LMS/MNT/S06596

Monticello Mill Tailings Site
Operable Unit III

Annual Groundwater Report
May 2009 through April 2010

September 2010

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
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
IRA	interim remedial action
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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1.0 Introduction

1.1 Scope and Objectives

This report provides the annual update of post-Record of Decision environmental monitoring conducted through April 2010 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 Superfund 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 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 through April 2010 and comparison to established toxicity thresholds

This report also includes (1) a summary of the performance of the groundwater pump-and-treat system that was recently adopted as a remedy enhancement for OU III under *Explanation of Significant Difference for the Monticello Mill Tailings (USDOE) Site, Operable Unit III, Surface Water and Ground Water, Monticello, Utah* (DOE 2009a); and (2) 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 conducted in accordance with *Monticello Mill Tailings Site Operable Unit III Water Quality Compliance Strategy*, December 2009 (DOE 2009b). 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 and groundwater 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 (see Section 8.3). Section 8.4 addresses an investigation, separate from the water quality

compliance strategy, regarding potential evaporative concentration of uranium 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 Superfund Site in 1989 (CERCLIS ID Number UT3890090035). It comprises the 110-acre site of a former uranium- and vanadium-ore-processing mill (mill site) and about 1,700 acres of surrounding private and municipal property. 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 into Montezuma Creek. Some mill tailings were dispersed by wind and water, which resulted in the contamination of properties surrounding and downstream of the mill site. Figure 2 depicts the approximate current extent of uranium contamination in groundwater. Uranium is the primary groundwater contaminant in OU III because of its relatively wide distribution at high concentrations, and it is the primary contributor to potential risk to human health. For these reasons, uranium is the focus of much of the evaluation of water quality restoration presented in this report. The affected aquifer has no historical, current, or projected future use because it is low-yielding and alternate domestic sources are readily available.

2.1.1 OU III History

The MMTS ROD, signed in August 1990, designated OUs I and II for remediating radiologically contaminated soil, sediment, and debris on the mill site (OU I) and on the peripheral properties (OU II). Those remedial actions were completed in 1999. All OU I and II wastes are encapsulated at the engineered repository located on DOE property one mile south of the former mill site and operated under the LM program. 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 (IRA) 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 initially completed under the RI. Results of the IRA are documented in *Monticello Mill Tailings Site Operable Unit III Remedial Investigation Addendum/Focused Feasibility Study*, January 2004 (DOE 2004c). The updated groundwater model predicted a restoration period by natural processes of 42 years beginning in 2002. This outcome, in conjunction with source control and the finding of no actual exposure scenario with significant risk, provided the technical basis in selecting monitored natural attenuation with institutional controls as the OU III remedy.

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 had 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 and DOE also committed to evaluate options to expand the scope of groundwater capture and treatment. That evaluation is currently in progress and will be documented in a remedial design work plan (*Monticello Mill Tailings Site Operable Unit III Remedial Design/Remedial Action Work Plan for Groundwater Remediation Expansion*; in preparation). Neither the ROD nor the contingency mandates the PRB as a remedy component.

3.0 Site Description

3.1 Physical Characteristics

The MMTS is located in rural San Juan County at an elevation of approximately 7,000 feet (ft), near and within the city of Monticello in southeastern Utah. According to the 2000 census, the population of Monticello is about 2,000 residents. The MMTS occupies the valley of Montezuma Creek, a small stream that flows eastward from its origins in the Abajo Mountains, which rise to 11,000 ft about 5 miles west of the site. The climate is semiarid with four distinct seasons. Average annual precipitation is 15 inches, most of which occurs during late summer and early fall storms. Native woody vegetation is dominated by oak brush, piñon/juniper, sagebrush, and 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 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-laying fine-textured floodplain deposits. Bedrock beneath the valley floor is generally within 10 to 15 ft of ground surface, and the saturated thickness of the aquifer averages about 5 ft. Groundwater flow is west to east following the slope of the valley. Where contaminated, the alluvial aquifer is underlain by low-permeability, variably saturated bedrock of the Dakota Sandstone. Contaminated water in the alluvial aquifer does not migrate to the deeper Burro Canyon Sandstone aquifer 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 diversions from North Creek near the base of the Abajo Mountains to the municipal drinking water treatment plant. Leakage through the reservoir dam is a main source of baseflow in Montezuma Creek and recharge to the alluvial aquifer. Leakage from North Creek is also a likely source of recharge to the alluvial aquifer. Montezuma Creek is often dry at the western boundary of the mill site but gains considerable flow (100 to 200 gallons per minute [gpm]) from groundwater discharge on the mill site.

