) and sample locations (0304 and 0305) are identified in Figure 3. Samples were collected there because of a land use change noted during the 2008 annual site inspection. The land use change occurred when the landowner diverted water from Montezuma Creek to the pond for subsequent application to an alfalfa field and pastures a short distance downstream on the property. The pond has been in use for many years to capture surface runoff, but the diversion from Montezuma Creek to the pond is recent. The State of Utah Division of Water Rights granted an appropriation for the surface water diversion in 2007. Use of water from Montezuma Creek for this purpose was recognized as a possible concern because the water at the point of diversion is contaminated by uranium and because evaporation in the pond could subsequently increase the uranium concentration to harmful levels.

The pond samples collected in October 2009 each contained 85 µg/L of uranium. In contrast, the sample collected from the creek at the point of diversion at that time contained 390 µg/L of uranium (location 0303, Figure 3). The pond samples collected in October 2010 each contained about 80 µg/L of uranium. In contrast, the sample collected from the creek at the point of diversion at that time contained 100 µg/L of uranium. Evaporative concentration of uranium in Adams Pond is therefore not significant, and the pond water does not pose additional risk to wildlife as compared to the concentrations in Montezuma Creek. Screening-level risk analysis by DOE for the evaporation pond at the LM site in Shiprock, New Mexico, concluded that safe levels of uranium in the pond reached concentrations of several hundreds of milligrams per liter. Furthermore, EPA concluded in a report received by DOE in November 2009 (EPA 2009, draft) that use of the pond water to irrigate the alfalfa field and pasture for livestock consumption posed no risk to human health.

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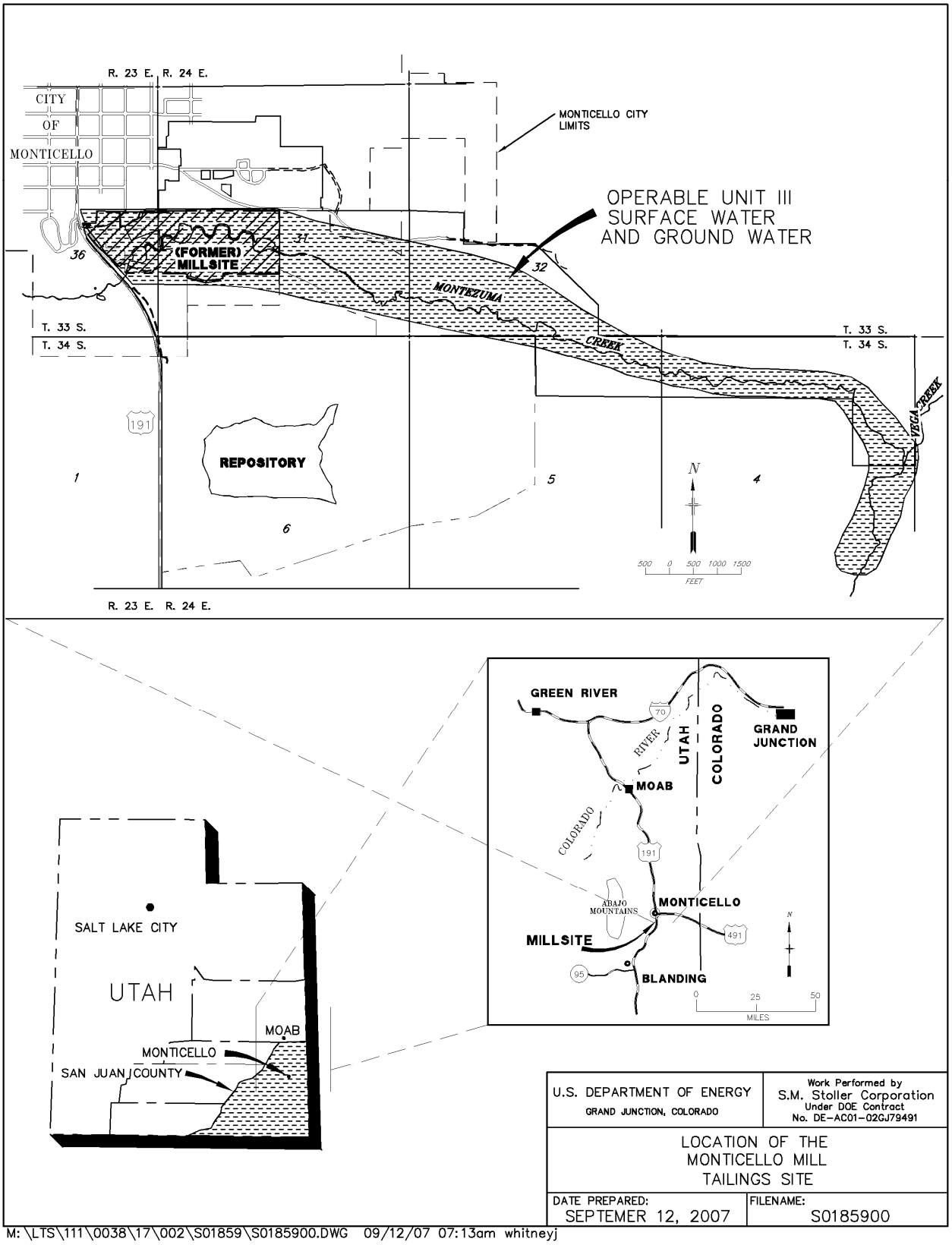

Figure 1. Location of the Monticello Mill Tailings Site

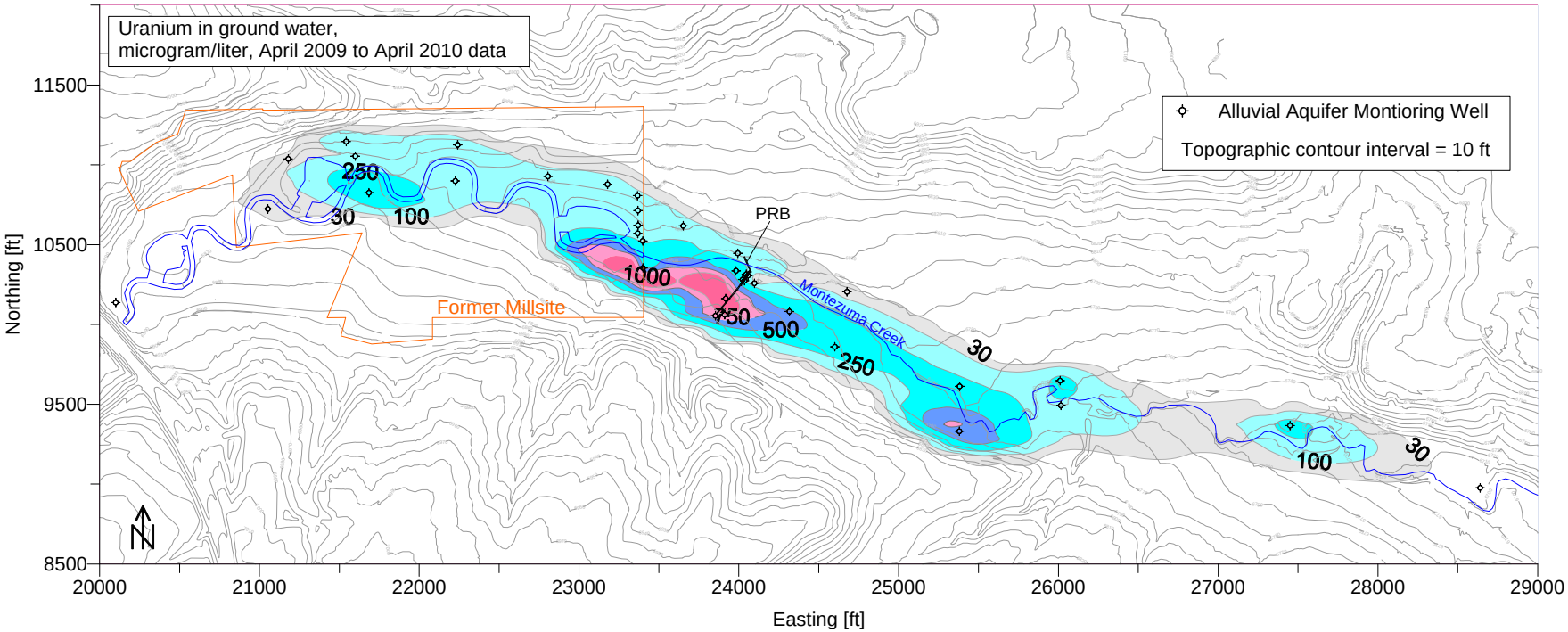

Figure 2. Uranium Groundwater Plume—Current Distribution

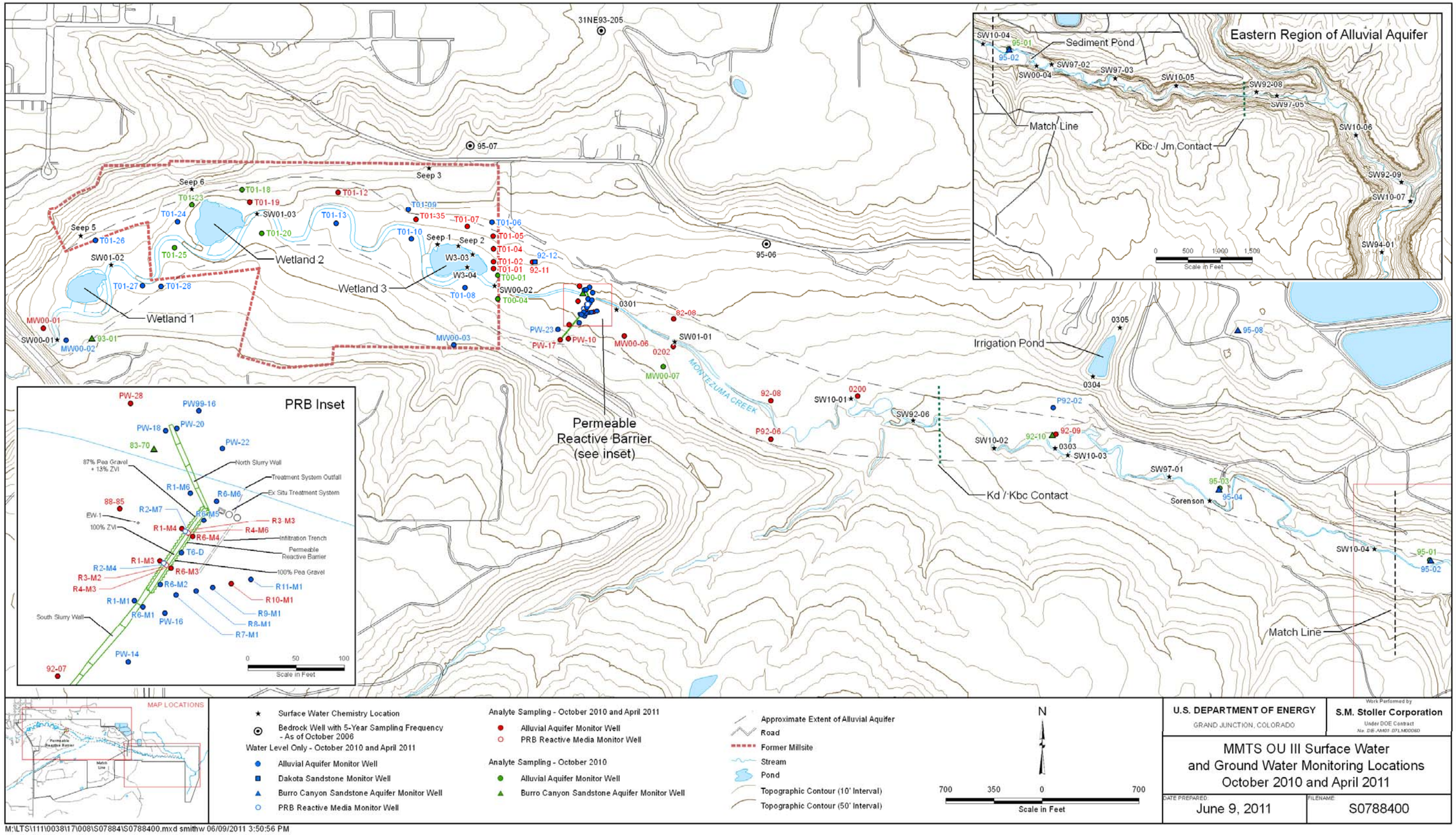

Figure 3. Reference Map for OU III Water Quality Monitoring Locations

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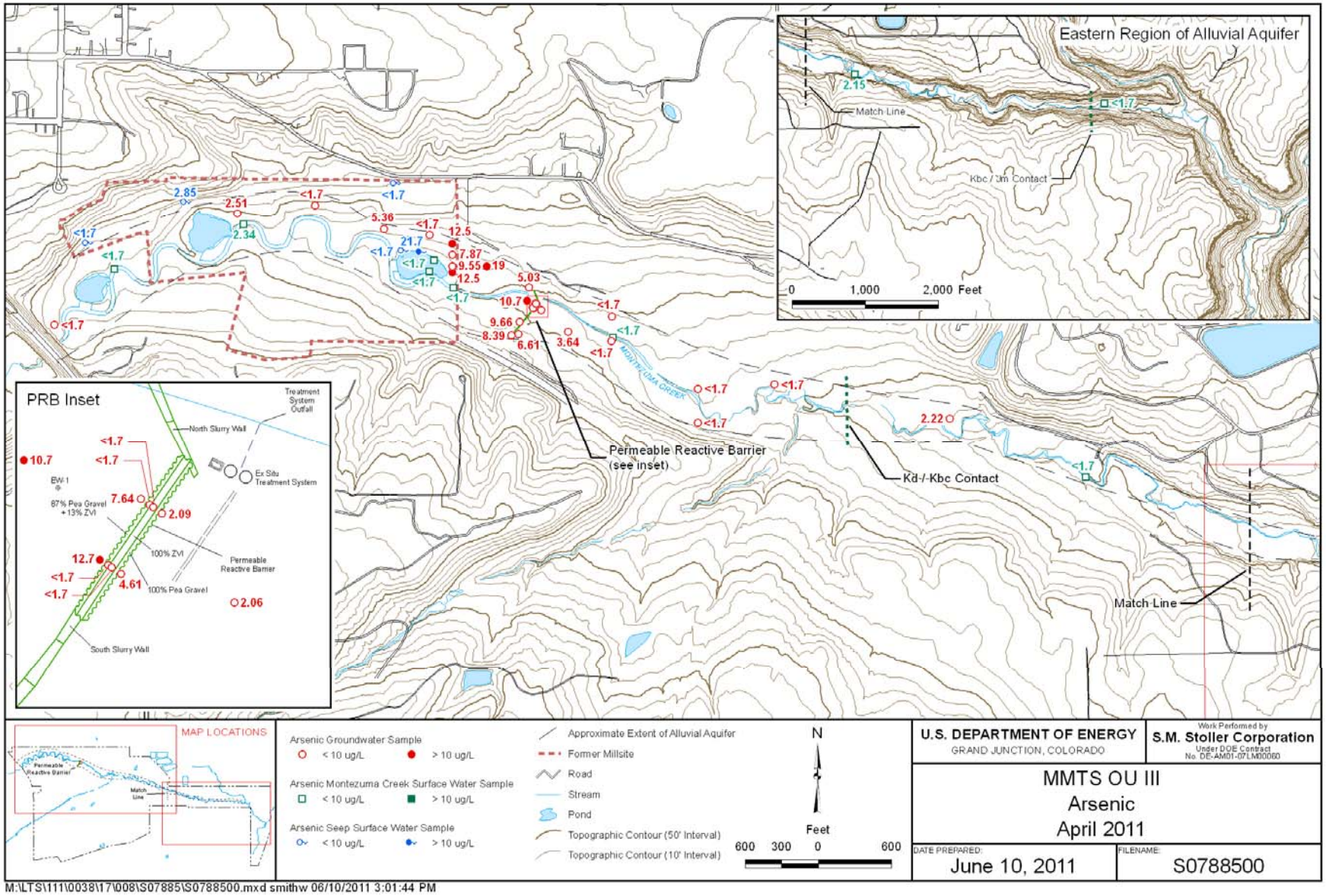

Figure 4. Distribution of Arsenic in Surface Water and Alluvial Aquifer Groundwater, April 2011

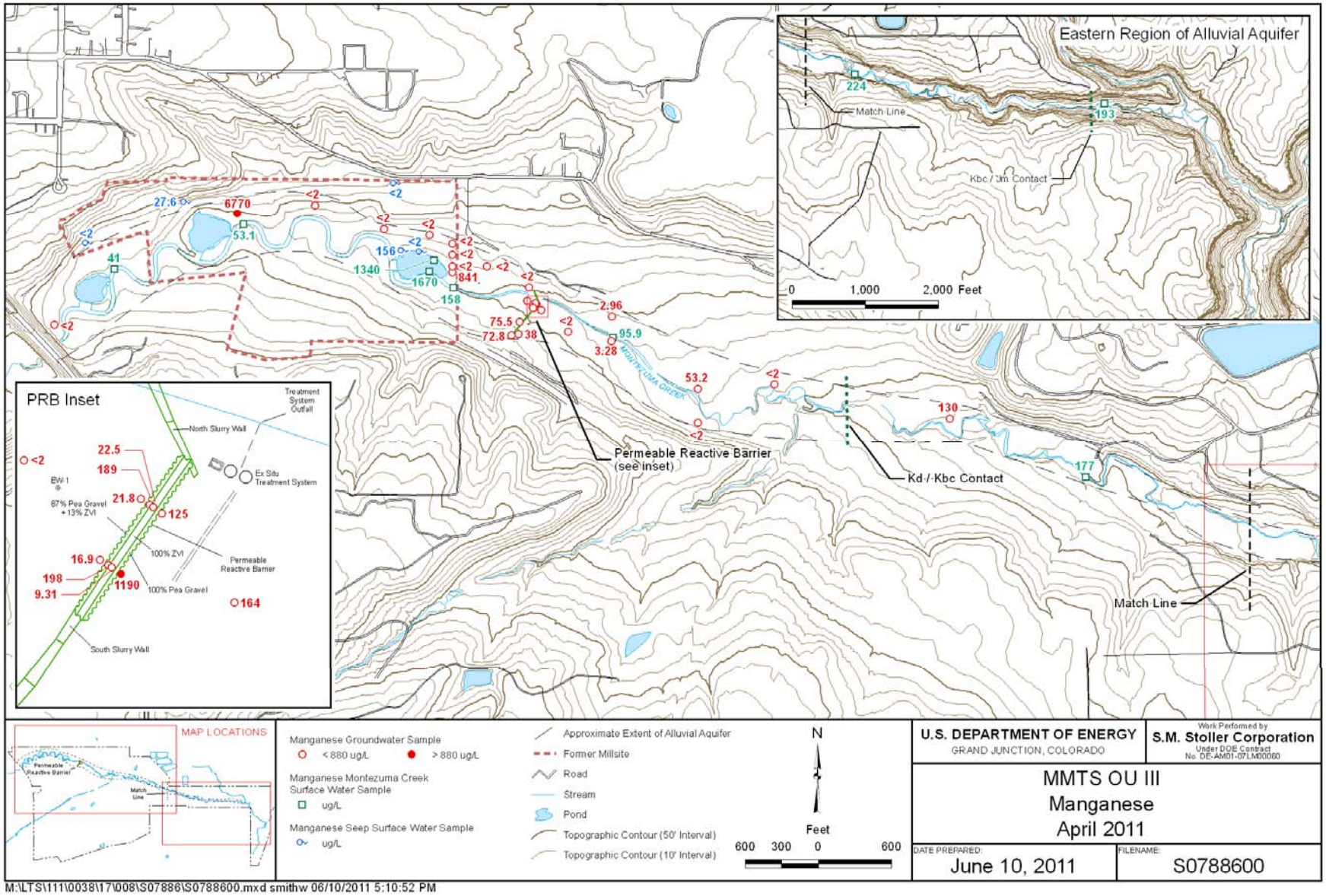

Figure 5. Distribution of Manganese in Surface Water and Alluvial Aquifer Groundwater, April 2011

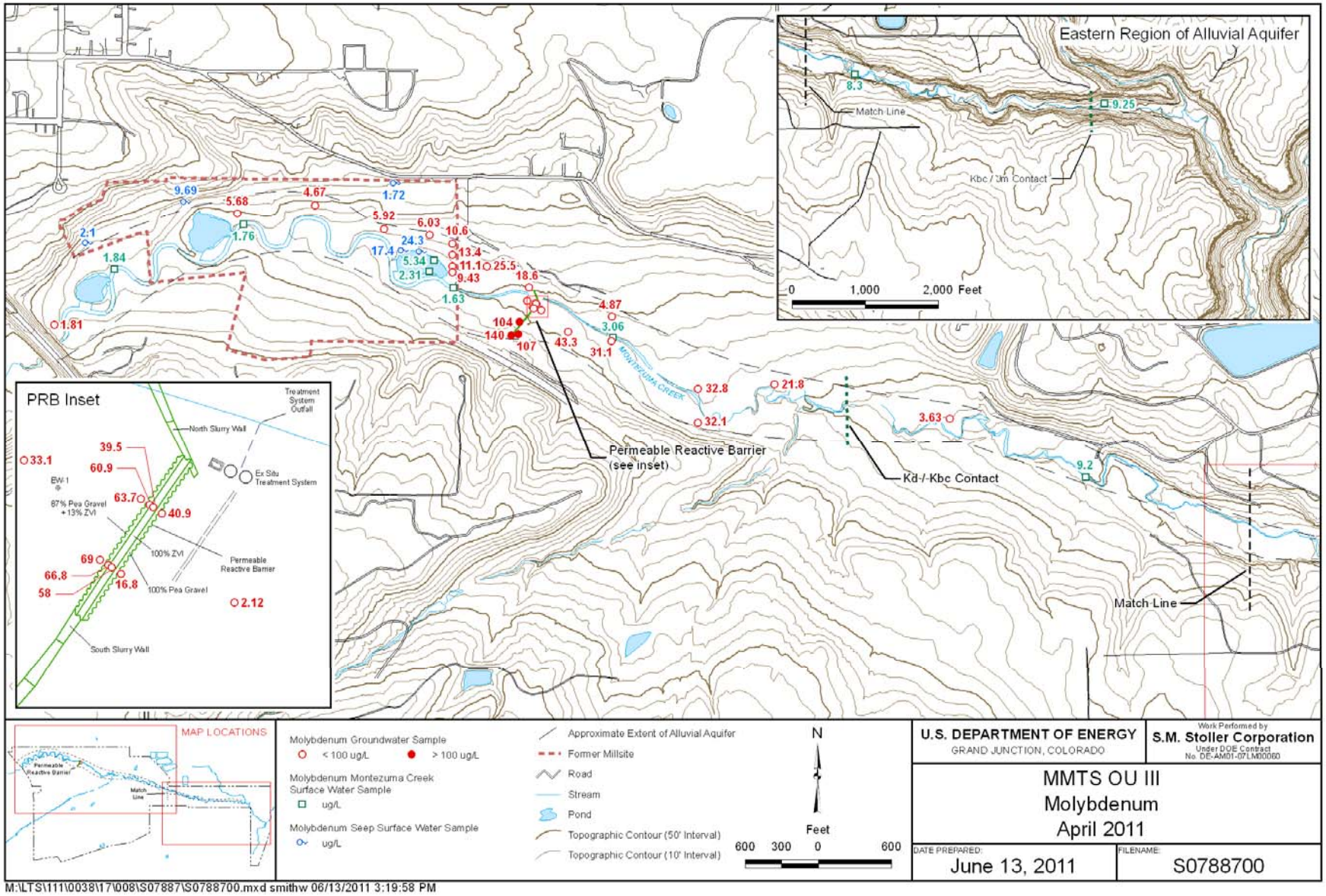

Figure 6. Distribution of Molybdenum in Surface Water and Alluvial Aquifer Groundwater, April 2011