To accommodate placement of the tailings during mill operation, the eastern reach of Montezuma Creek on the mill site was rerouted in a channel constructed 200 to 300 ft south of its natural course in the center of the valley. The new channel was about 25 ft above the natural course at the east boundary of the mill site. The new channel also extended several hundred feet east of the mill site. In an early effort to stabilize the site after milling ceased, an energy dissipater was constructed at that location to prevent creek erosion 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 comprise 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 center and lowest portion of the valley.

During site restoration, artificial wetlands were constructed at three locations adjacent to the creek to provide wildlife habitat. Creek water enters each wetland by way of an infiltration gallery (cobbles and boulders) built into the upstream banks. The wetlands were excavated into bedrock and fully penetrate the alluvial aquifer. Groundwater discharge from the alluvial aquifer therefore contributes water to the wetlands through bank seepage. The eastern base of Wetland 3 rests on native alluvium, which allows some leakage to the alluvial aquifer. A downstream outlet connects each wetland to Montezuma Creek. Additional description of the wetlands is provided in Section 7.0, "Biomonitoring."

The reconstructed aquifer on the mill site is recharged by underflow from the west and by anthropogenic sources along the north margin of the valley where a conspicuous seep zone is

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

A gaining stream condition resumes 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 alluvial groundwater into Montezuma Creek. Also in this reach, the Dakota sandstone aquitard has been eroded by the creek, allowing semiconfined groundwater in the Burro Canyon aquifer to discharge to the overlying alluvium and to Montezuma Creek. These conditions form a natural hydrologic boundary that prevents eastward movement of contaminated alluvial groundwater beyond this location. The approximate location of the contact between the Dakota sandstone (Kd) and Burro Canyon sandstone (Kbc) in the valley floor is indicated in Figure 3.

The canyon remains narrow for nearly 1 mile farther east where the creek incises the Burro Canyon sandstone (with a total thickness of approximately 120 ft). Numerous seeps near the base of the canyon walls in this reach are evidence of groundwater discharge from the Burro Canyon aquifer. The canyon then widens, coincident with the transition to the 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 for human consumption. The creek has insufficient water for boating and swimming and does not support fish. Montezuma Creek is used to for limited crop irrigation: water is diverted from the creek near the center of the mill site to irrigate crops on private land immediately downstream of the mill site, and creek water is diverted for crop and pasture irrigation about 1 mile east of the mill site. The creek is accessible for livestock watering at many locations in OU III. Water retained in the municipal reservoir is used primarily for residential irrigation; however, the reservoir was recently connected with the municipal treatment plant to augment the domestic-use supply.

3.2.3 Permeable Reactive Barrier

The PRB 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 (perpendicular to flow) by about 13 ft deep by 8 ft wide (parallel to flow) and is constructed of two treatment zones. The first zone is 2 ft wide and consists of crushed gravel and 13 percent 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 downgradient 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 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 Ex Situ Remediation System

DOE operates the treatment system as directed by the ESD to enhance natural attenuation as part of the contingency remedy. The treatment system was installed in June 2005 and expanded in March 2007 as an alternate to the PRB in evaluating groundwater treatment by ZVI. It functions by pumping groundwater through two cylindrical concrete cells that contain the treatment media (ZVI and gravel mixture). Each cell, serviceable from ground surface, measures 6 ft in diameter by 6 ft in length and is set approximately 4½ ft into the ground. Groundwater is extracted at a single well located in the groundwater mound upgradient of the PRB (well EW-1 in Figure 3, PRB inset) and pumped upward, in parallel, through the two cells. A third vault (rectangular in outline in Figure 3, PRB inset) houses flow 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 12 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 2 gpm.

3.3.1 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 water levels in the extraction well, the treatment cells, and the 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 equipped 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.

3.3.2 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 established 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 to determine 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

Containments of concern (COCs) for OU III surface water and groundwater are arsenic, manganese, molybdenum, nitrate, selenium, uranium, vanadium, and gross alpha and beta activity. Table 1 lists the remediation goals for these constituents in groundwater and surface water. The groundwater goals correspond to either a maximum contaminant level as established by EPA, a maximum concentration limit from the Uranium Mill Tailings Remedial Action (UMTRA) program, or a value derived from the OU III human health risk assessment, as indicated in the table. Surface water remediation goals correspond to 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 (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 in concurrence with EPA and UDEQ.

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

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

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

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 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, is comprised 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 2010 samples; the several results for wells sampled in October 2009 are asterisked. Symbol coding identifies sample type (circles for groundwater and squares for surface water) and whether the remediation goal for the respective COC was exceeded (filled symbol) or not (open symbol) at the given location.

In the past year, each COC was present in alluvial groundwater at one or more location in excess of the respective remediation goal. Uranium remains the most widespread contaminant in groundwater, extending about 0.75 mile (4,000 ft) downgradient of the mill site, with concentrations that are greater than 10 times the remediation goal at many locations. Excepting uranium, COC concentrations generally do not exceed the remediation goal by more than a factor of 2 and are limited in distribution to the area between the former mill site and the PRB. Discussion of a special investigation to characterize uranium distribution in groundwater between the PRB and former mill site is provided in Section 8.1 of this report.

In summary:

- Arsenic contamination is limited to the area between the mill site and the PRB; concentrations are generally less than 2 times the remediation goal.
- Manganese contamination is limited to one or two locations in the central of the mill site. Maximum concentrations there occasionally reach up to 10 times the remediation goal (well T01-19, for example) but the pattern over time and location is highly variable. Manganese levels have often slightly exceeded the remediation goal at several locations immediately downgradient of the PRB. This did not occur in 2010. 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).
- Molybdenum contamination is limited to a single location in the gravel/ZVI zone of the PRB. The maximum concentration (120 μg/L) detected in April 2010 only marginally exceeds the remediation goal (100 μg/L).
- Nitrate contamination in April 2010 was limited to two locations on the north side of the aquifer, upgradient of the PRB. Nitrate contamination in this area is not uncommon and likely originates from nearby livestock feedlots. Maximum nitrate concentrations exceed the remediation goal by a factor of 2 to 3.5.
- Selenium contamination in April 2010 (Figure 8) was distributed up- and downgradient of the PRB in concentrations that ranged to approximately 2 times the remediation goal (50 μg/L). Selenium in groundwater is attributed in part to natural bedrock sources (shale deposits within the Dakota Sandstone). Selenium contamination is absent in groundwater downgradient of the contact of the Dakota Sandstone and Burro Canyon Formation.
- Vanadium contamination is limited to two locations at the eastern boundary of the mill site. The maximum concentration detected in April 2010 (350 μg/L) only marginally exceeds the remediation goal (330 μg/L).
- The remediation goal for gross alpha activity (15 pCi/L), which excludes uranium and radon, is not exceeded in OU III groundwater. Previous review of site data identified

uranium-234 and uranium-238 as the sole contributors to gross alpha activity in OU III groundwater (DOE 1998a). Although radon-222 is present throughout OU III groundwater and is a significant alpha emitter, it is intentionally expelled during sample preparation and so does not contribute to the laboratory measurement of gross alpha activity.

4.4.1 PRB and Ex Situ Treatment System

Figures 4 through 10 (see PRB 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. High manganese concentrations immediately downgradient of the PRB may be a remnant of its early operation when, as a trace constituent of ZVI, manganese 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 2010, the ex situ treatment system had treated about 14 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 35 pounds of uranium have been removed by the treatment system from the alluvial aquifer cumulatively through March 2010. Additional information on treatment system performance, including influent and effluent water quality, is provided in quarterly reports distributed by DOE.

4.4.1.1 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. 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 as established in the *Utah Administrative Code* for surface water quality protection. Operation of the treatment has complied with these allowances to date. The rise in iron concentration in April 2009 reflects the change-out of the reactive media in March 2009. Iron concentrations in the effluent have since remained between 30 and 35 mg/L. In Figure 13, uranium concentrations at the upstream and downstream sample locations (SW00-02 and 0301, respectively) are very similar, indicating that operation of the treatment system has no appreciable impact on Montezuma Creek. Discharge monitoring and performance assessment of the treatment system are provided quarterly in Federal Facilities Agreement reports.

4.5 Concentration Trends in the Alluvial Aquifer

Figures 14 through 20 illustrate the concentrations of arsenic, manganese, molybdenum, nitrate (as nitrogen), selenium, uranium, and vanadium, respectively, as they vary over time at selected 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. Laboratory column desorption and batch sorption tests conducted under the IRA indicated that arsenic is relatively immobile in the OU III groundwater environment (DOE 2001). At the few locations where arsenic contamination remains, concentrations are less than twice the remediation goal.