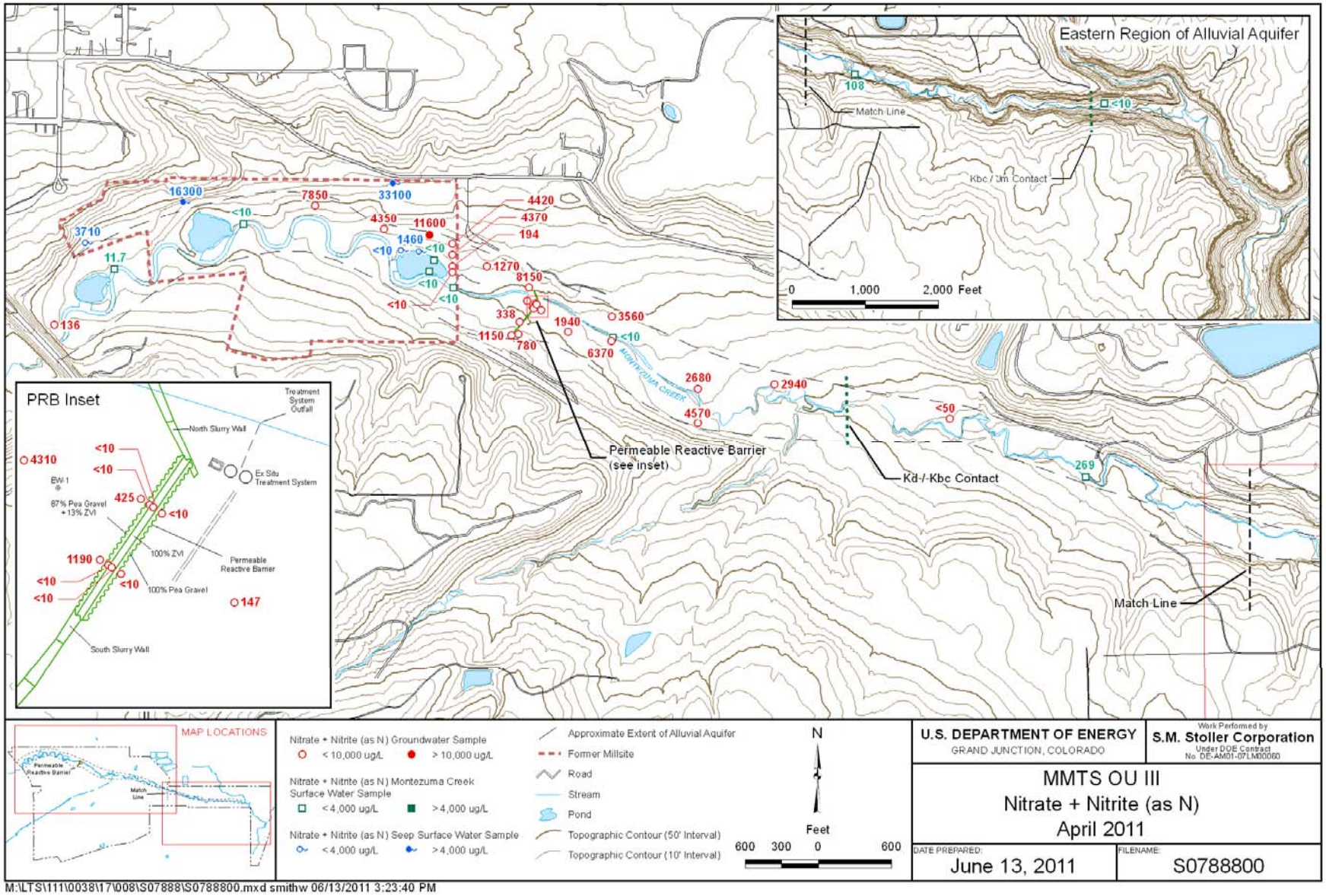

Figure 7. Distribution of Nitrate (as Nitrogen) in Surface Water and Alluvial Aquifer Groundwater, April 2011

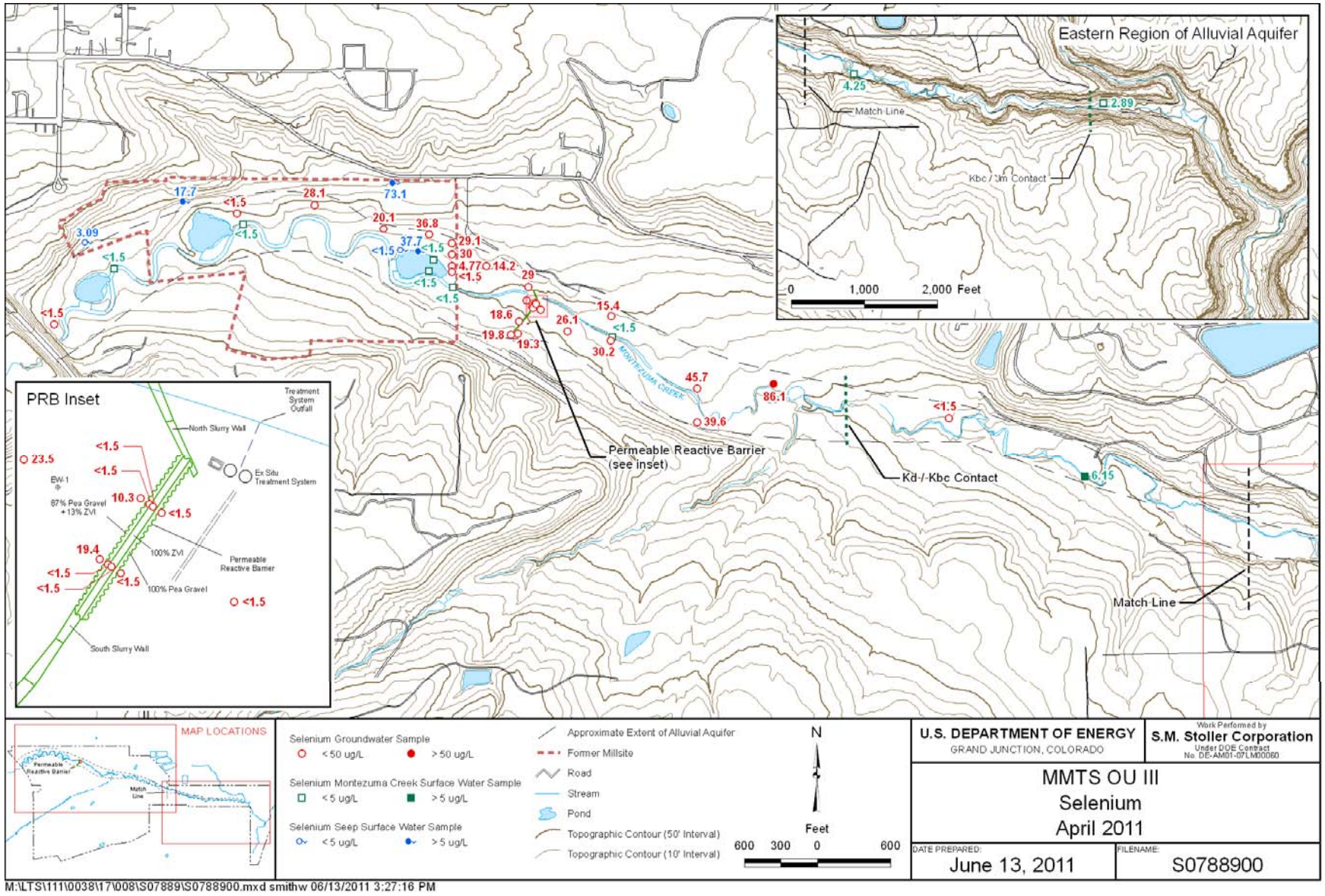

Figure 8. Distribution of Selenium in Surface Water and Alluvial Aquifer Groundwater, April 2011

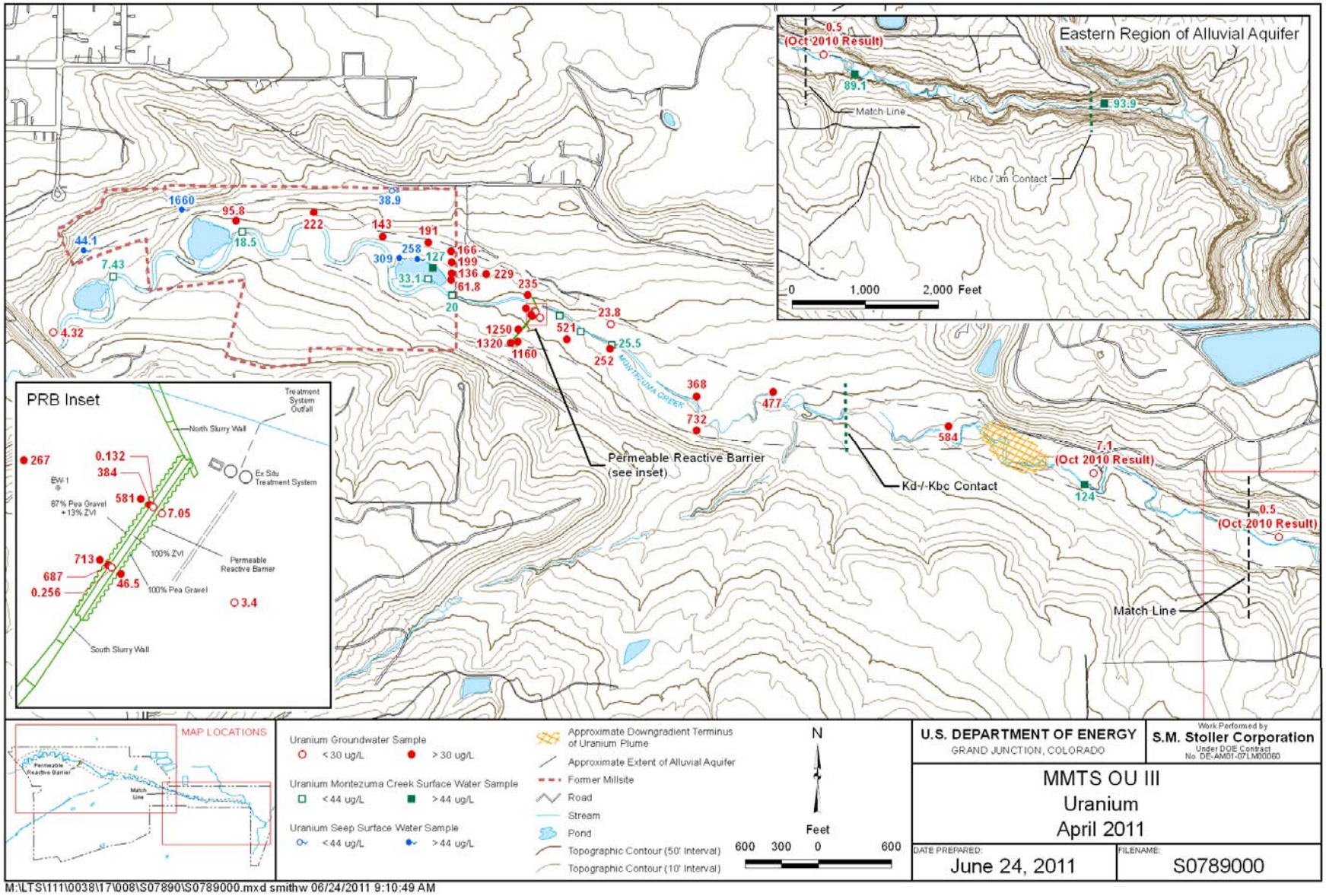

Figure 9. Distribution of Uranium in Surface Water and Alluvial Aquifer Groundwater, April 2011

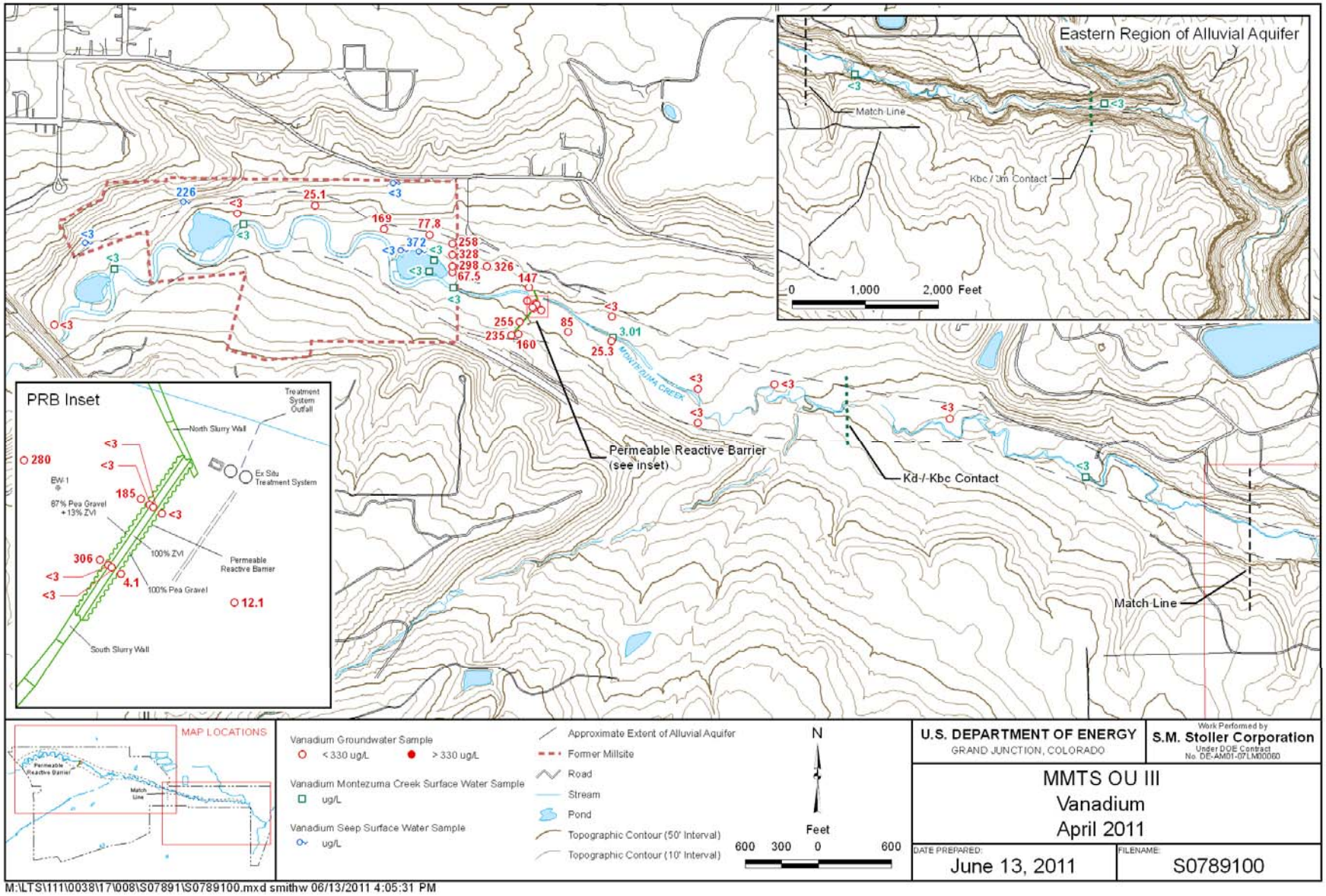

Figure 10. Distribution of Vanadium in Surface Water and Alluvial Aquifer Groundwater, April 2011

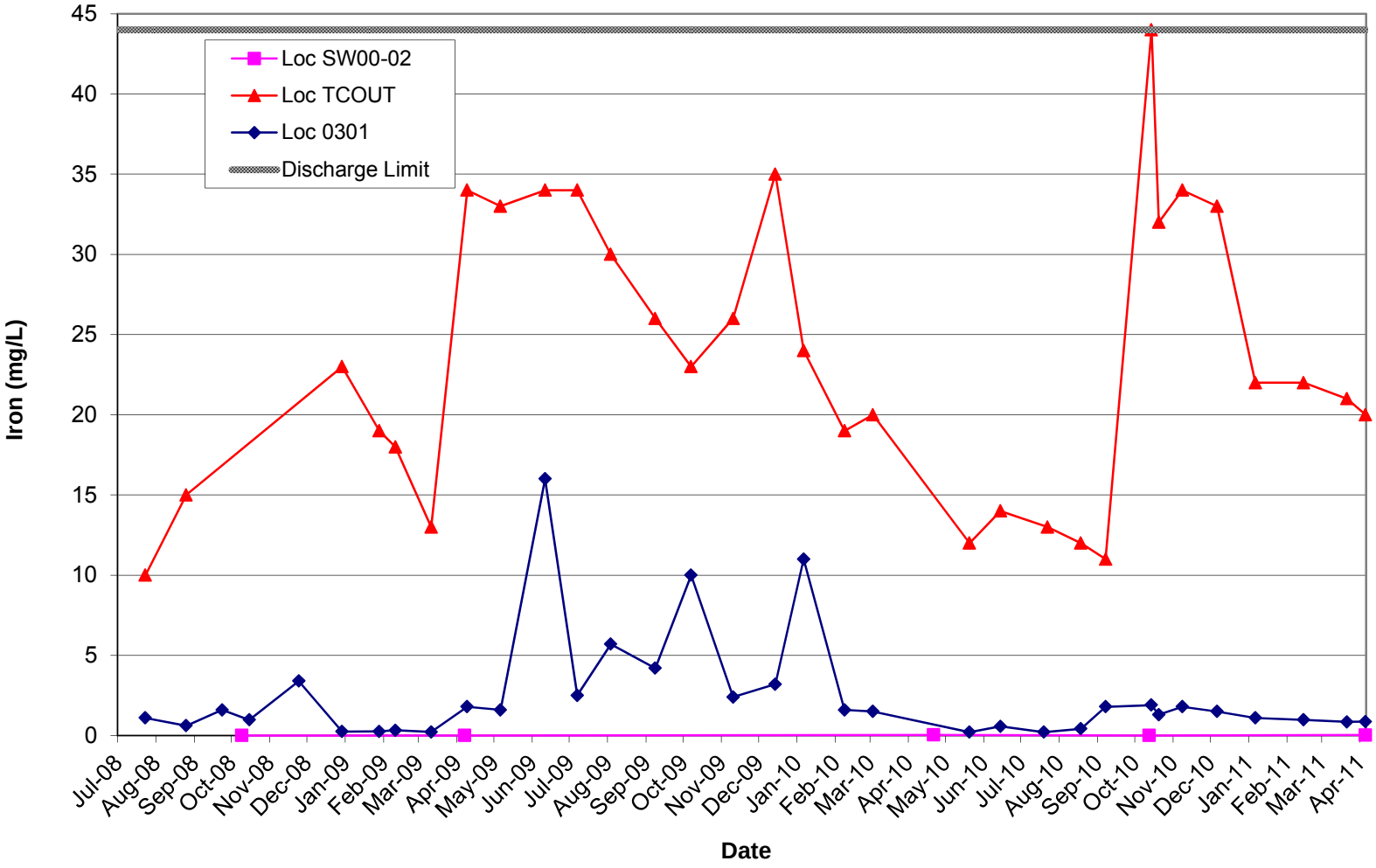

Figure 11. Ex Situ Treatment System Monitoring Results, Iron

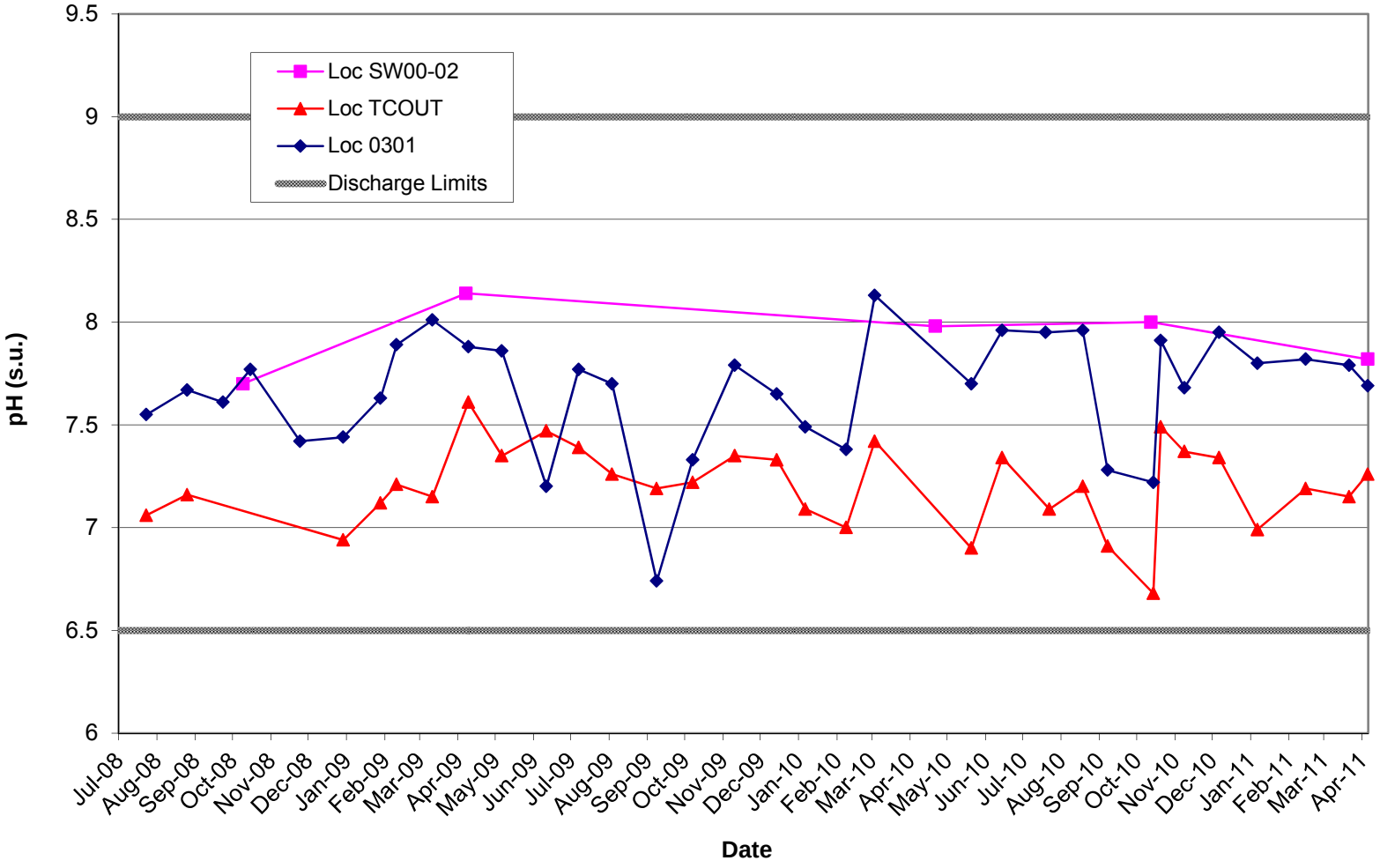

Figure 12. Ex Situ Treatment System Monitoring Results, pH

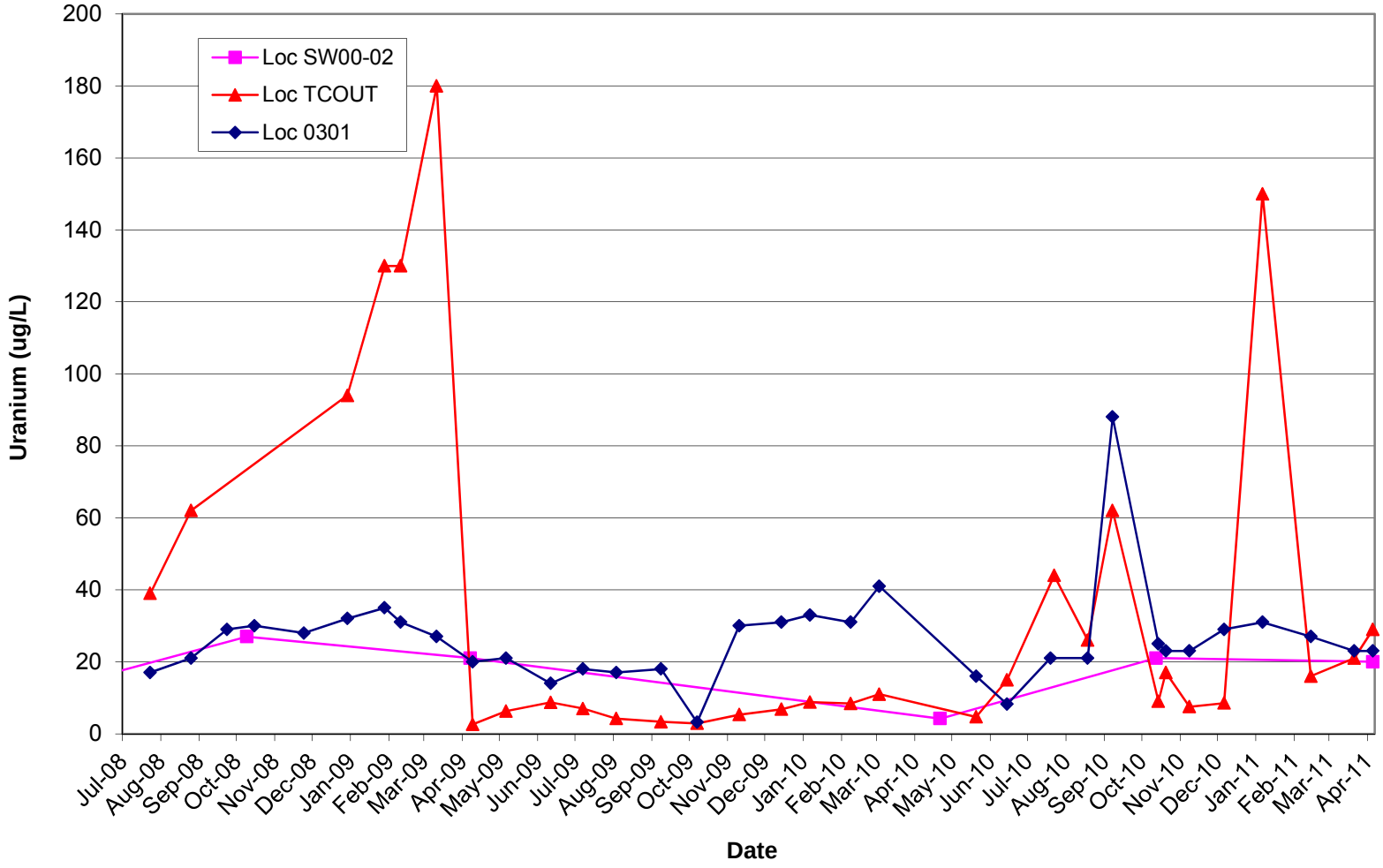

Figure 13. Ex Situ Treatment System Monitoring Results, Uranium

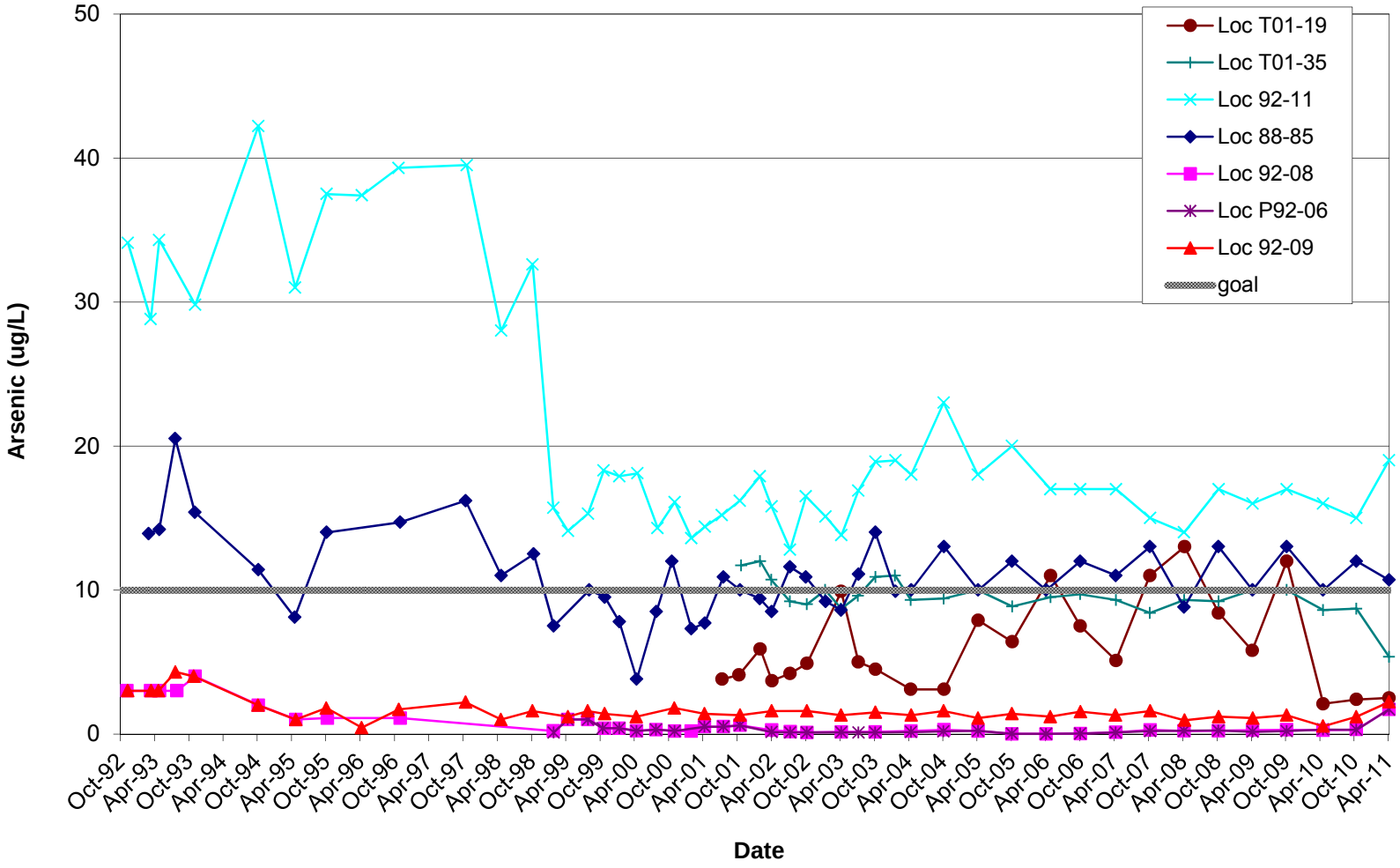

Figure 14. Arsenic Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

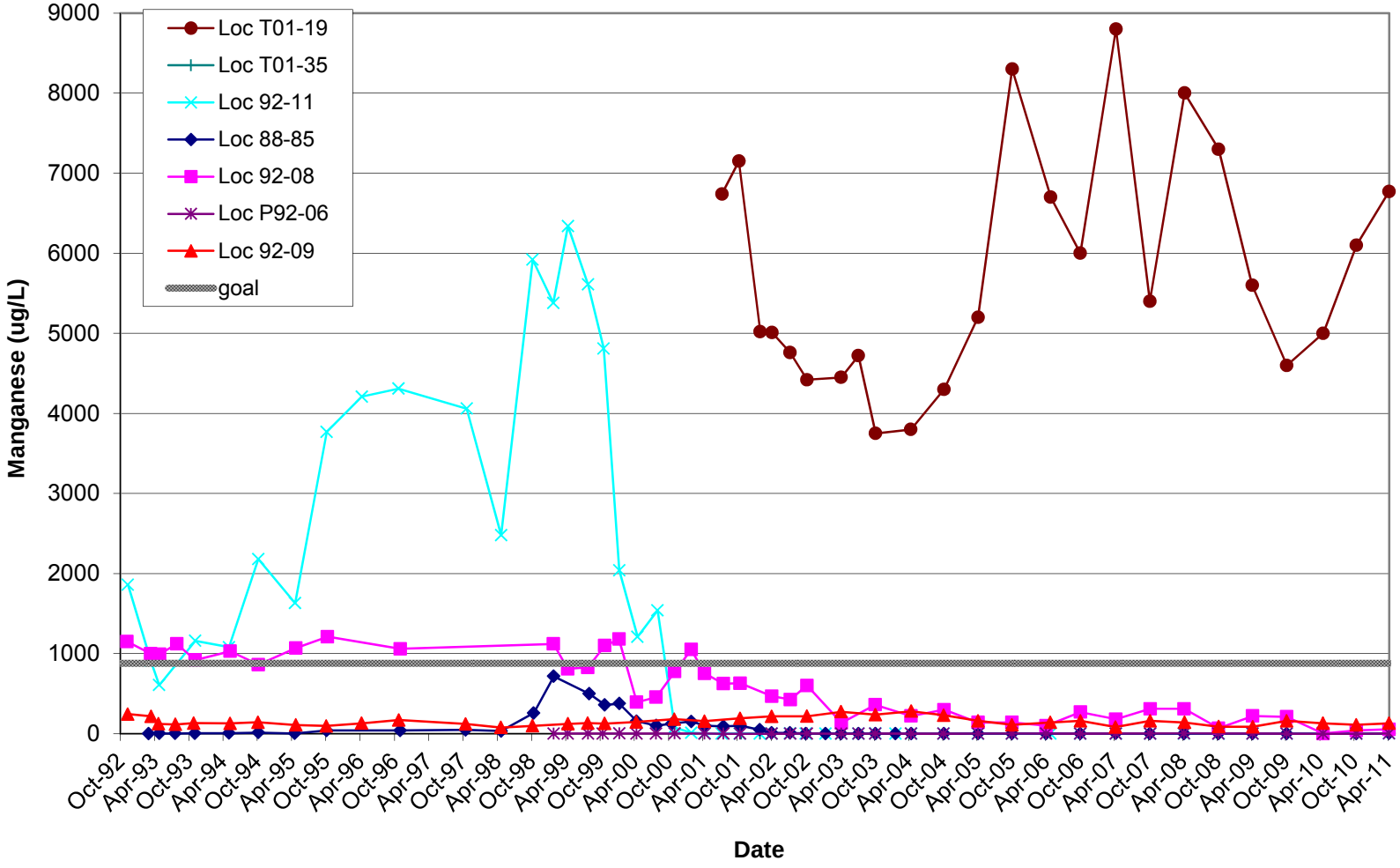

Figure 15. Manganese Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

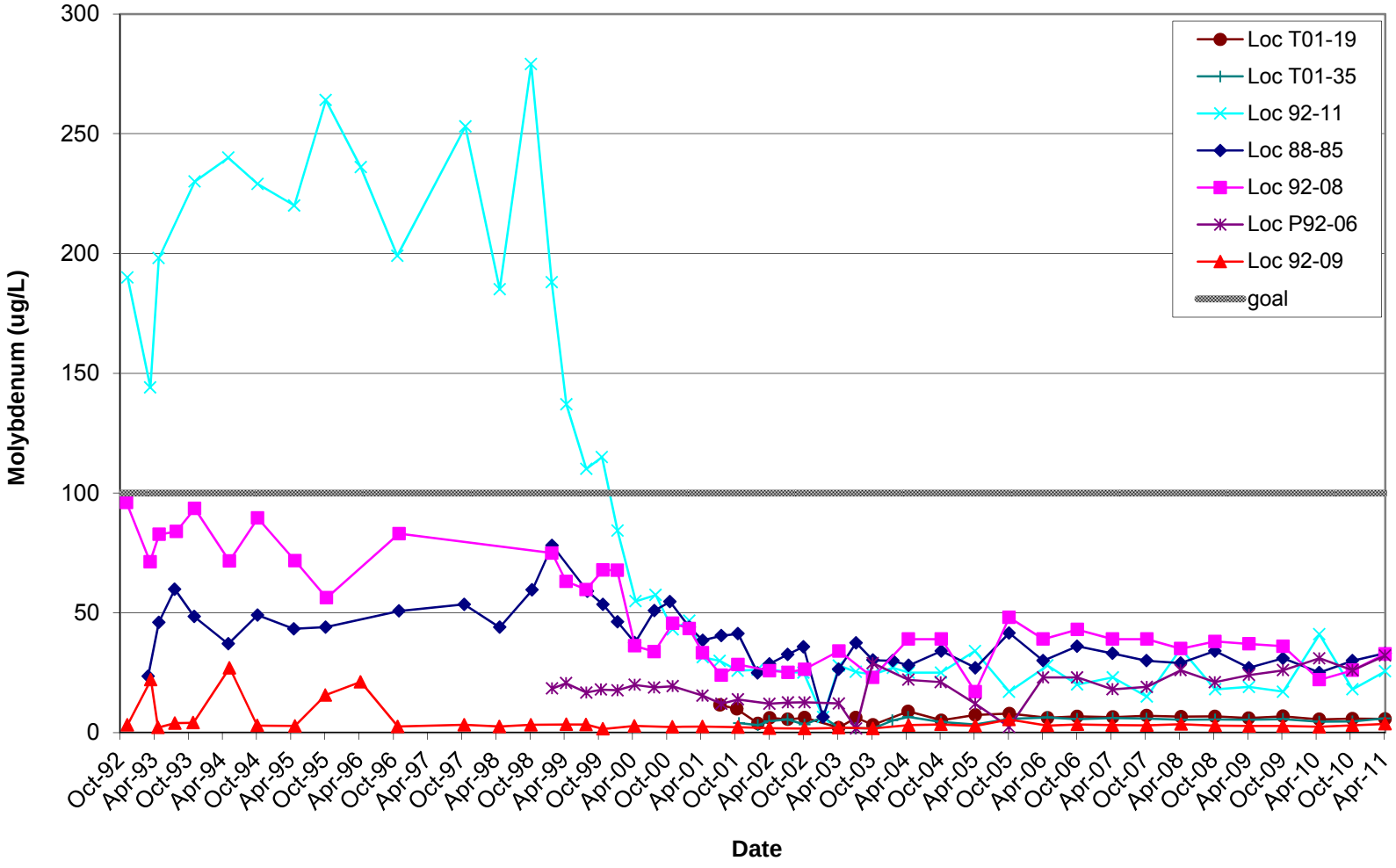

Figure 16. Molybdenum Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

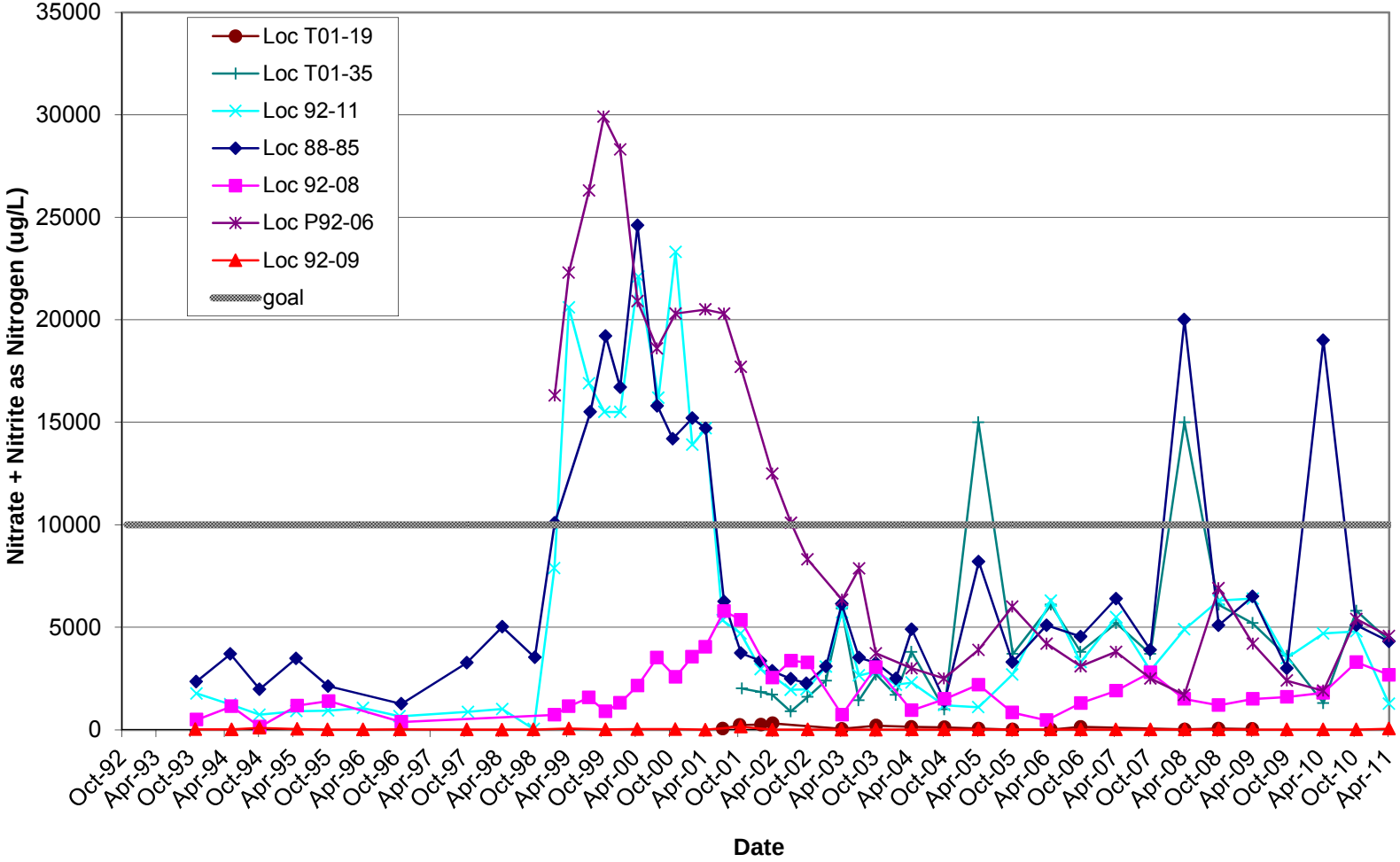

Figure 17. Nitrate (as Nitrogen) Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