Figure 15 shows that manganese concentrations at most wells are relatively non-trending and 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 were location prior to source removal were erratic and were often greater than the remediation goal by a factor of 4 to 5. At well T01-19, and at the remaining wells where manganese concentration exceeds the remediation goal (see Figure 5), obvious trending is not evident. Manganese concentrations have decreased sharply at well T01-19 in the past two years from levels that often exceeded the remediation goal by a factor of 8 or more.

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 of nitrate in groundwater from 1999 through 2001 (Figure 17) is attributed to known fertilizer applications during site restoration. Dissipation of this pulse was complete by 2004. In April 2005 and 2008, order-of-magnitude increases again occurred at many 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 occurrence of nitrate downgradient of livestock operations suggest nitrate contamination since source removal is not related to past mill site operations.

Selenium concentrations in groundwater increased significantly following OU I remedial action (Figure 18), particularly in the eastern area of the mill site where an extensive area of carbonaceous, pyritic shale of the Dakota Sandstone was freshly exposed. Presumably, naturally occurring selenium in these deposits was mobilized by oxygenated groundwater of the newly reconstructed alluvial aquifer. Selenium concentrations in groundwater have generally decreased significantly since this effect of the bedrock exposure. Locations where selenium concentrations

increased in April 2005 and April 2008 (Figure 18) 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 selenium from bedrock formations or bedrock residuum similar in composition to those underlying the mill site (Wright 1999; Wright and Butler 1993; Weres et al. 1990) as first presented for OU III in DOE 2001. The increases in selenium concentration at several wells in April 2010 were not accompanied by increased nitrate concentration. The effect of increasing selenium concentrations in April 2010 increases with distance from the mill site for reasons that are not known.

Uranium and vanadium concentrations each show large initial effects of source removal (Figures 19 and 20, respectively). Vanadium concentrations have slowly decreased to the extent that the remediation goal is now exceeded at only two locations (wells T01-02 and T01-04, located at the eastern boundary of the former mill site; see Figure 10). Vanadium concentrations at these locations in April 2010 were 350 and 330 μg/L, respectively, and only marginally exceed or are equal to the remediation goal (330 μg/L). Uranium trending is highly variable depending on location. This is because uranium was relatively mobile in the aquifer and the legacy plume is now subject to a greater variety of hydrologic and geochemical effects as it spans over a much greater region of the alluvial aquifer. Analysis of concentration trending for uranium is provided in greater detail in Section 6.0.

4.5.1 Plume Expansion in the Alluvial Aquifer

The uranium contamination plume terminates between monitoring wells 92-09 and 95-03 (see Figure 3 for well locations and Figure 9 for uranium concentrations). For this reason, monitoring well 95-03 is regarded as a sentinel well to detect if the plume is advancing past the current downgradient extent. 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.

4.6 Burro Canyon Aquifer Water Quality

The Burro Canyon aquifer was sampled in the past year at wells 83-70, 92-10, and 93-01. These locations are monitored annually in October. Well 93-01 provides 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 2009[a]						
	Arsenic	Manganese	Molybdenum	Nitrate[b]	Selenium	Uranium	Vanadium
83-70	0.13	280	1.1	10U[c]	0.03U	0.02	0.05U
92-10	0.08	480	1.5	10U	0.03U	0.07	0.05U
93-01	0.38	88	0.02U	10U	0.03U	0.07	0.2
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.

4.7 Surface Water Quality

Results for the surface water samples collected in April 2010 at the routine OU III sampling locations are shown in Figures 4 through 10. Surface water sites sampled in October 2009 and April 2010 are identified in Figure 3. A special surface water quality investigation was conducted in October 2009 to evaluate the surface of uranium contamination in the creek where it flows through supplemental standards properties downstream of the mill site. Results and analysis of that investigation are presented in Section 8.3 of this report.

Uranium and selenium are the only COCs to exceed the respective remediation goal among the April 2010 samples collected from within Montezuma Creek (seeps and wetlands are addressed below in Section 4.8.1). 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 and selenium then persists through the remainder of OU III although some dilution in the creek is evident. This is a common pattern for these analytes in the creek, although selenium has only rarely exceeded the standard since 2004. Selenium concentrations recently increased at and downstream of Sorenson between October 2008 and October 2009 (see Section 4.8 for selenium concentration trending in Montezuma Creek). The source of the contamination increases at the Sorenson location is

addressed in Section 8.3 of this report. The remaining COCs for which there is no applicable surface water standard (manganese, molybdenum, and vanadium) are present in Montezuma Creek at concentrations that exceed background values but are much less than the respective groundwater standard.