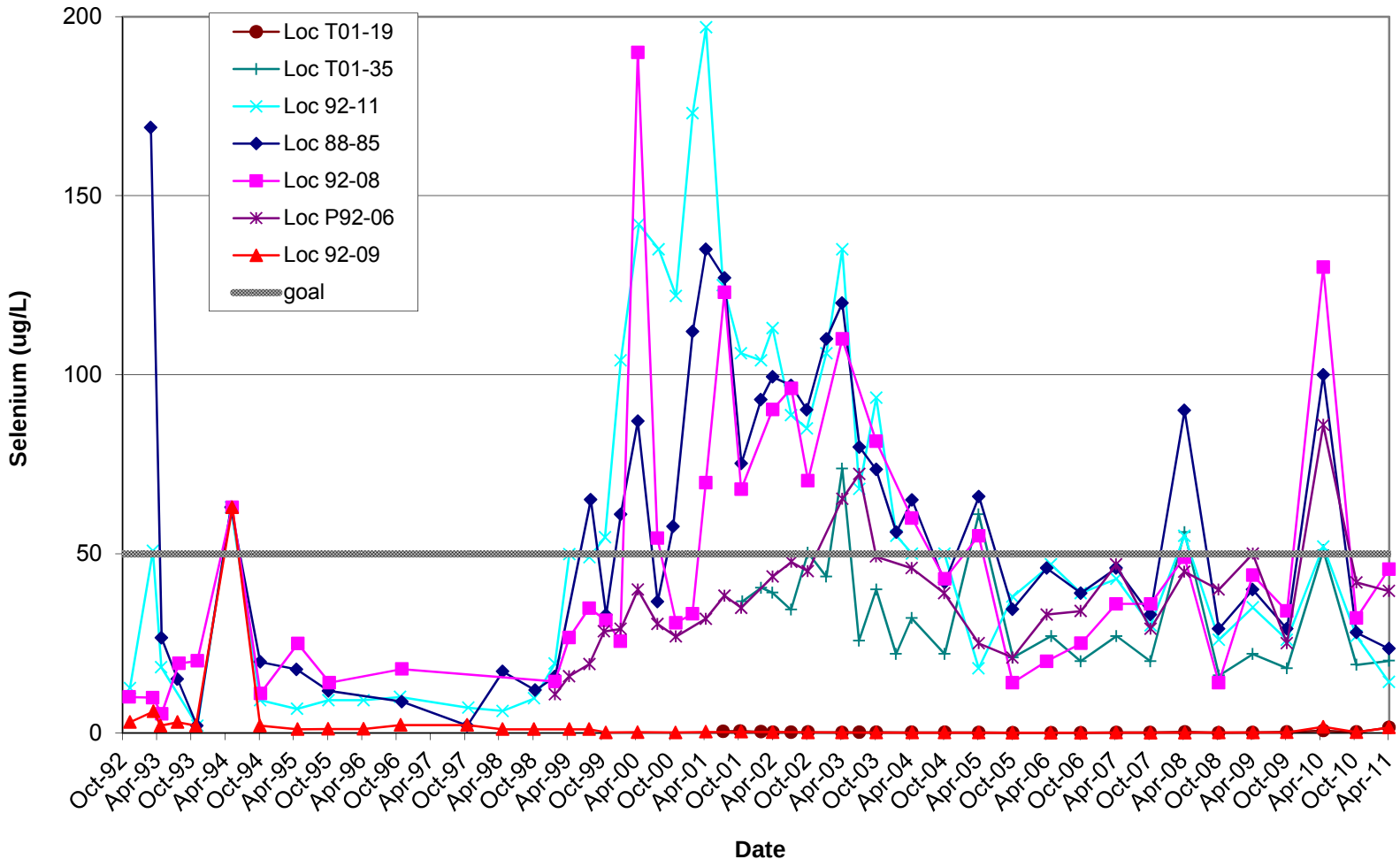

Figure 18. Selenium Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

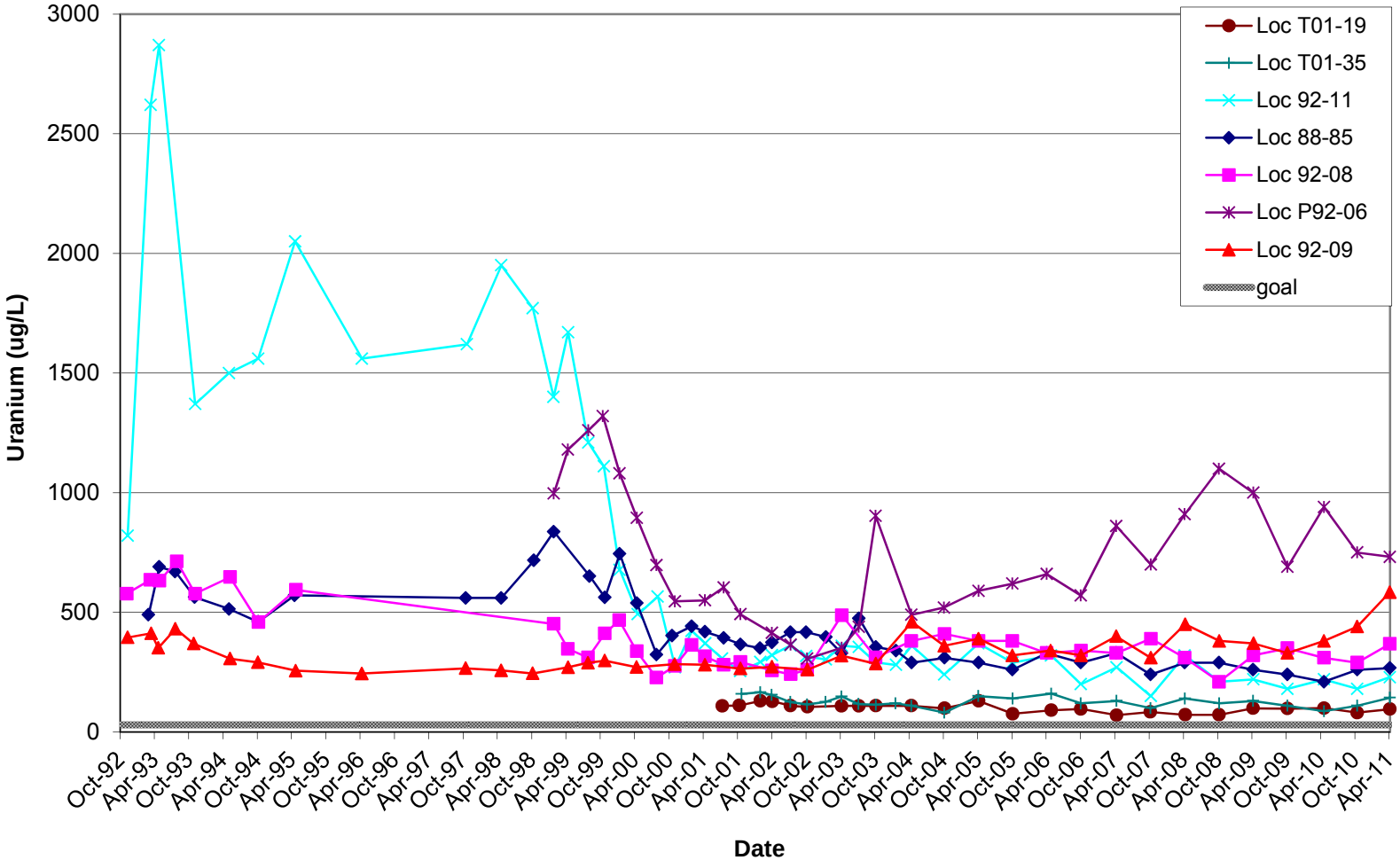

Figure 19. Uranium Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

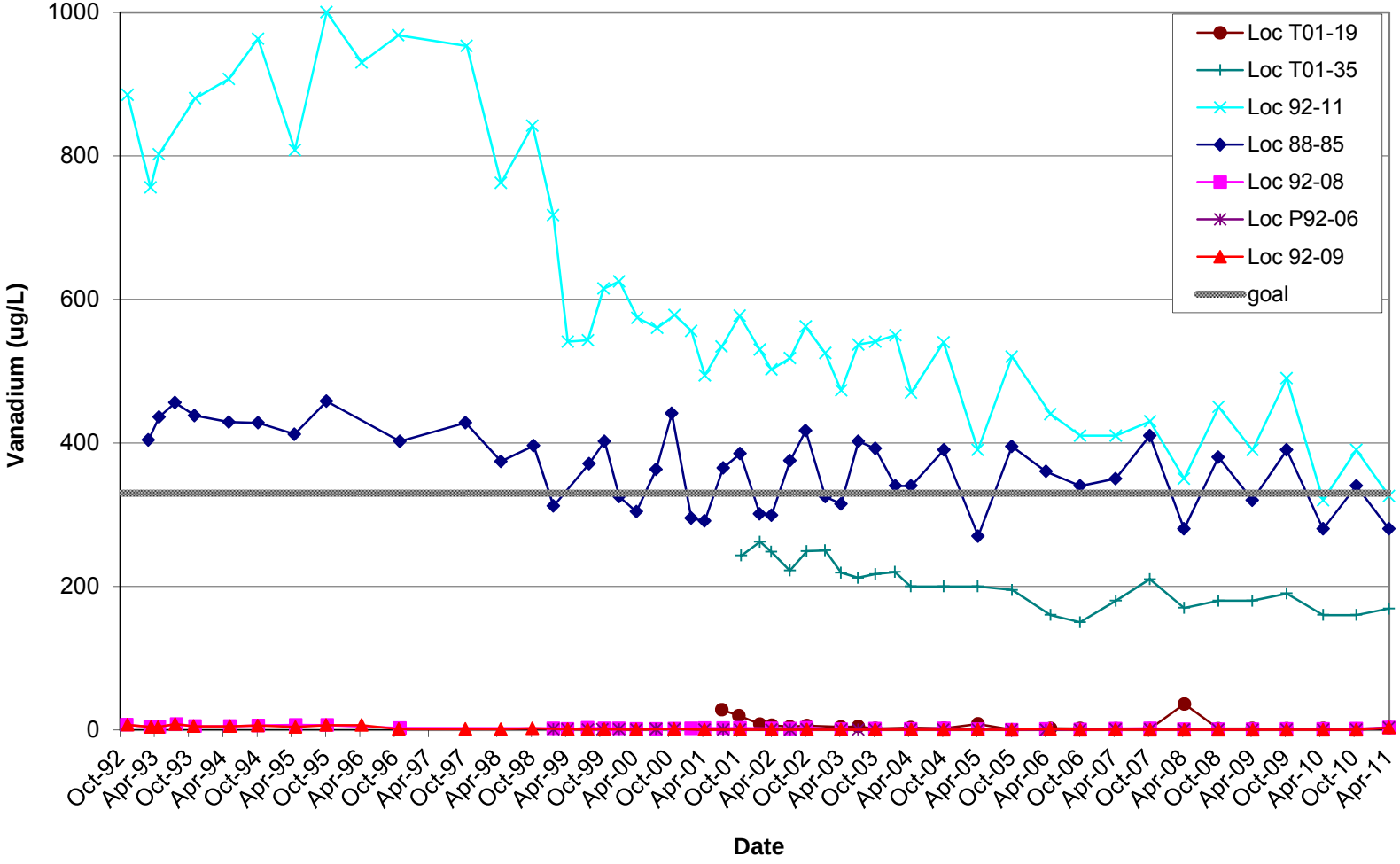

Figure 20. Vanadium Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

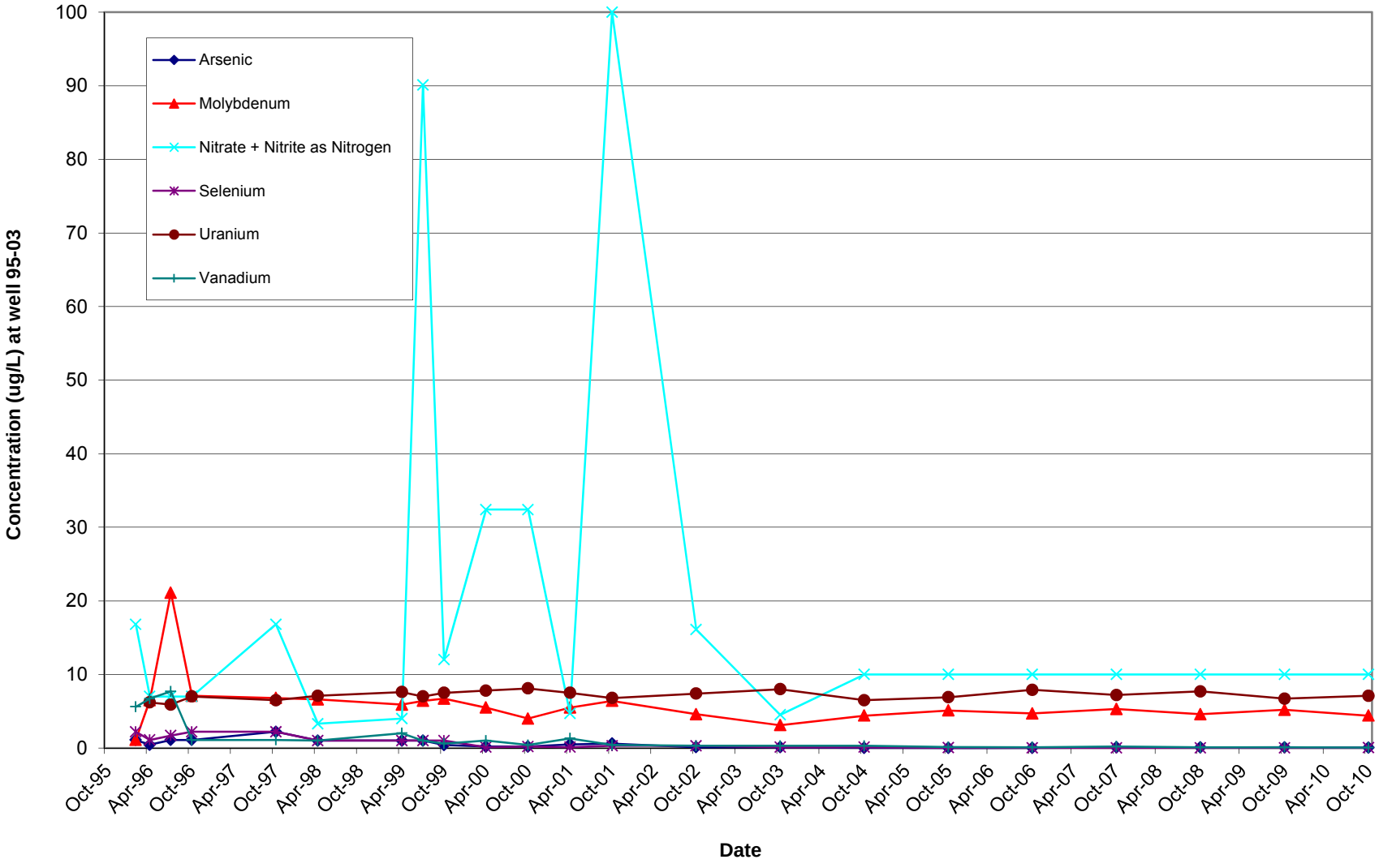

Figure 21. Contaminant Concentrations Over Time at Sentinel Well 95-03

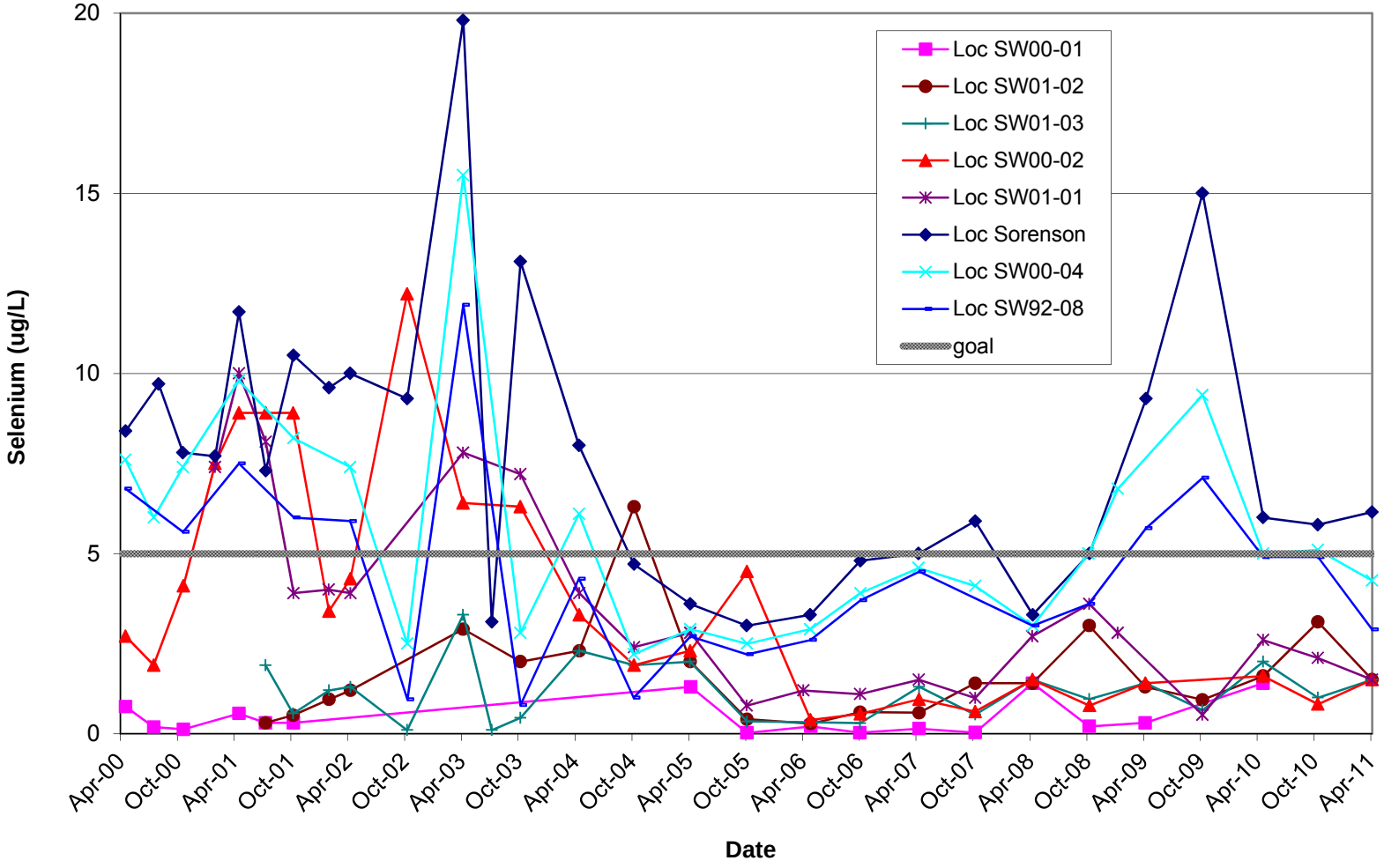

Figure 22. Selenium Concentration Over Time in Montezuma Creek

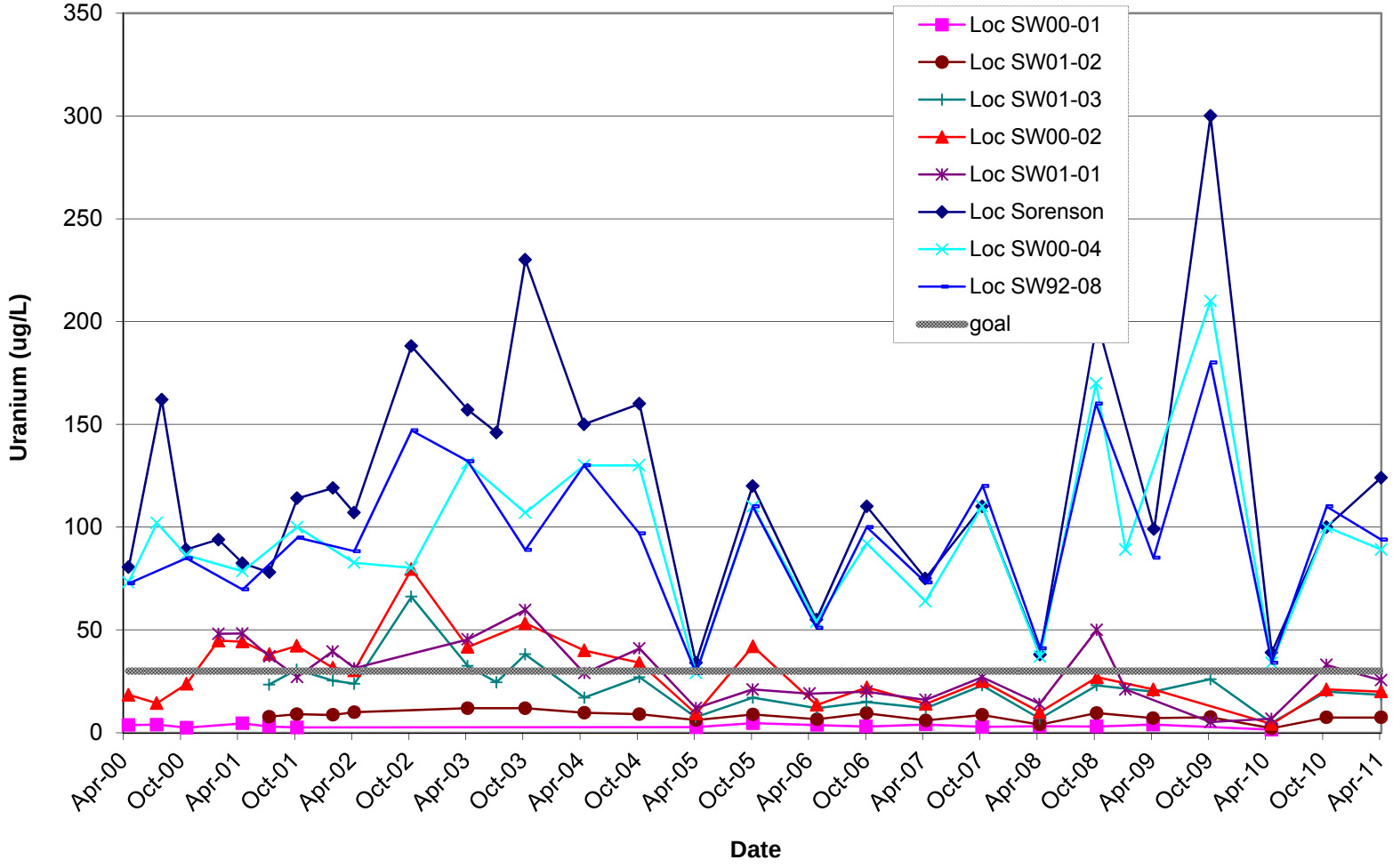

Figure 23. Uranium Concentration Over Time in Montezuma Creek

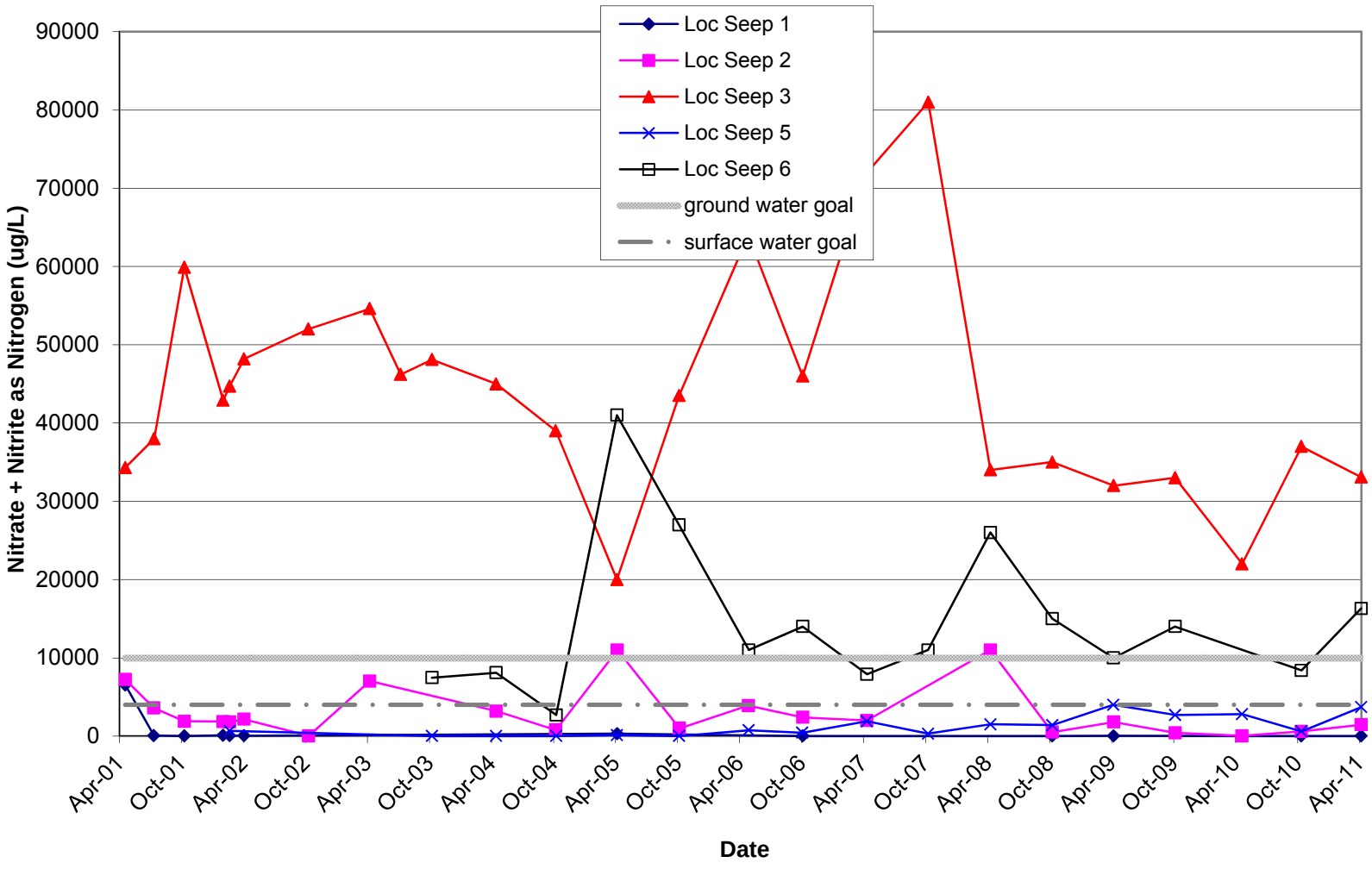

Figure 24. Nitrate (as Nitrogen) Concentration Over Time at Selected Seep Locations

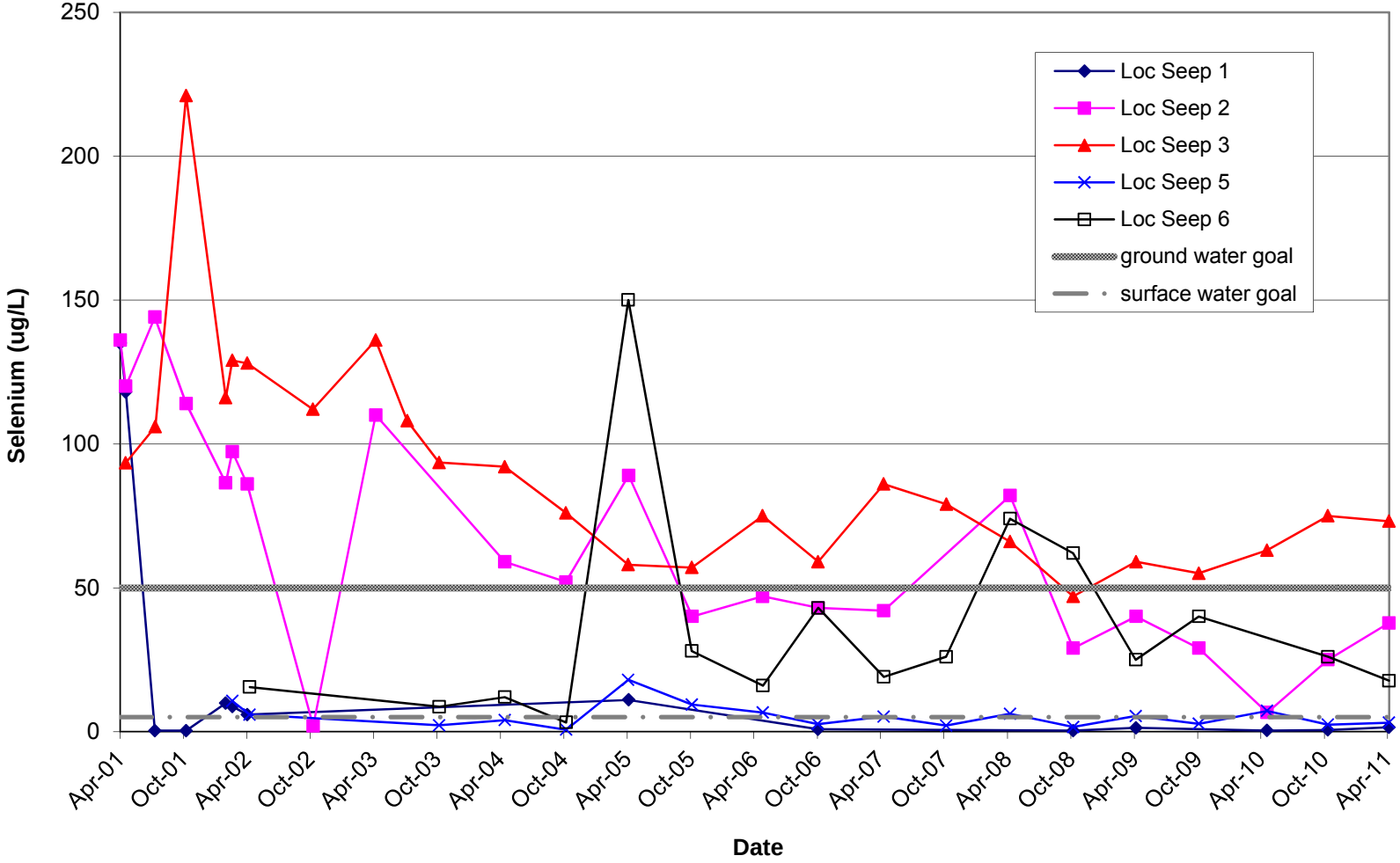

Figure 25. Selenium Concentration Over Time at Selected Seep Locations

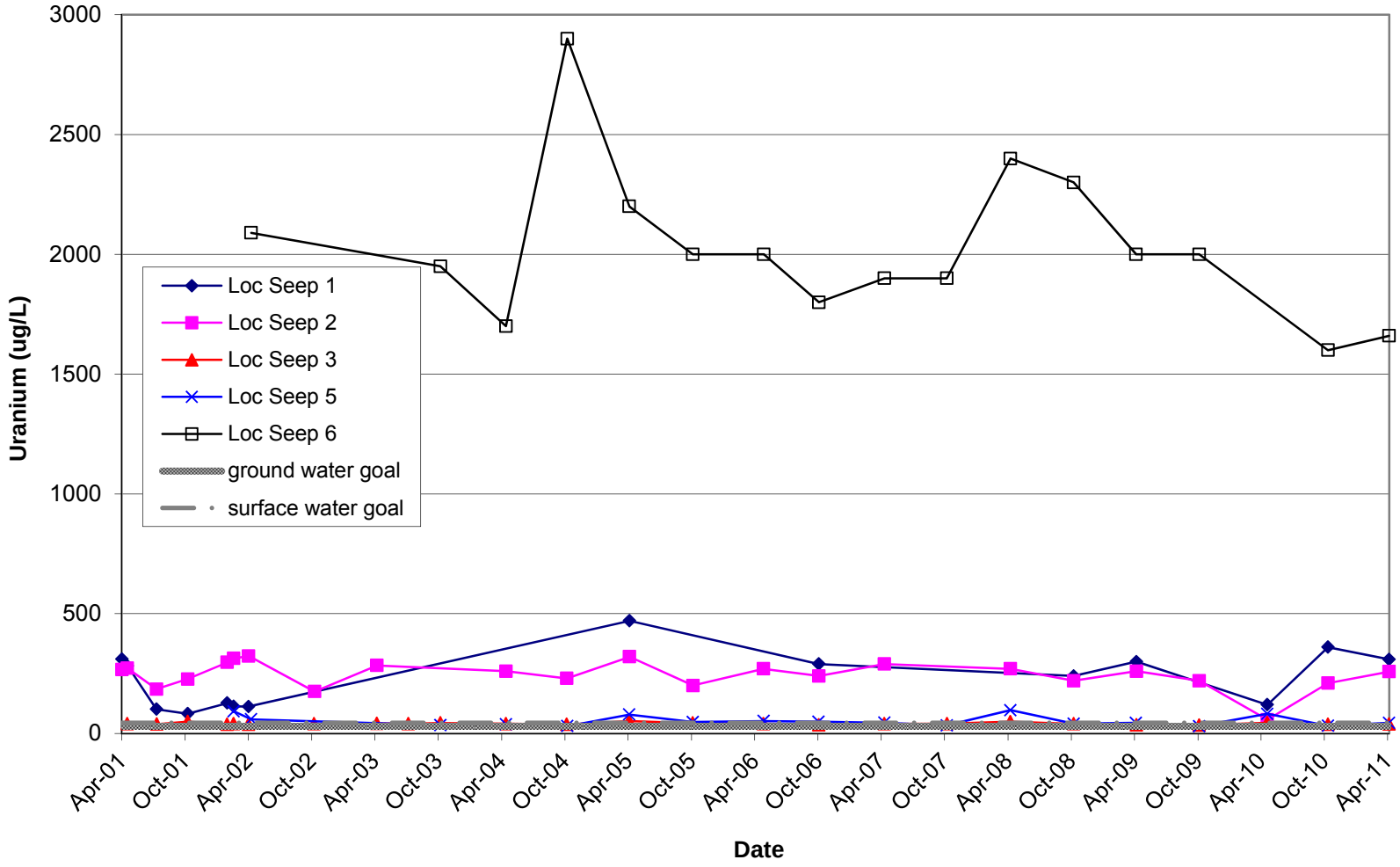

Figure 26. Uranium Concentration Over Time at Selected Seep Locations

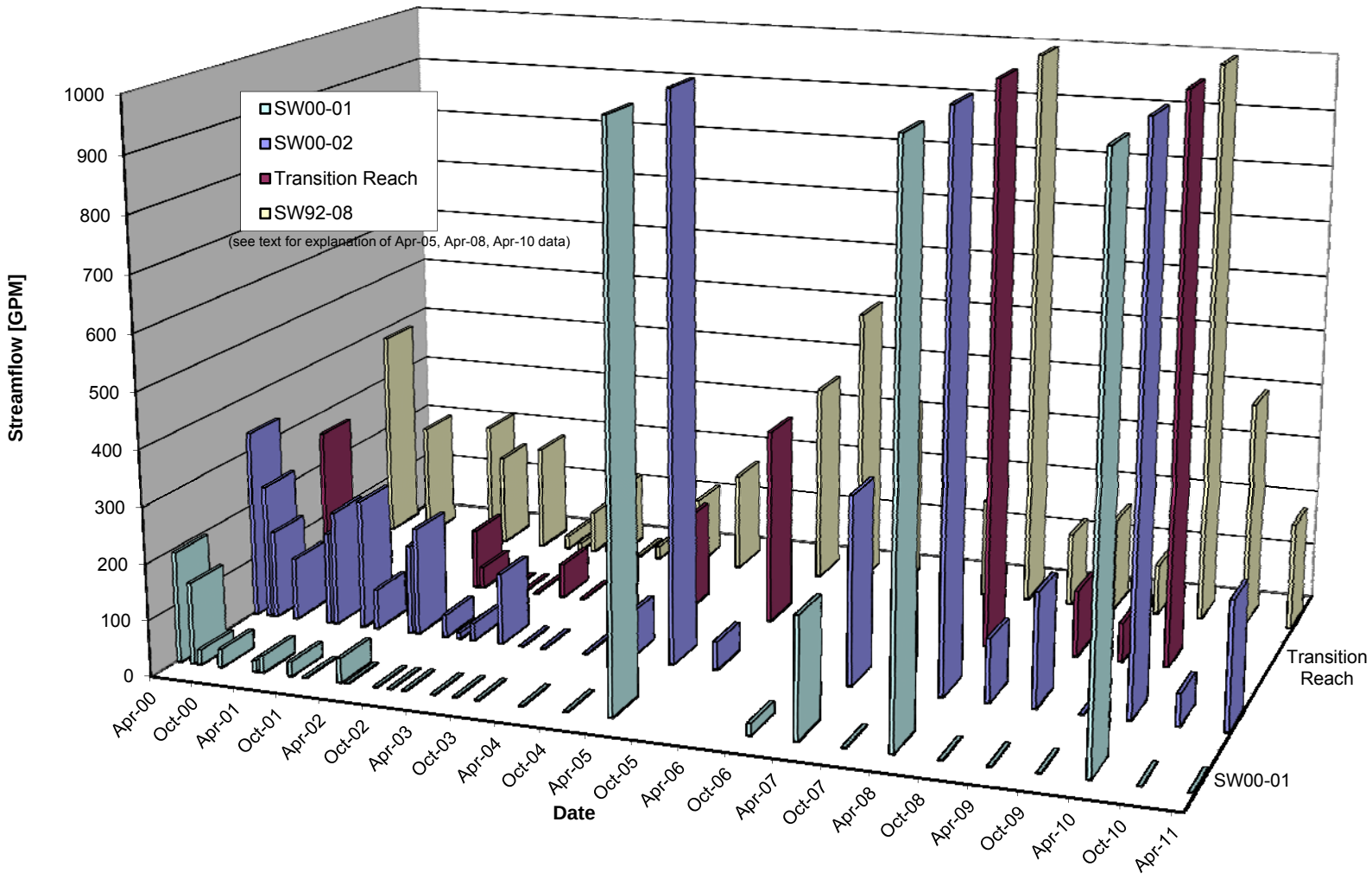

Figure 27. Stream Flow Hydrographs for Selected Sites on Montezuma Creek

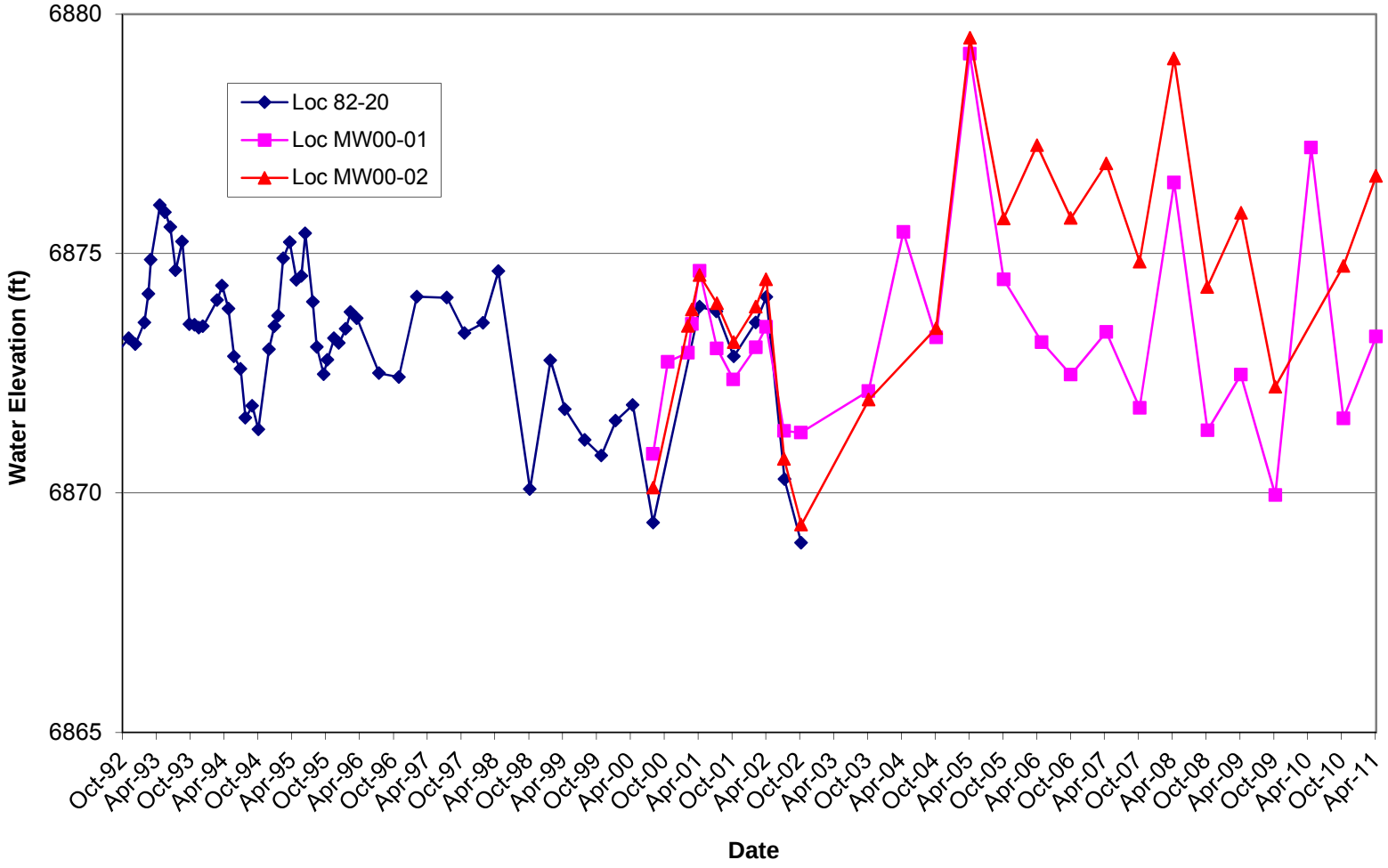

Figure 28. Water Level Hydrographs for Upgradient Alluvial Wells

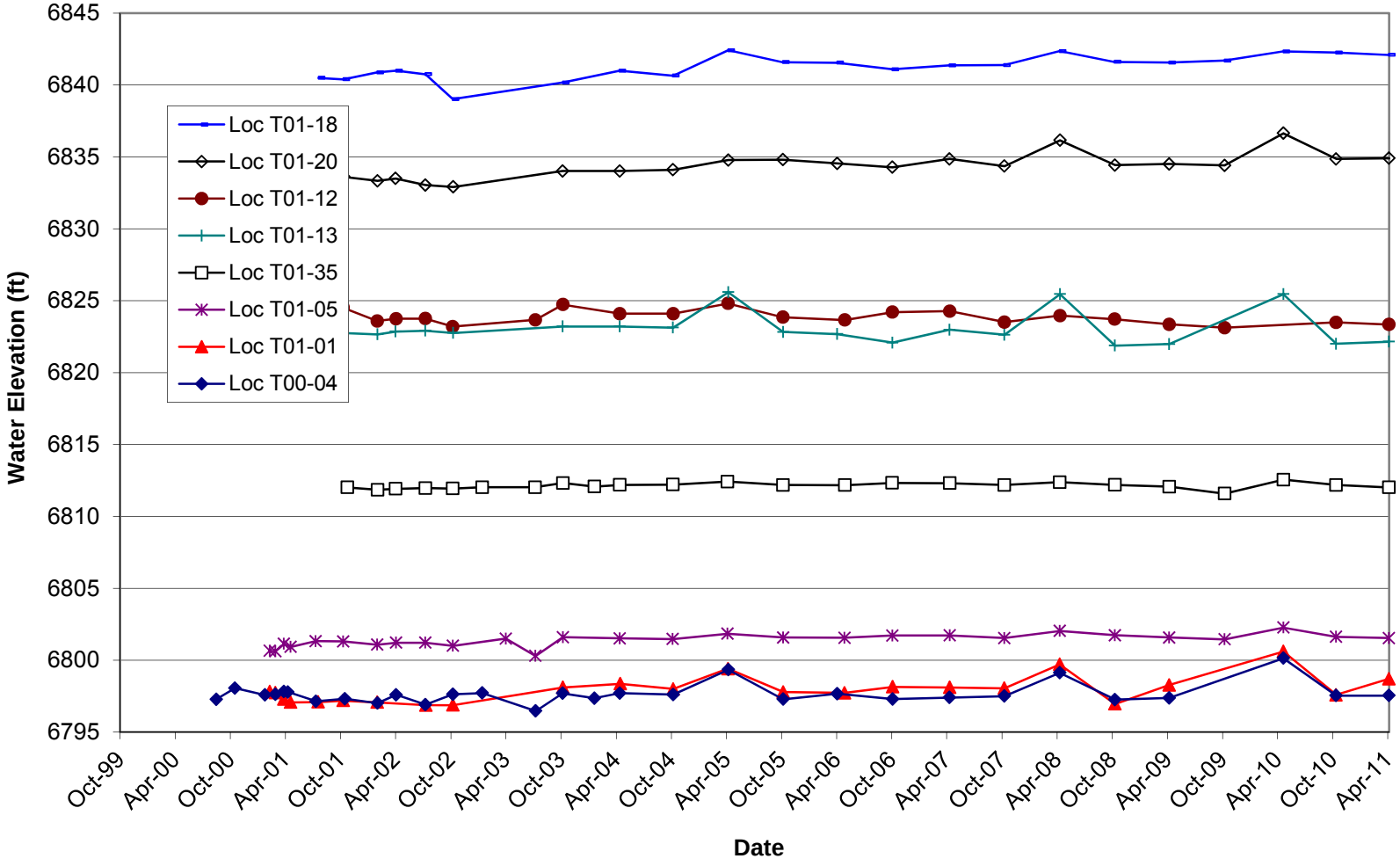

Figure 29. Water Level Hydrographs for Selected Mill Site Alluvial Wells

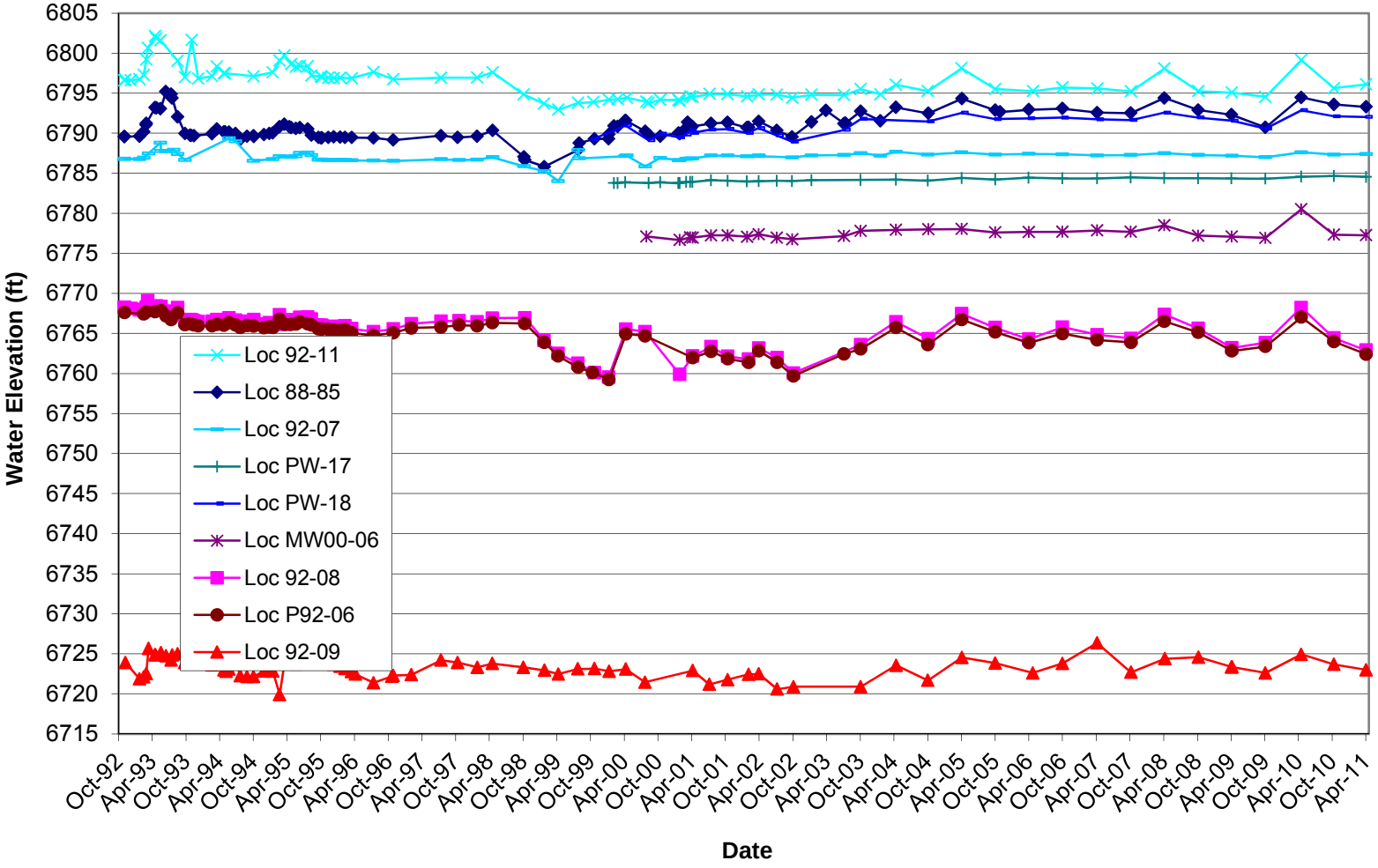

Figure 30. Water Level Hydrographs for Downgradient Wells

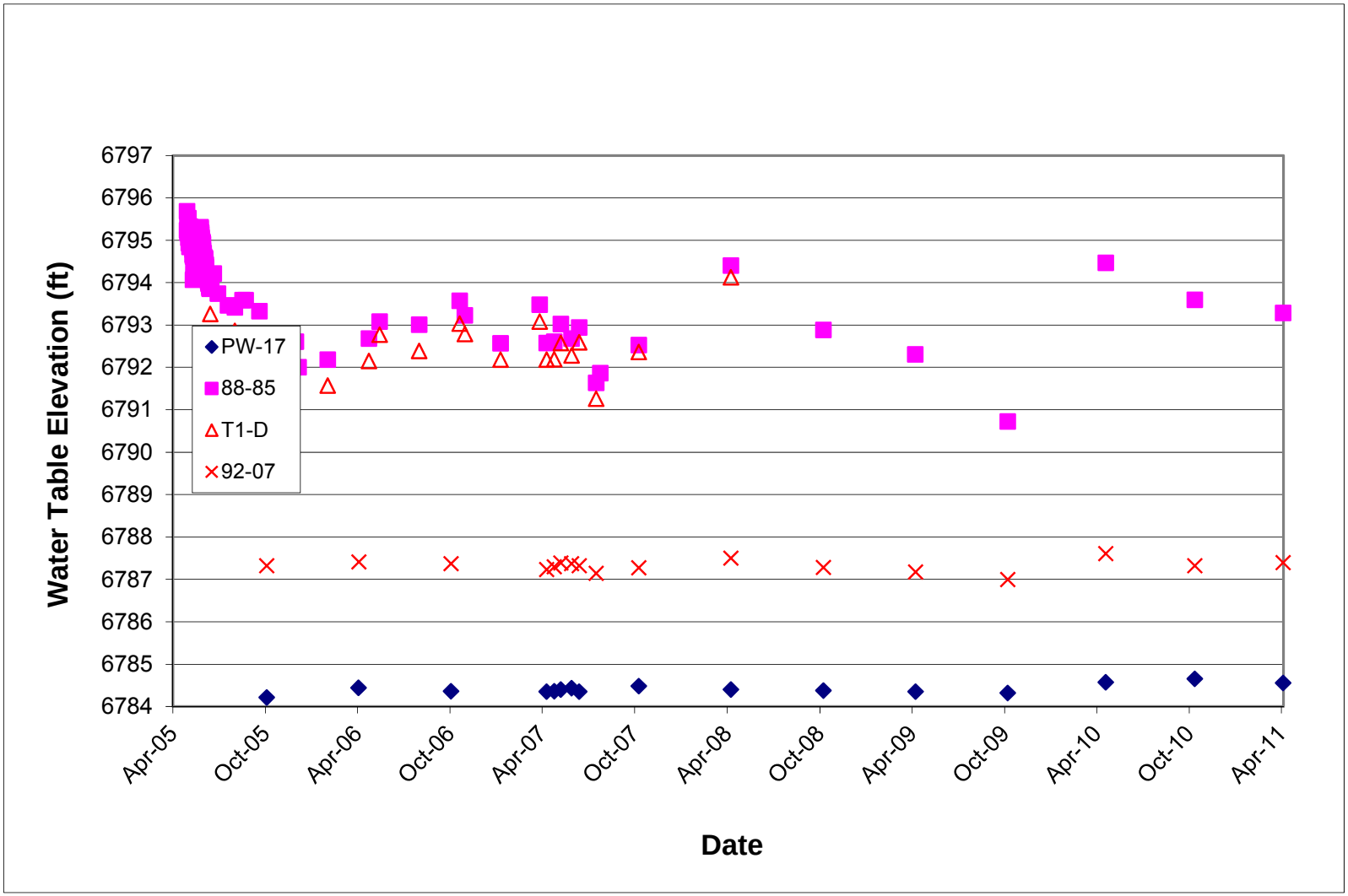

Figure 31. Water Table Trends Near the PRB