A second non-routine evaluation of surface water quality was conducted in October 2009 to evaluate uranium concentrations in a private pond used to store creek water for irrigation on agricultural land about 0.75 mile downstream of the mill site. The rationale and results of that special sampling event are presented in Section 8.4 of this report. The pond sampling will be repeated at the end of the 2010 irrigation season.

4.8 Concentration Trends in Surface Water and Seeps

Figures 22 and 23, respectively, present selenium and uranium concentrations in surface water samples collected from numerous sites along Montezuma Creek since April 2000 (seeps and wetlands are addressed separately in Section 4.8.1). Ordering of the sampling sites in the legend of these figures is from west to east in the direction of creek flow. These analytes were selected for presentation because uranium contamination is most extensive in OU III groundwater and because selenium concentrations in surface water are particularly relevant to the ongoing biomonitoring task (biomonitoring scope and results are presented in Section 7.0 of this report).

Selenium concentrations trended downward for about 5 years following the exposure of fresh bedrock associated with remedial actions, as described in Section 4.5. In the past year however, selenium concentrations at several locations downstream of the mill site rose to exceed the remediation goal (locations Sorenson, SW00-04, and SW92-08 in Figure 22). Uranium concentrations coincidently increased at those locations (Figure 23). In April 2010, selenium and uranium concentrations at these locations decreased sharply (Figures 22 and 23) probably because of high flow in Montezuma Creek from spring snowmelt. Section 8.3 of this report address possible sources and trends of contamination detected at these downstream locations.

4.8.1 Groundwater Seeps

Seeps 3, 5, and 6 (see Figure 3 for seep locations) are located along the north margin of the mill site and originate from water sources above the valley of Montezuma Creek. The seeps are topographically 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. Seep 6 was reported by field personnel to be dry in April 2010.

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 Seep 3 have continued to decline since monitoring began there in 2001. Uranium concentration at Seep 6 in October 2009 was high at about 2,000 μg/L (Figure 26), which is

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 are summarized in Section 8.2 of this report.

4.8.1.1 Wetland 3

Groundwater from the alluvial aquifer discharges to Wetland 3 at Seeps 1 and 2 near 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. No COC was present in April 2010 in excess of its respective remediation goal at the routine sampling locations within Wetland 3 (locations W3-03 and W3-04 in Figure 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 Stream Flow

Results of periodic measurements of flow at several locations on Montezuma Creek since April 2000 are depicted in Figure 27. The ordering of the flow measurement locations in the legend is from west to east, parallel to the direction of flow. The transitional reach identified in the figure refers to the segment of Montezuma Creek between wells 0200 and 92-09 (see Figure 3 for well locations) where the upper bedrock changes from the Dakota sandstone to the Burro Canyon sandstone 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 baseflow 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. Creek flow has since returned to approach pre-drought levels.

In April 2005, following abundant winter and spring snow, measured creek flow was about 2,000 gpm (April 2005 results are off-scale in Figure 27). City officials reported a short-term

peak flow in Montezuma Creek in spring 2005 of 30,000 gpm when deliberate releases from the reservoir occurred and from anomalously high flow in North Creek. The spring 2005 snowpack in the Abajo Mountains was 250 percent above normal. Recorded flows were approximately 3,000 gpm (off-scale in Figure 27) during the April 2008 monitoring event following another year of abundant winter and spring snow. 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.

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 greater than 2 ft and is also sensitive to larger-scale climatic effects. For example, following the low-water years of 1999 through 2003, water levels responded to above-average precipitation in 2005 by rebounding nearly 10 ft to peak levels in April 2005. This response was then followed by water table declines of similar magnitude into 2007 and 2008. The water table recorded in April 2010 is relatively high compared to historic measurements, likely because of rapid spring runoff of above-average mountain snowpack and deliberate releases from the reservoir in spring 2010.

On the mill site, the water table does not fluctuate as widely as observed at 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 water table response to abundant moisture in spring 2005, 2008, and 2010 was relatively mild (2 ft or less). The drain effect of the creek on the aquifer may dampen water fluctuations in this area by promoting 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.

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). High 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 that groundwater extraction from well EW-1 has not significantly reduced the groundwater mound at 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 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. The water table in the mounded area was about 2 ft below ground surface in April 2010.