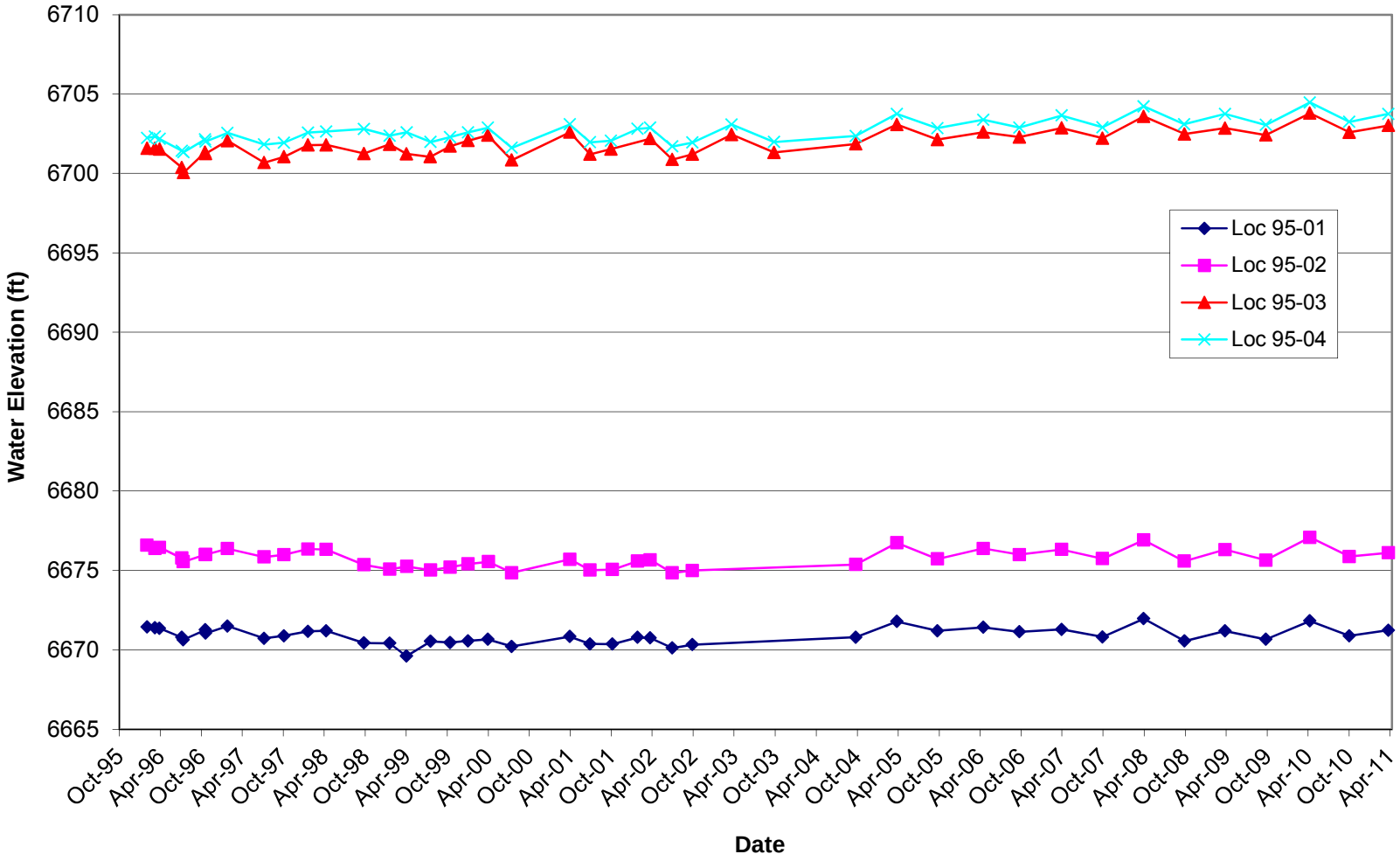

Figure 32. Water Level Hydrographs for Alluvial/Burro Canyon Well Pairs 95-01/95-02 and 95-03/95-04

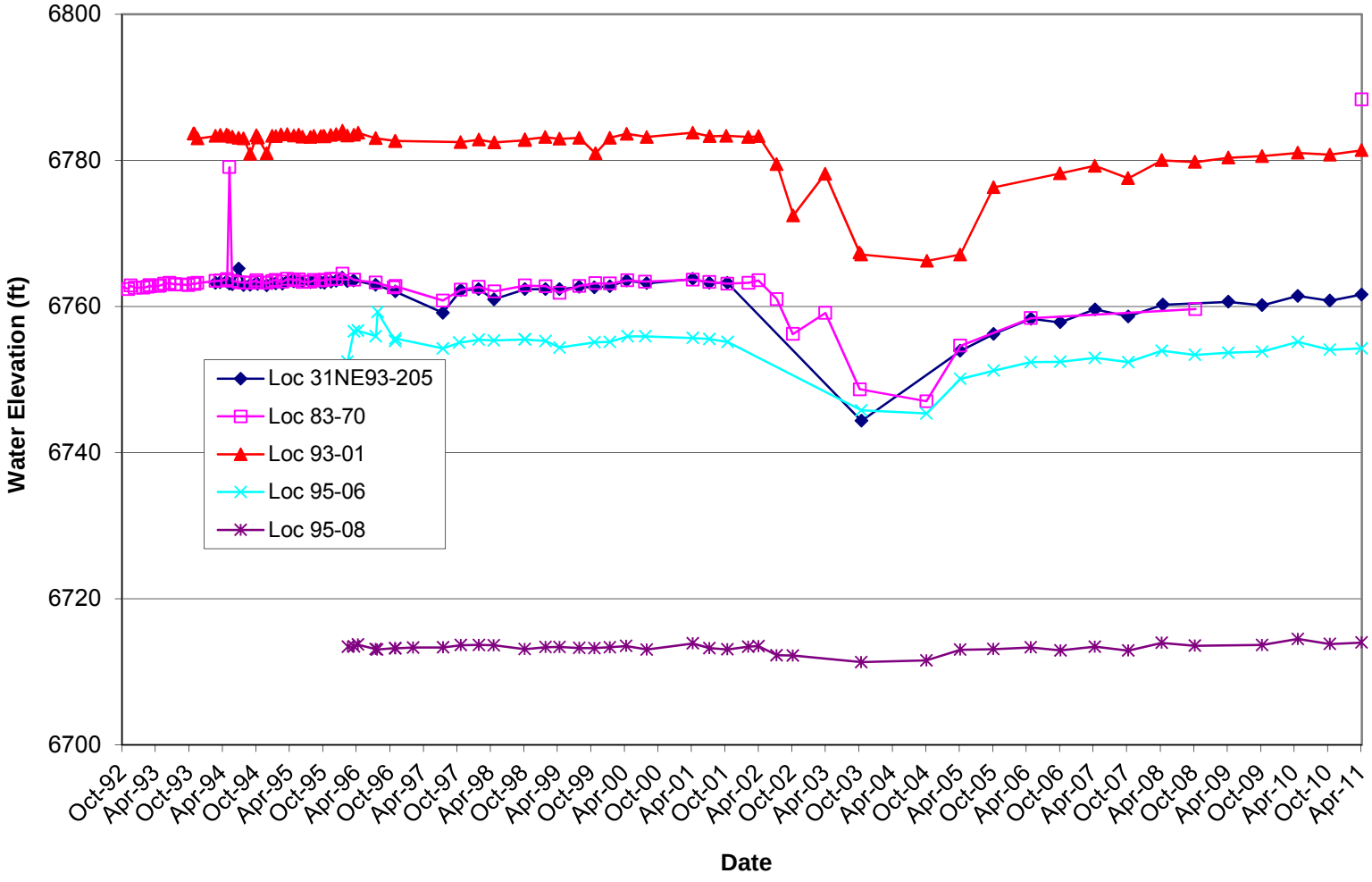

Figure 33. Water Level Hydrographs for Selected Burro Canyon Aquifer Wells

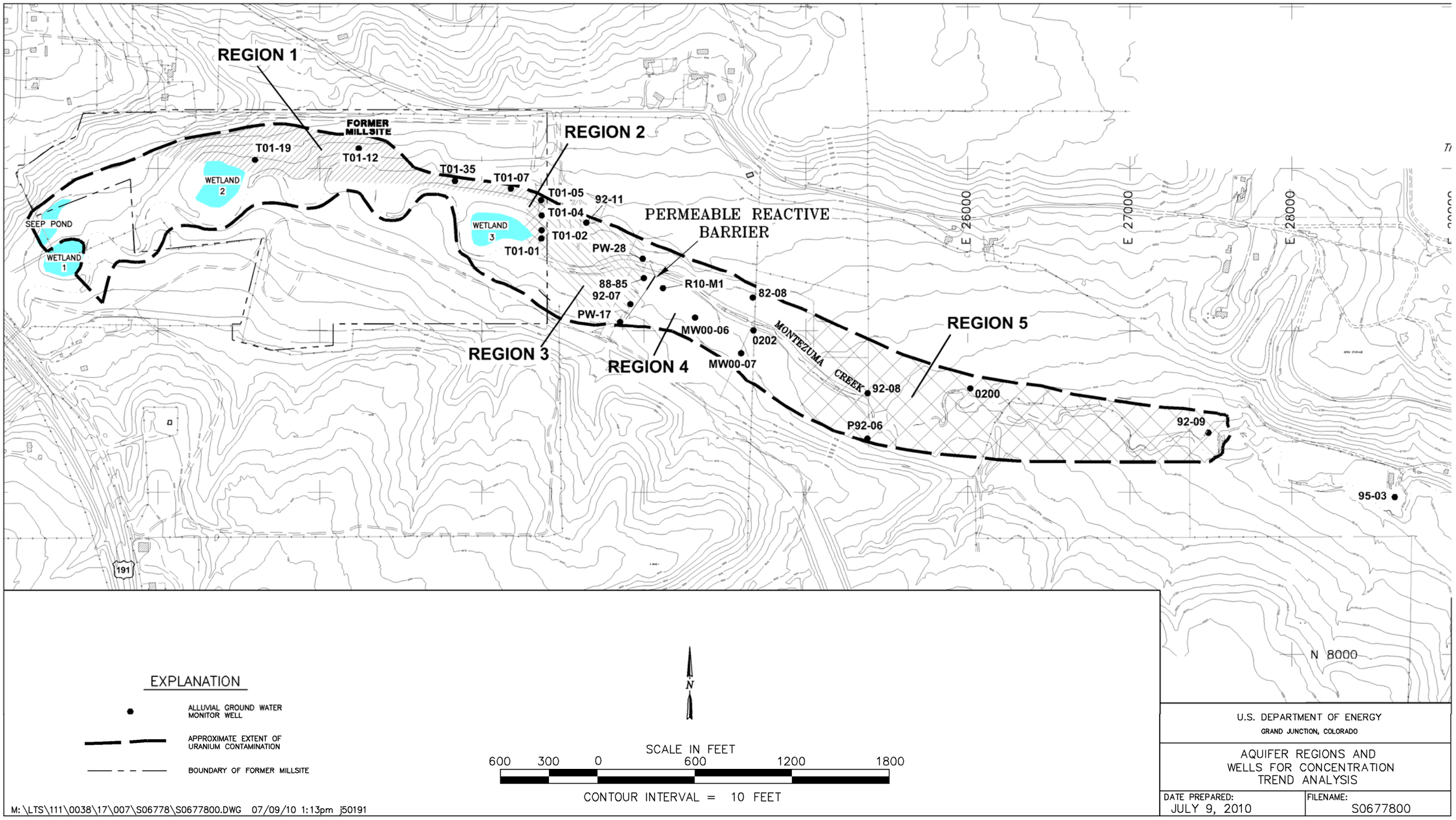

Figure 34. Aquifer Regions and Monitoring Wells Selected for Concentration Trend Analysis

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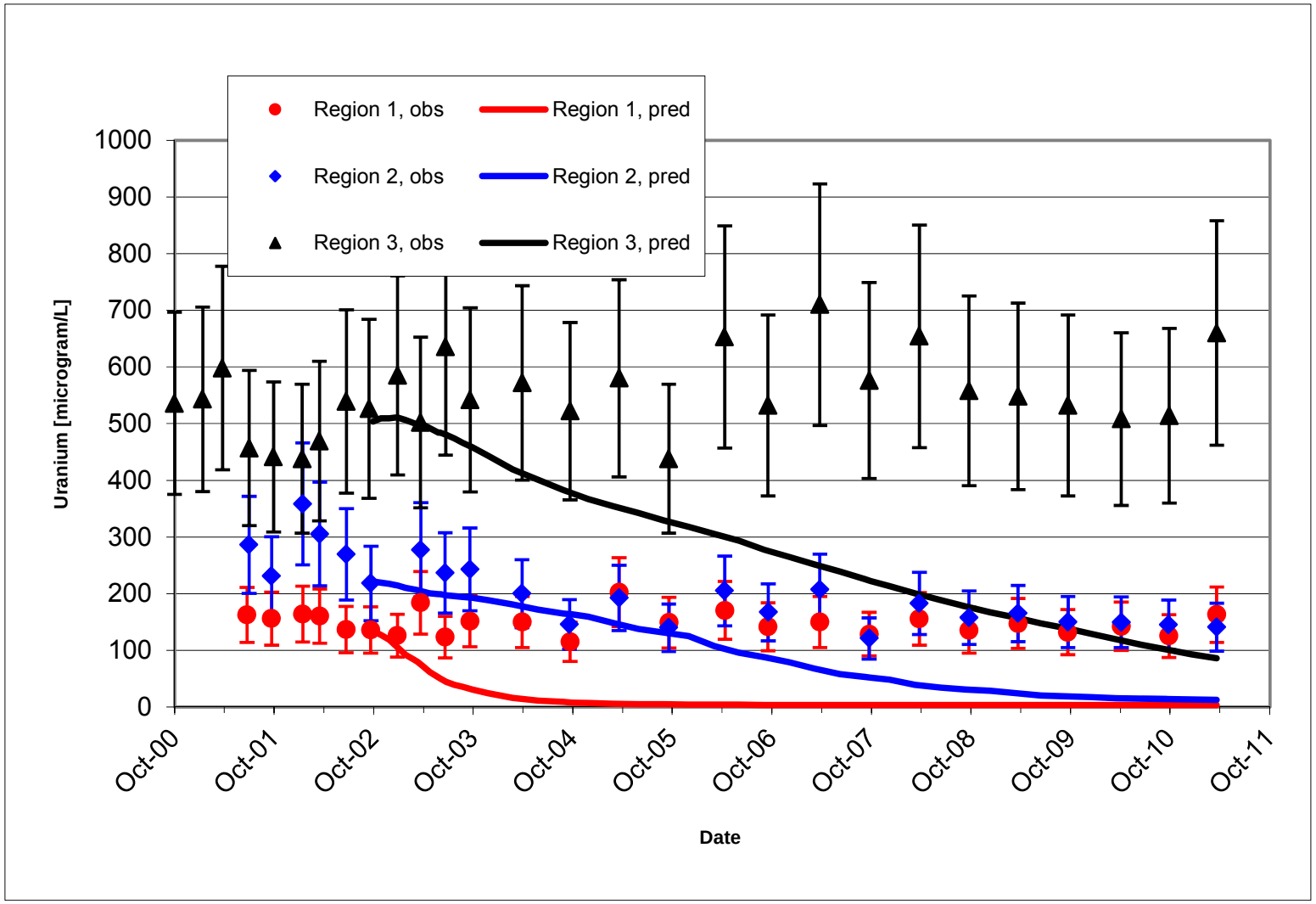

Figure 35. Comparison of Model Prediction to Observed Restoration Progress—Aquifer Regions 1 to 3

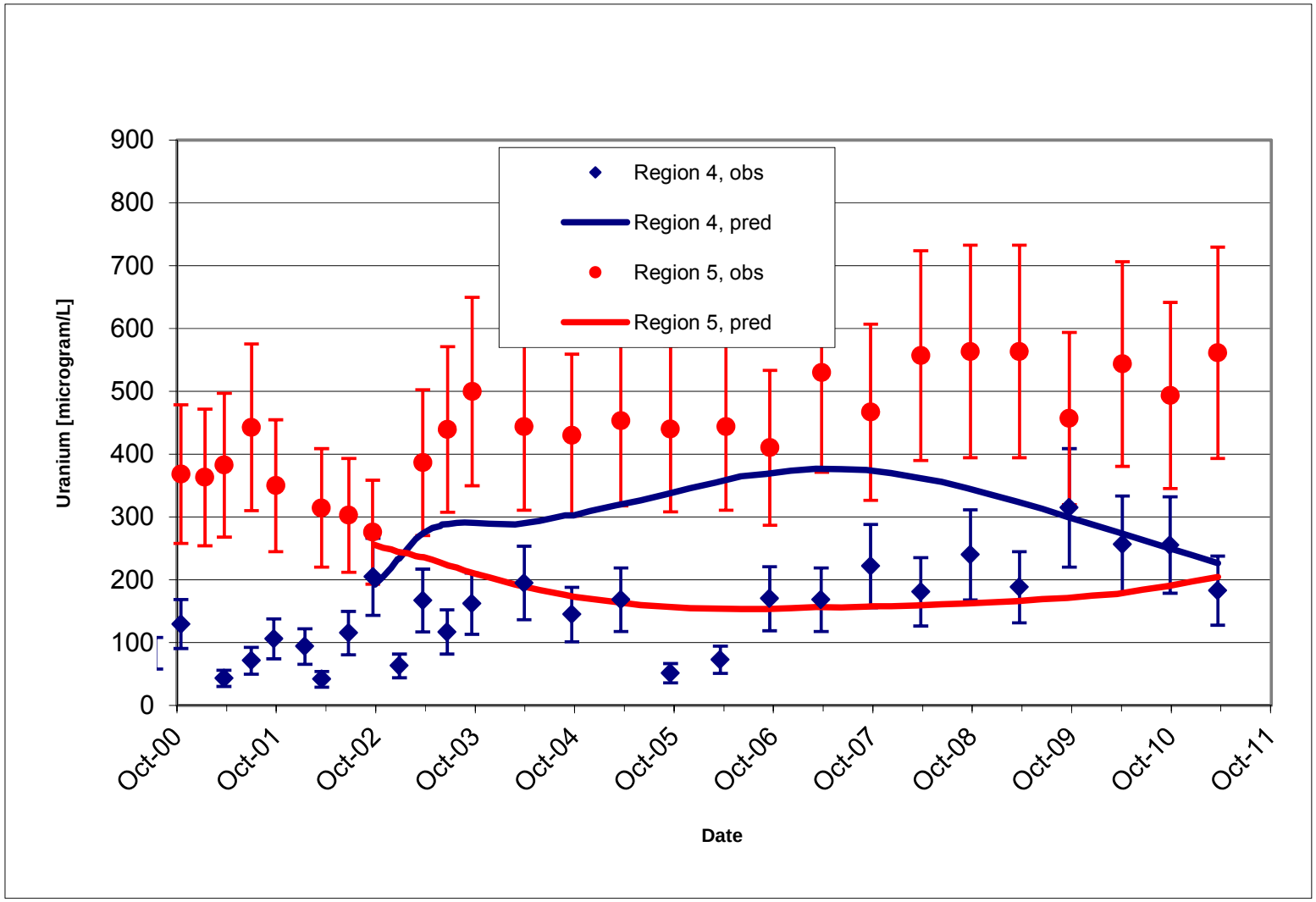

Figure 36. Comparison of Model Prediction to Observed Restoration Progress—Aquifer Regions 4 and 5