5.3 Burro Canyon Aquifer Water Levels

Well pairs 95-01/95-02 and 95-03/95-04 are the easternmost groundwater monitoring locations in OU III (see Figure 3 for well pair locations). Wells 95-01 and 95-03 are completed in the alluvial aquifer and wells 95-02 and 95-04 are completed in the upper 20 ft of the Burro Canyon aquifer. Groundwater is not contaminated at 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). Groundwater withdrawal from the Burro Canyon aquifer by the city of Monticello during 2001 to 2004 did not affect the direction or magnitude of this gradient at these locations, nor was the hydraulic head at 95-08 significantly affected (Figure 33). This Burro Canyon well (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 an indication 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.

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) distinguished by contaminant distribution and hydrogeology. 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 (see Appendix G) for the corresponding wells are similarly averaged, normalized to calendar date (model time zero is October 2002), and graphed along with the observed averages, as shown in Figures 35 and 36. In these figures, solid lines represent 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 in 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 (DOE 2007a).

6.3 Summary of Restoration Progress

Region 1 Obvious trending is not evident at the wells in this region (Figure 37). This implies a cleanup time in excess of the established 42-year period. Uranium persists at concentrations between about 100 and 200 µg/L. Only well T01-19 is recognized as trending downward (Figure 37). Well T01-12 did not produce sufficient water for sample collection in April 2010 after the purge process was completed.

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 of groundwater recharge at the eastern end of Wetland 3 and a losing stream condition.

Region 3 Three of five wells exhibit a slight downward trend, and the remaining two wells (92-07 and PW-17) show apparent upward trends (Figure 39). Wells 92-07 and PW-17 are within the area of the aquifer that was investigated in detail in April 2009 to evaluate lack of restoration progress in this area. A detailed analysis of the investigation was presented in the 2009 annual groundwater report (DOE 2009c). A summary of the findings is provided in Section 8.1 of this report. Trends at wells 92-11, 88-85, and PW-28, which are located in the portion of Region 3 that is north of Montezuma 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. Upward trending is expected to occur in this region as the groundwater hot spot in Region 3 moves eastward.

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

6.3.1 Uranium Trending and Hydrologic Factors

Figures 42 to 45 depict the variation of uranium concentration with water level at wells T01-01, 92-11, 88-85, and P92-06, respectively. Each data point represents the difference in uranium concentration ("del uranium") and in water level ("del water table") between successive monitoring events. There is no apparent correlation between these variables at 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, which were designed as physical analogs of the OU III groundwater environment, uranium was rapidly removed from the aquifer substrate through the first several pore volumes. Uranium concentrations in the column effluent then stabilized at between 100 and 200 µg/L through the passage of an additional 20 to 25 pore volumes of water (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. Biomonitoring activities are conducted in accordance with the ROD and the Post-ROD Monitoring Plan (DOE 2004a and DOE 2004b), and in consultation with the Biological Technical Assistance Group (BTAG), consisting of representatives from the U.S. Fish and Wildlife Service, EPA, UDEQ, and DOE. Biomonitoring, which focuses on wetland habitat in OU III, has been implemented in phases since 2004; the scope is determined annually in consultation with BTAG, following a review of the previous year's results. Field activities are then implemented through program directives prepared by DOE. 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.

Until 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). In 2007 and 2008, biomonitoring focused only on Wetland 3 and the Sediment Pond, where selenium levels remain elevated. Biomonitoring was not conducted in 2009 but resumed in June 2010. Results of biomonitoring conducted in 2010 will be included in the 2011 annual groundwater report and may be distributed to the BTAG at an earlier date (see Section 7.5 for biomonitoring scope in 2010). The remainder of Section 7.0 summarizes the results of OU III biomonitoring cumulatively through 2008 and describes the scope of 2010 biomonitoring and the proposed scope of biomonitoring beyond 2010. Tabulated results for selenium in biotic and abiotic samples are provided in Appendix H.

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 Surface Water and Sediment Results

Surface water and sediment samples were collected and analyzed for selenium in Wetlands 1 and 2 between October 2004 and April 2007. All surface water samples were below the level of concern (2 µg/L) since October 2005, and all sediment samples were well below the level of concern (2 mg/kg) during the entire monitoring period (Figures 47 and 48, respectively). Because selenium benchmarks have not been exceeded in Wetlands 1 and 2 (in DOE 2005a, DOE 2007b, and DOE 2007c), monitoring at these wetlands was discontinued in 2007.