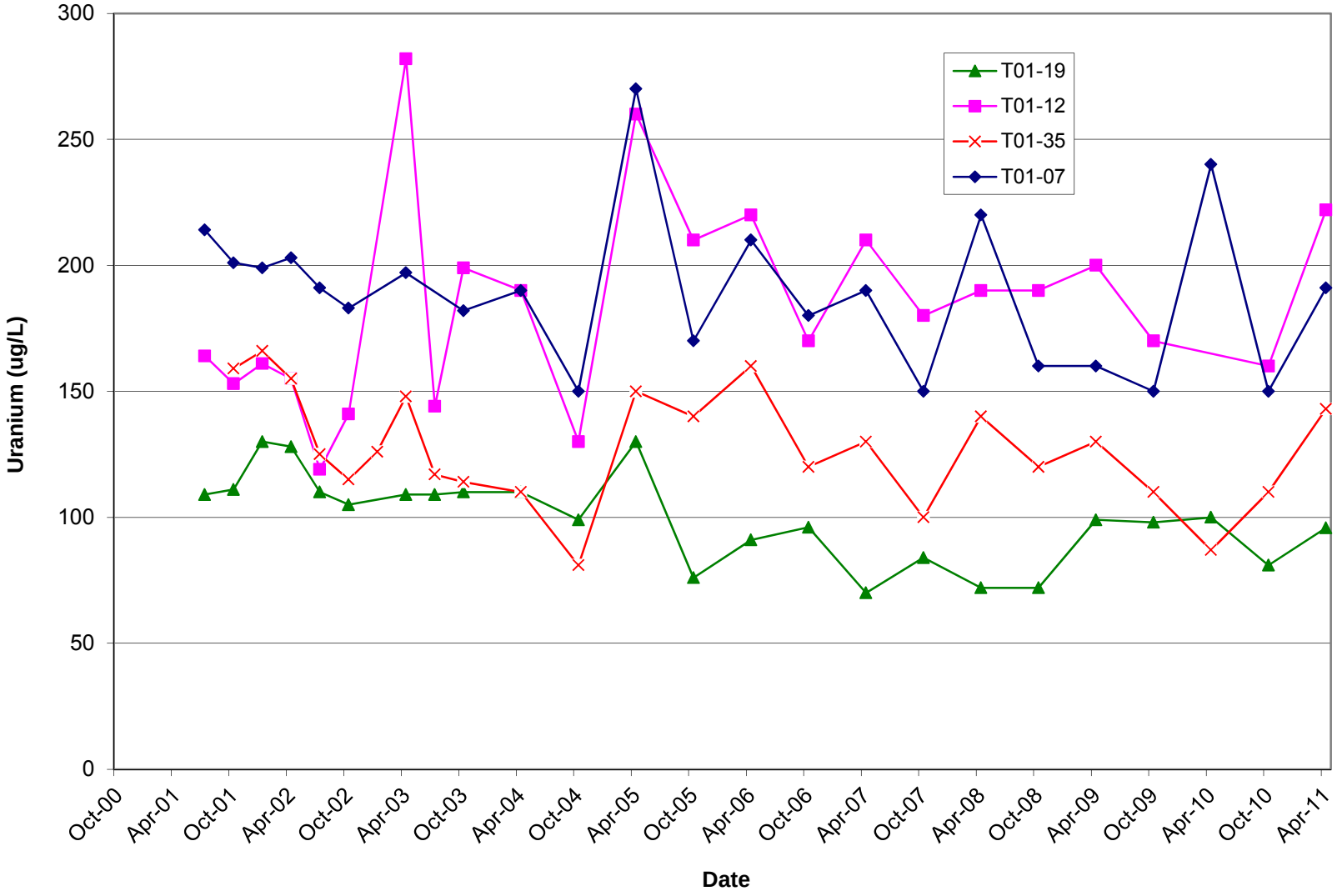

Figure 37. Region 1 Uranium Concentration Trends in Groundwater

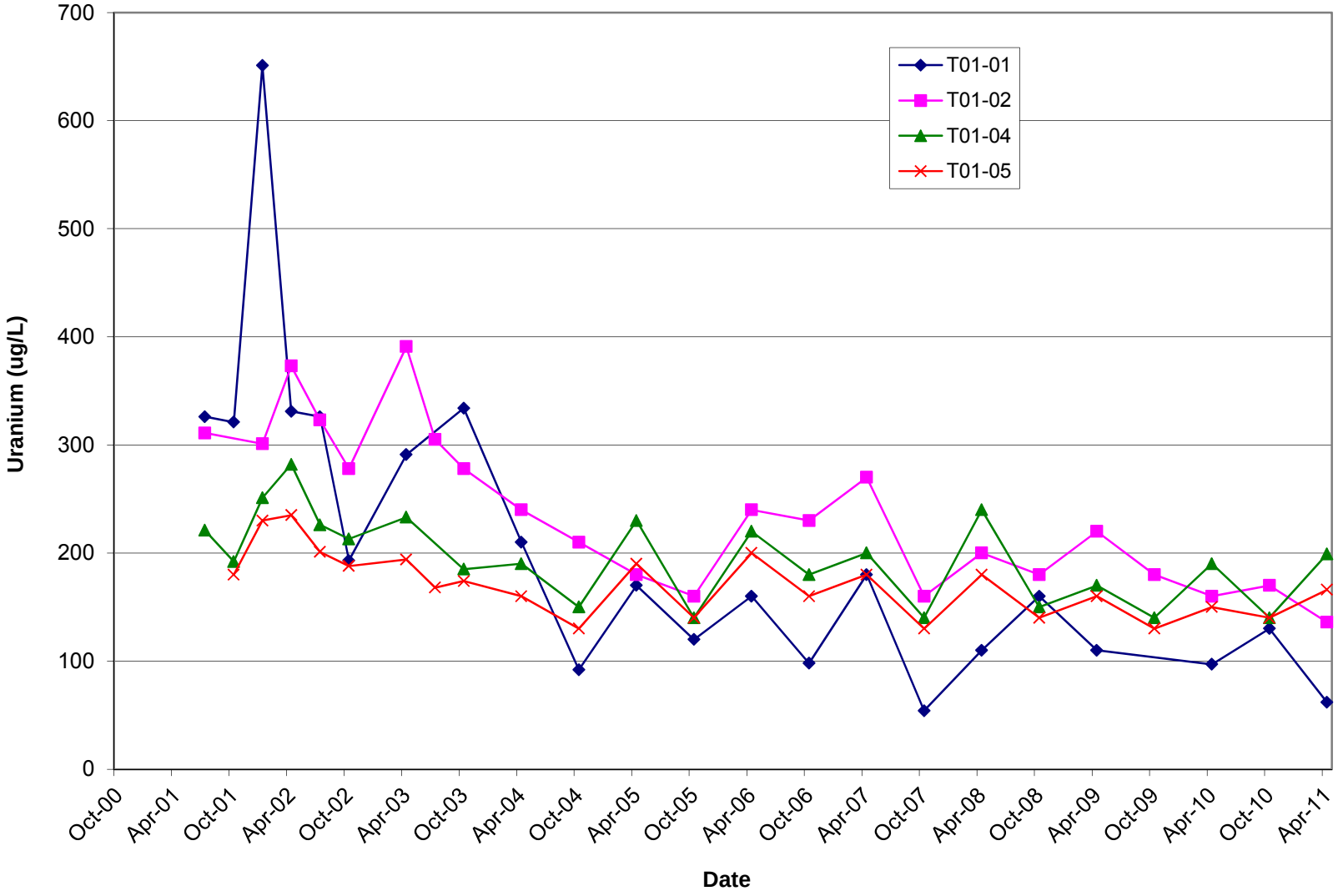

Figure 38. Region 2 Uranium Concentration Trends in Groundwater

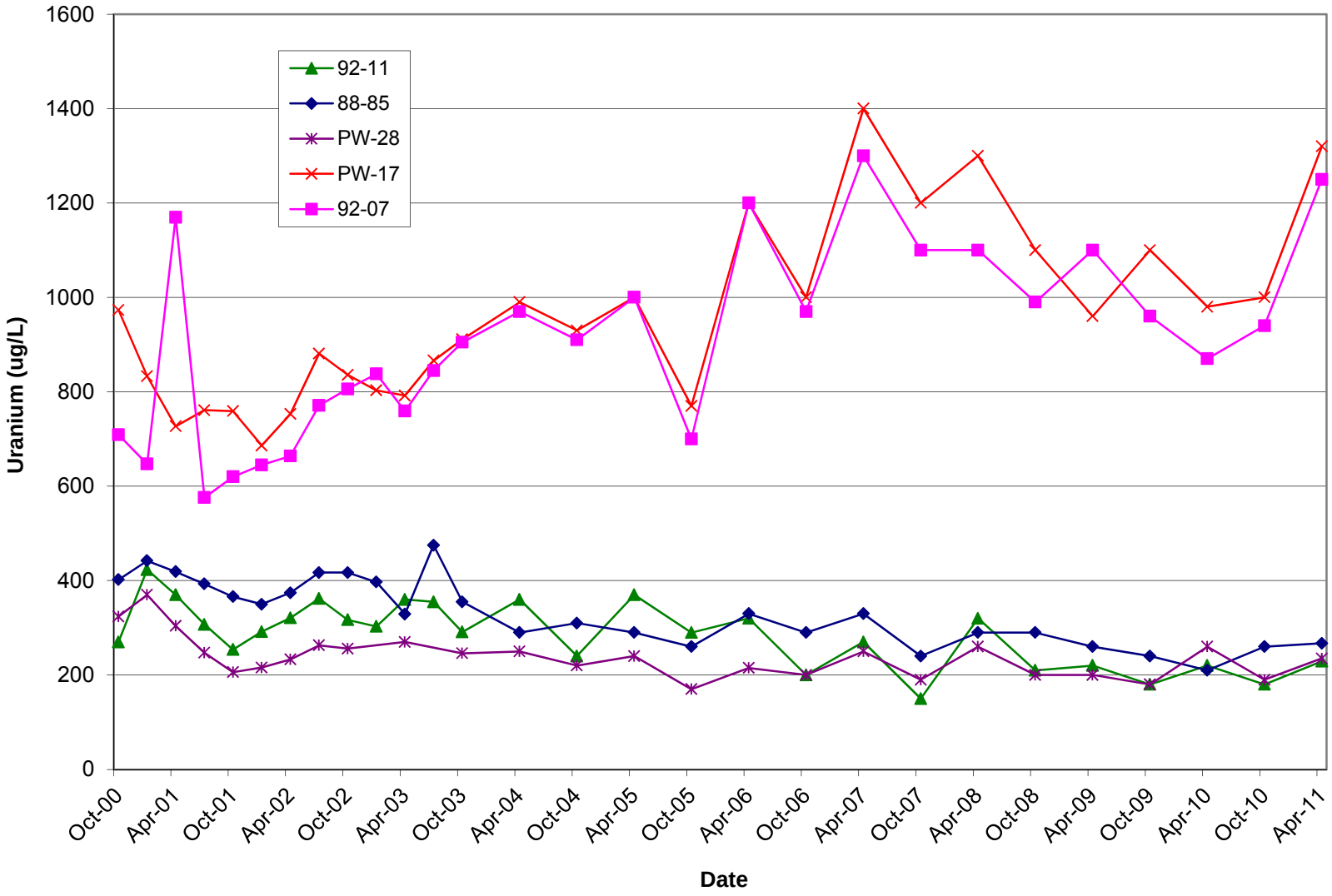

Figure 39. Region 3 Uranium Concentration Trends in Groundwater

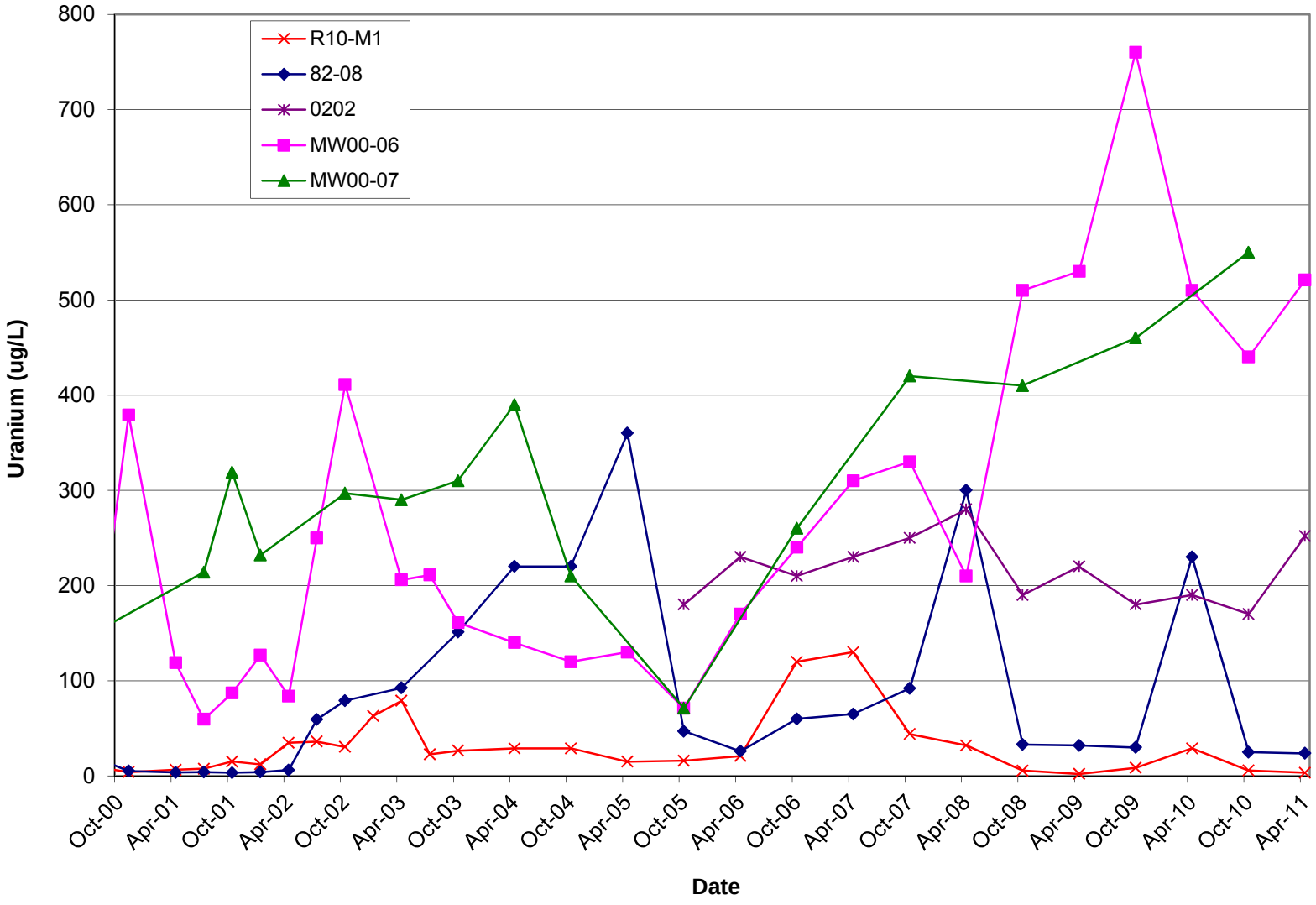

Figure 40. Region 4 Uranium Concentration Trends in Groundwater

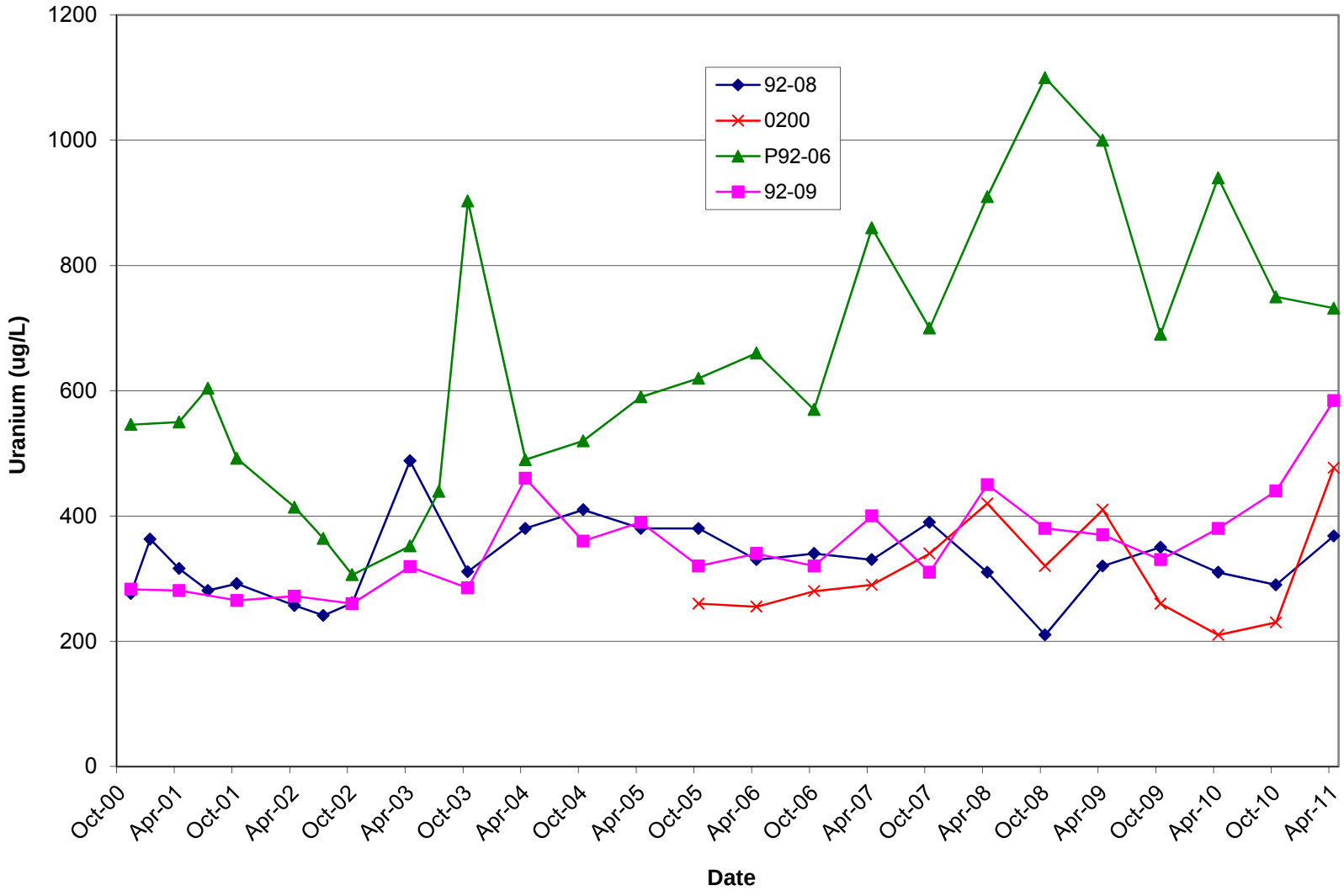

Figure 41. Region 5 Uranium Concentration Trends in Groundwater

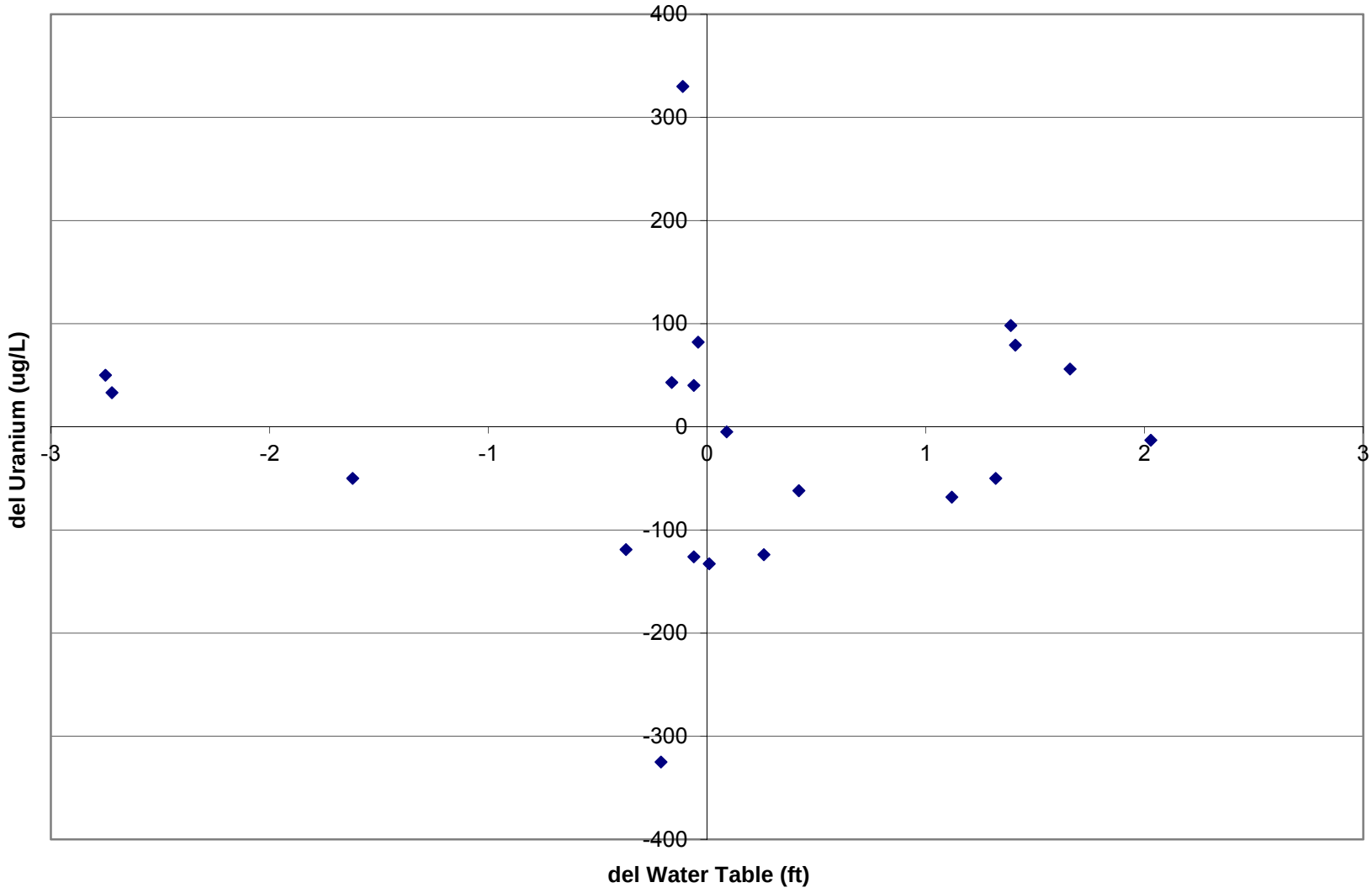

Figure 42. Uranium Concentration vs. Water Table Elevation, Well T01-01

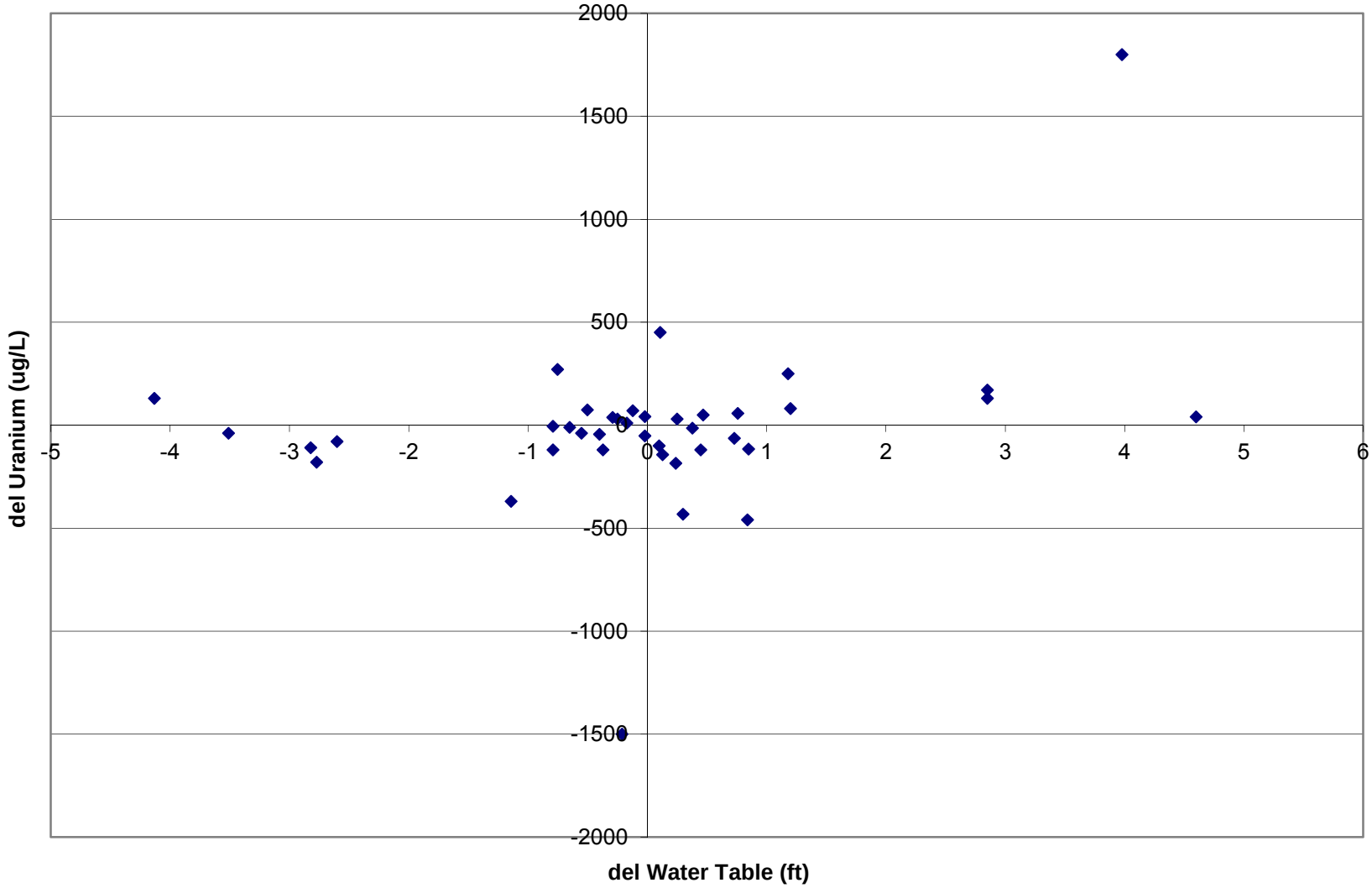

Figure 43. Uranium Concentration vs. Water Table Elevation, Well 92-11

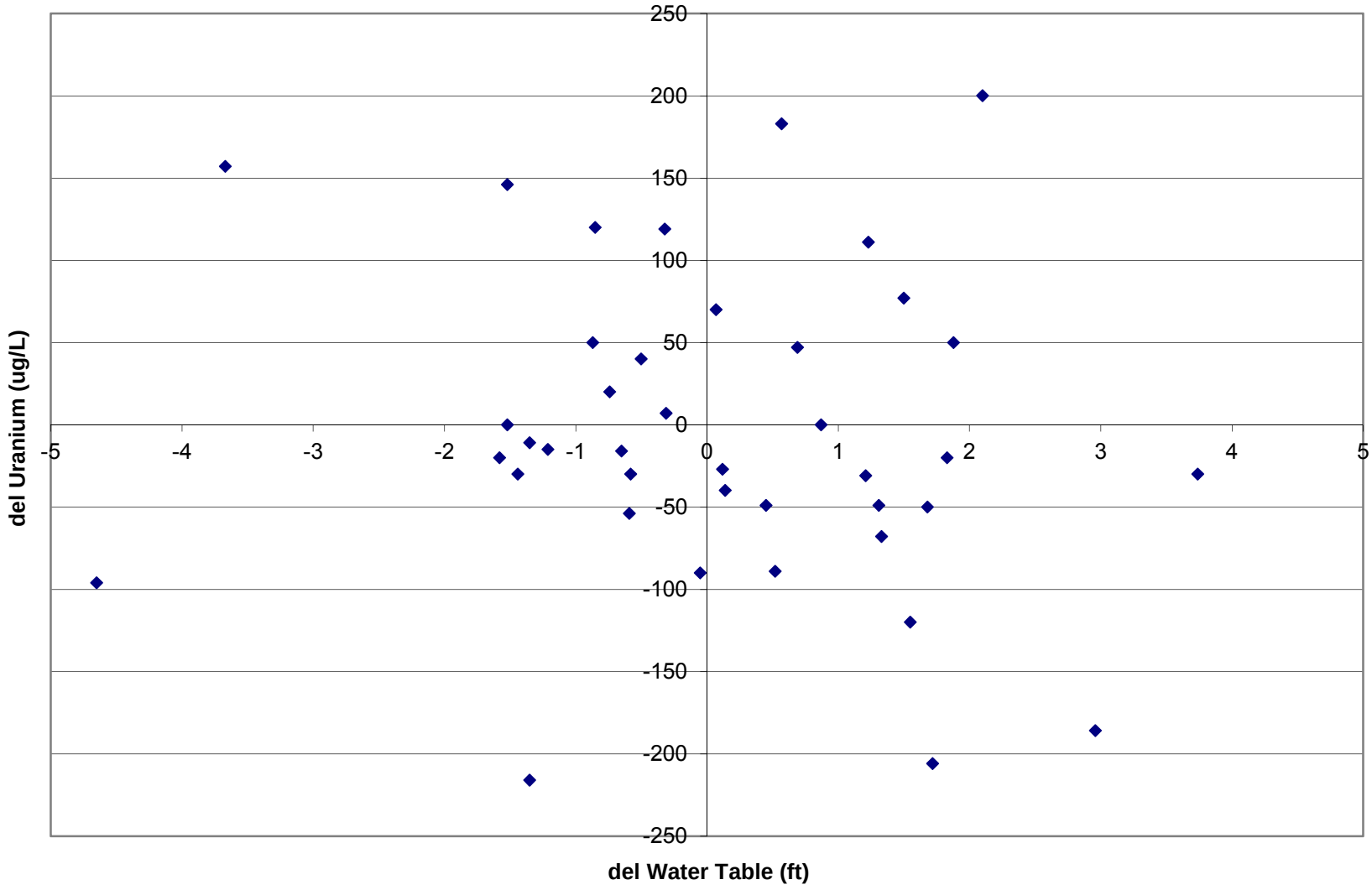

Figure 44. Uranium Concentration vs. Water Table Elevation, Well 88-85

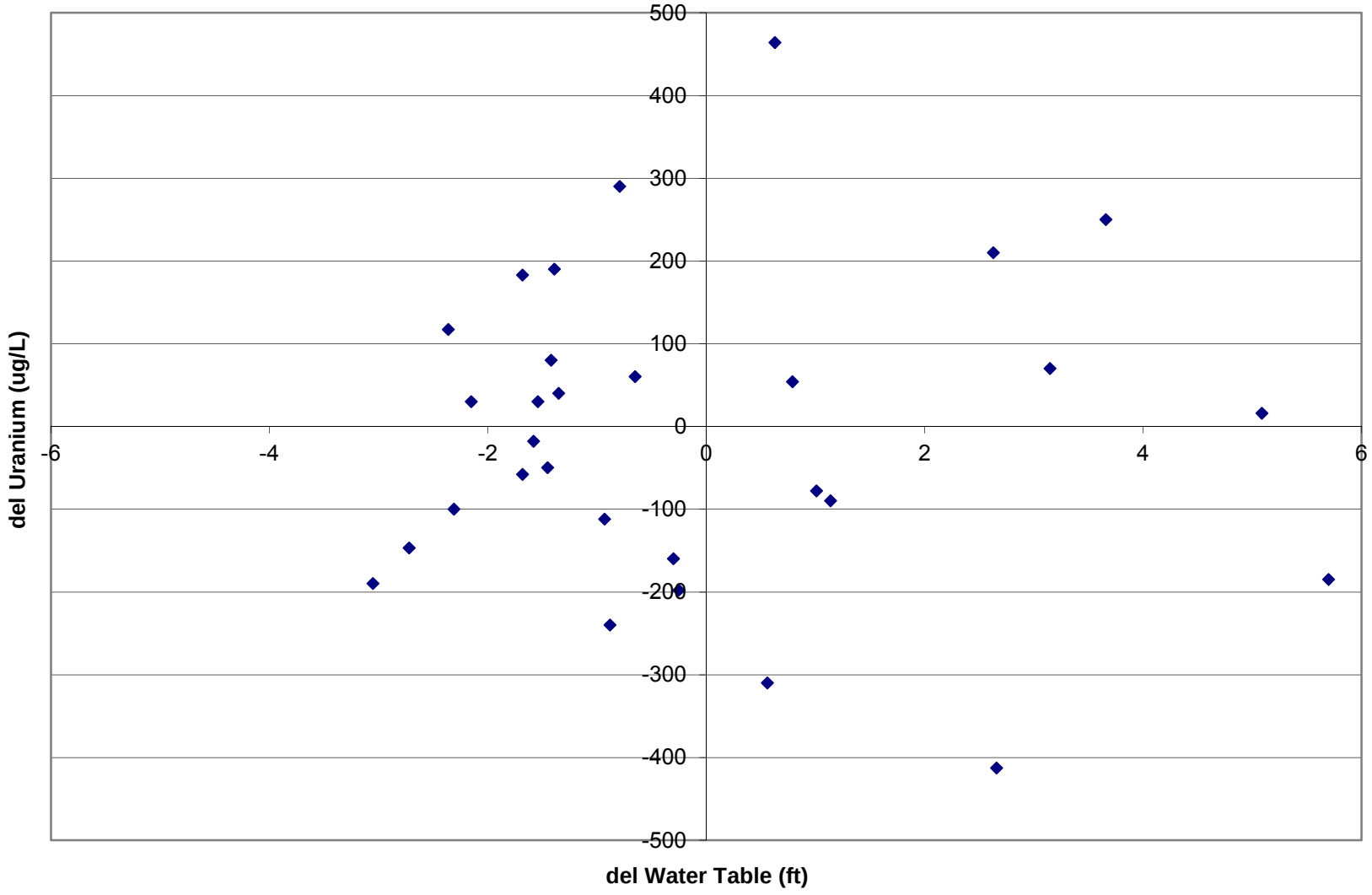

Figure 45. Uranium Concentration vs. Water Table Elevation, Well P92-06

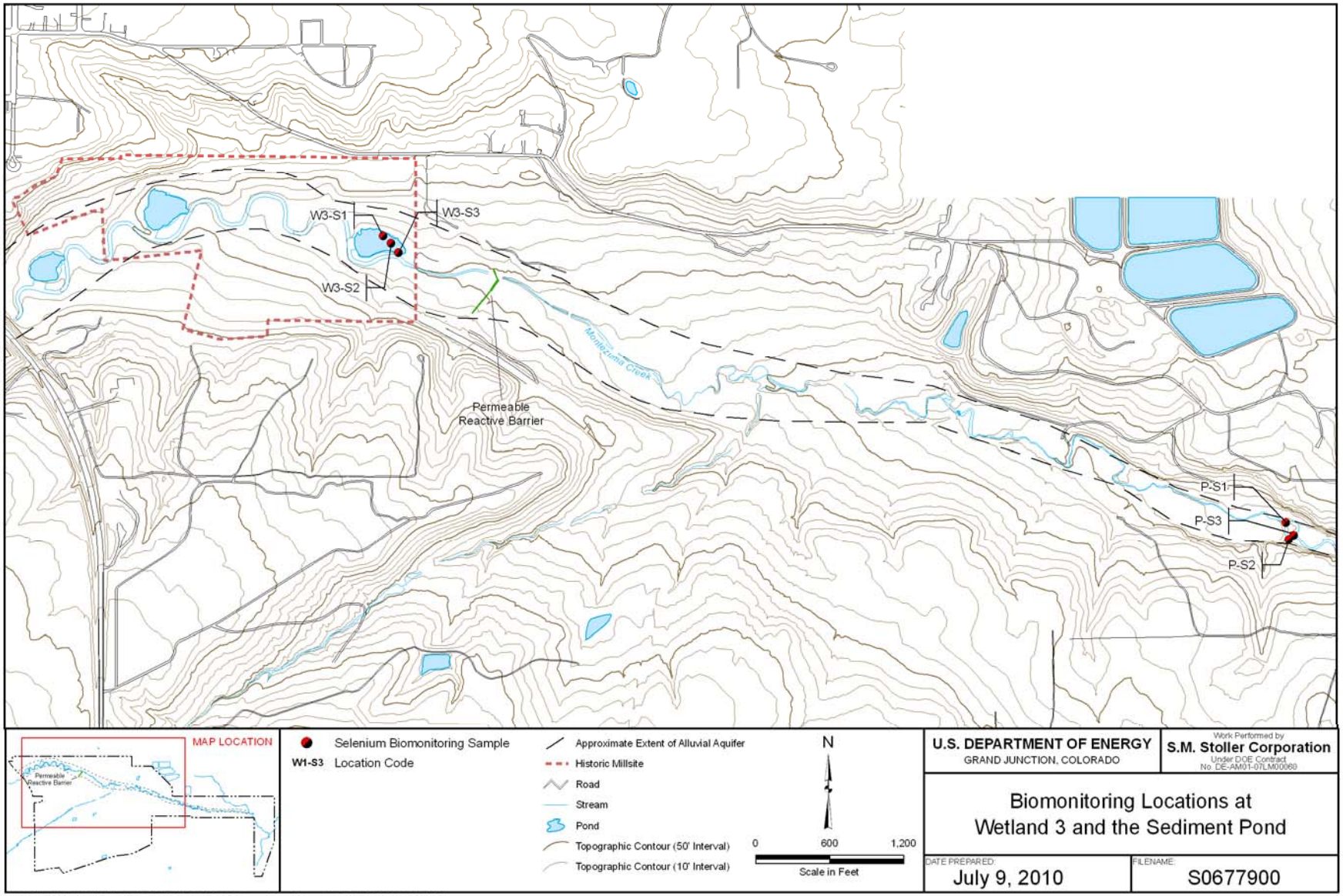