In Wetland 3, samples were collected between October 2004 and April 2008. Selenium concentrations in surface water were generally below the level of concern except at location W3-S1 (see Figure 46 for sampling location), which is near the point where Seep 2 discharges contaminated groundwater into the wetland. The groundwater expressed at Seep 2 contains selenium at concentrations of about 50 µg/L. Selenium concentrations at Seep 2 exhibit a downward trend (Figure 25). The geometric mean for selenium in surface water in Wetland 3 remained near the level of concern, including the two most recent events (April 2007 and April 2008) when outlier values of selenium were detected at W3-S1, which is also referred to as the inlet location (see Figure 47). The arithmetic mean (not shown) on those occasions slightly exceeded the toxicity threshold in 2008 (5 µg/L) because of the bias caused by the high selenium concentration in samples collected at the inlet location. Trending of the geometric mean of selenium concentration is not apparent.

The inlet sampling location (or W3-S1) was selected to monitor the maximum concentration of selenium present in Wetland 3 surface water. The occasional wide variation in selenium concentration in the inlet sample is thought to depend on water level in the wetland. At relatively high water level, a sample can be collected closest to the point of groundwater discharge at Seep 2. This results in less dilution by creek water present in Wetland 3 than on occasions when a sample is collected farther from the seep because of low water level. The quantity of water (uncontaminated) from Montezuma Creek that enters Wetland 3 greatly surpasses that contributed by Seep 2.

Selenium sediment concentrations in Wetland 3 have remained below the level of concern except on occasion at the inlet location, where the toxicity threshold (4 mg/kg) was exceeded on two occasions (Figure 48). Arithmetic and geometric mean concentrations of selenium remained below the level of concern during the entire monitoring period with no apparent trending (Figure 48). As with surface water, selenium sediment concentrations are typically highest and more variable at the inlet location, likely reflecting sample collection proximity to Seep 2 at different times as a function of water depth in the wetland.

Samples were collected at the Sediment Pond between October 2004 and April 2008. Selenium levels in surface water were all higher than the level of concern but below the toxicity threshold (Figure 47). An early upward trend in the geometric mean for surface water appears to have leveled off since 2006. Most sediment samples fell below the level of concern. Obvious trending in selenium concentration in the Sediment Pond sediments is not apparent (Figure 48). Detailed results for both Wetland 3 and the Sediment Pond are in DOE 2005a, DOE 2007b, DOE 2007c, DOE 2008a, and DOE 2008b.

7.3 Macroinvertebrate Results

Aquatic macroinvertebrates were sampled at Wetlands 1 and 2 in 2005 using kicknets for juvenile forms and light traps for adult forms. Only kicknet samples yielded organisms, which were analyzed for selenium. Arithmetic mean values were below the level of concern (3 mg/kg) in both wetlands (upper-left graphic in Figure 49), so sampling was discontinued in these wetlands. Detailed results are in DOE 2005a.

In Wetland 3, macroinvertebrates were sampled with a kicknet from 2005 through 2008. Individual samples all exceed the level of concern (see upper-right graphic in Figure 49). The geometric mean for selenium in macroinvertebrate tissue remained below or slightly in excess of the toxicity threshold during the monitoring period. In 2005 and 2008, when the arithmetic mean slightly exceeded the toxicity threshold, a single sample of relatively high selenium biased the mean value. In both cases the value in question was located closest to Seep 2 (see Section 7.2). The variation in the geometric mean over time indicates no obvious trending at Wetland 3.

Figure 49 also shows selenium concentrations from kicknet samples collected in the Sediment Pond between 2005 and 2008 (lower-left graphic in Figure 49). Most samples fell between the level of concern and toxicity threshold. Arithmetic means were less than the toxicity threshold. Although the geometric mean for selenium in macroinvertebrate tissue has remained below the toxicity threshold, a slight upward trend may be evident at the Sediment Pond.

At the Sediment Pond, both kicknet and Hester-Dendy (artificial substrate) samplers were used to collect macroinvertebrates from 2005 through 2008. Hester-Dendy samplers yielded few organisms with low biomass between 2005 and 2007 (DOE 2008b). No organisms colonized the Hester-Dendy samplers in 2008. Results of samples collected with the artificial substrate devices are shown in Figure 49 (lower right graphic).

7.4 Avian Survey Results

Avian surveys, each with a different scope, were conducted in 2005, 2006, and 2008. The 2005 survey (detailed in DOE 2005b), focused on all observed bird species at Wetlands 1, 2, and 3 and the Sediment Pond. Most species identified during the 2005 survey 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. Except for transient sightings, no sensitive species were observed. A black-throated grey warbler and an olive-sided flycatcher, both species of concern, were each observed once near the Sediment Pond. Migrating white-faced ibis were also observed in the wetlands.