Figure 46. Biomonitoring Locations at Wetland 3 and the Sediment Pond

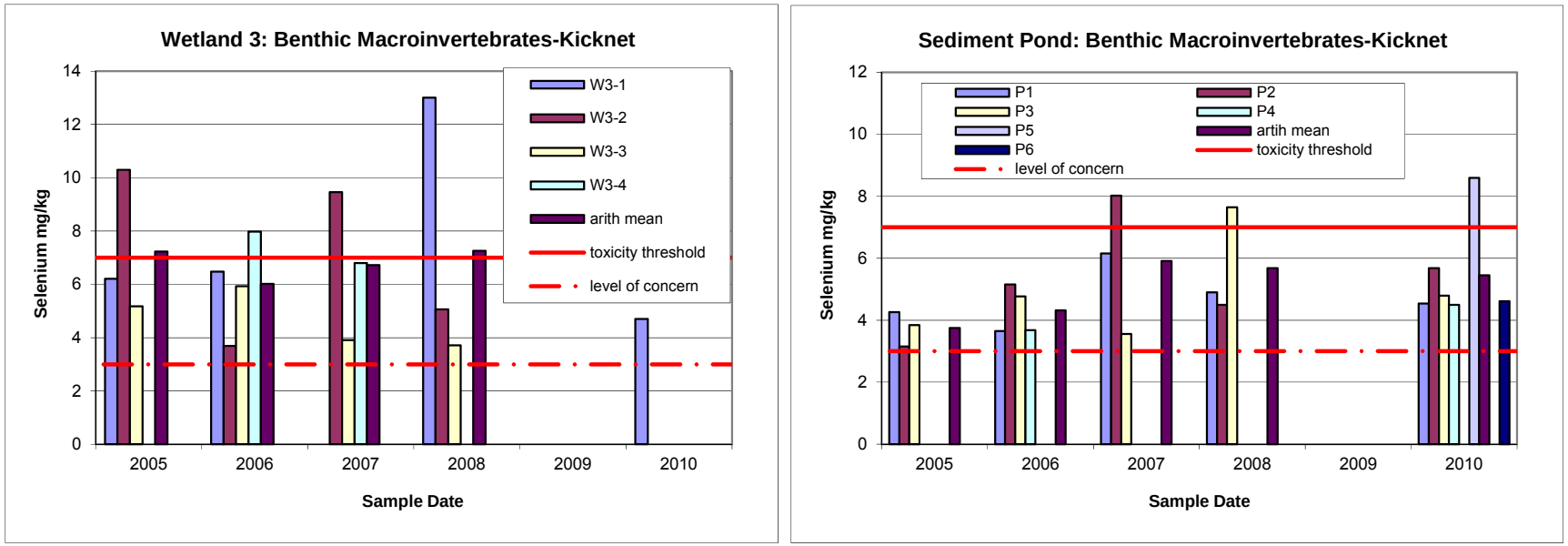

Figure 47. Selenium Concentrations in Surface Water

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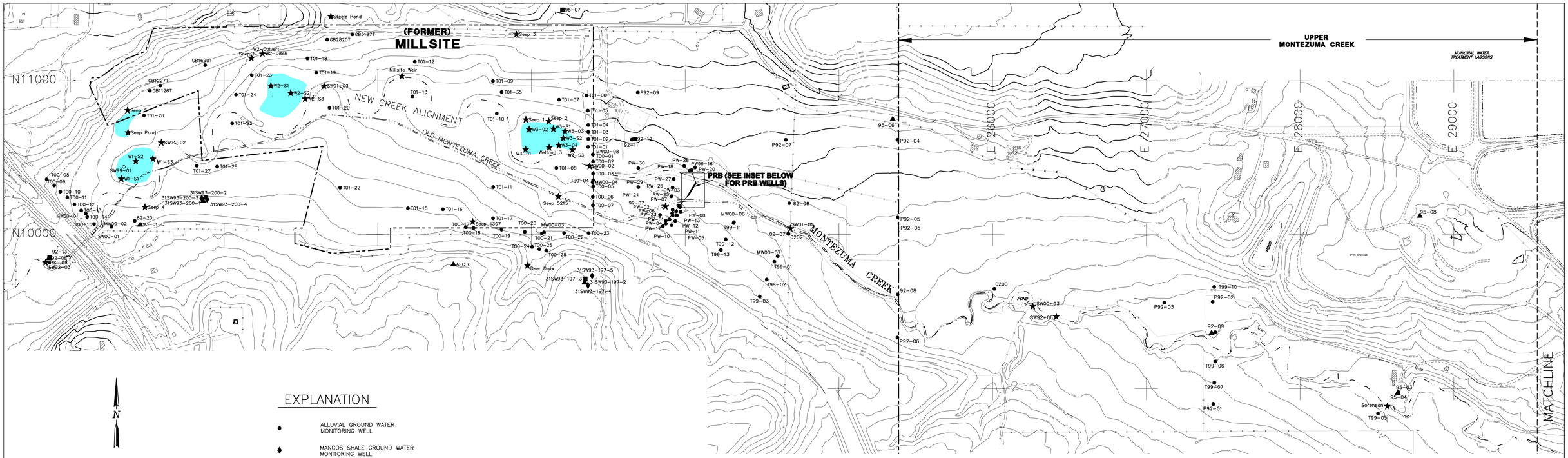
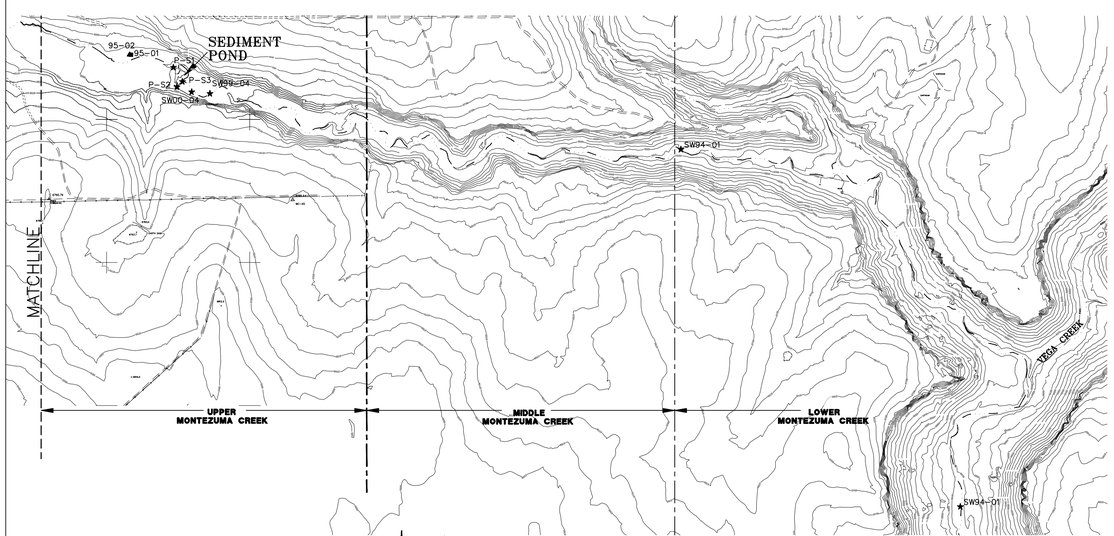


EXPLANATION

- ALLUVIAL GROUND WATER MONITORING WELL
- MANCOS SHALE GROUND WATER MONITORING WELL
- LOWER DAKOTA SANDSTONE GROUND WATER MONITORING WELL
- BURRO CANYON AQUIFER GROUND WATER MONITORING WELL
- SURFACE WATER CHEMISTRY LOCATION
- FORMER MILLSITE BOUNDARY
- NEW WETLAND AREA

N

SCALE IN FEET
300 150 0 300 600 900
CONTOUR INTERVAL 10 FEET



N

SCALE IN FEET
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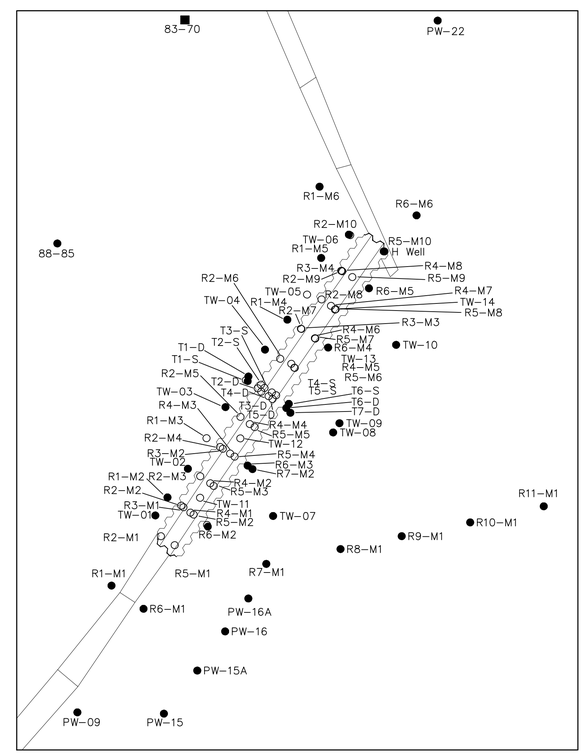
CONTOUR INTERVAL 10 FEET



N

PRB AREA INSET

SCALE IN FEET
20 10 0 20 40 60

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 GROUND WATER LOCATIONS MONITORED SINCE JANUARY 2000
DATE PREPARED: JULY 20, 2010	FILENAME: S0679900

M:\LTS\111\0038\17\007\S06799\S0679900.DWG 07/20/10 10:43am whitneyj