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

The main purpose of the 2008 surveys was to determine whether federally protected, state-of-Utah-listed, or other avian species of concern not identified in previous surveys exist on or near Wetland 3 or the Sediment Pond. Comprehensive avian surveys were conducted in 2008 at these locations, as in 2005, by surveyors trained and experienced in the identification of threatened, endangered, and sensitive bird species. Eight field surveys were conducted between May 2 and August 12, 2008. In addition, five willow flycatcher surveys were conducted between May 22 and July 16, 2008. Migrant willow flycatchers were observed near the Sediment Pond in May and June, but additional surveys revealed that they were not nesting in the area. The subspecies

of willow flycatcher was not identified, but southwest willow flycatchers (federally listed as endangered) can potentially be observed in the area. A migrating bobolink, a state-listed species, was observed once near Wetland 3. Two Birds of Conservation Concern (as listed by the U.S. Fish and Wildlife Service) were each observed once: a black-throated grey warbler, and a Virginia's warbler. A pair of northern harriers, also a Bird of Conservation Concern, was observed throughout the summer at Wetland 3, where they nested and fledged three young. As in 2005 and 2006, the most common bird species at Wetland 3 was the red-winged blackbird, and cliff swallows were most common at the Sediment Pond. Detailed results of the surveys are in DOE 2008c.

7.5 Future Scope of Biomonitoring

The scope of biomonitoring conducted in 2010 (June 16−18, 2010) consisted of the collection of benthic macroinvertebrates and co-located surface water samples for analysis of selenium. Sample collection was conducted at Wetland 3 and the Sediment Pond and at background locations on Montezuma Creek and Verdure Creek. DOE will consider conducting an avian survey in 2011 if anomalously high selenium is detected in benthic macroinvertebrates in 2010. This determination is pending review and interpretation of the 2010 data. These data were not available for inclusion in this report. Results of biomonitoring conducted in 2010 will be included in the 2011 annual groundwater report and may be distributed to the BTAG at an earlier date in a separate report.

DOE will use the results from the background locations sampled in 2010, in conjunction with background data obtained in 1995 and 1996 during the OU III baseline ecological risk assessment, to determine if selenium concentrations in environmental media are comparable to background and pre-remediation conditions. DOE will also further analyze selenium trending in environmental media for comparison to criteria established in the ROD by which biomonitoring may be discontinued. The trending analysis and comparison to background conditions will be documented in the 2011 annual groundwater report and in a separate document if determined appropriate by the BTAG.

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

This section presents the results of activities conducted in 2009 that are outside of the scope of the routine OU III water quality monitoring program. These activities were conducted to (1) characterize an area of elevated uranium in groundwater located immediately east of the former mill site (see Section 8.1), (2) evaluate the source of uranium contamination and groundwater at a seep located on the north side of the former mill site (Seep 6, see Section 8.2), and (3) evaluate the source of uranium contamination in Montezuma Creek downstream of the former mill site where the remediation goal is exceeded (see Section 8.3).

These activities were conducted in accordance with *Monticello Mill Tailings Site Operable Unit III Water Quality Compliance Strategy*, December 2009 (DOE 2009b) and complete the field-related scope of work identified in Table 1 of that document excepting the evaluation of pump-and-treat remediation. Evaluating pump-and-treat remediation will be ongoing once the planned expansion of the existing remediation system is implemented. Details to expand groundwater remediation are provided in *Monticello Mill Tailings Site Operable Unit III*

Remedial Design/Remedial Action Work Plan for Groundwater Remediation Expansion (in preparation).

An additional investigation of surface water quality reported in this section was conducted independent of the water quality compliance strategy and ESD. As addressed in Section 8.4, surface water in an irrigation pond in OU III was sampled to determine if the water posed an environmental risk through evaporative concentration of contaminated creek water, a source of the water in the pond. The potential risk was first identified in 2008 following a land and water use change by a property owner.

8.1 Groundwater Contamination Investigation

A follow-up activity to the 2009 ESD for OU III and the water quality compliance strategy was conducted in April 2009 to more fully characterize the uranium plume and groundwater setting in the area between the PRB and mill site than was accomplished during the RI and the design phase of the PRB demonstration project. The April 2009 study was also conducted to determine if a continuing source of contaminated groundwater exists in the southeast area of the former mill site. These goals were identified in because restoration progress in this area of relatively high uranium contamination departs significantly from the predictions of the OU III groundwater model. This area was also identified as potentially feasibility for expanding the current scope of active groundwater remediation because contaminant levels and the hydrologic boundaries of the area (Montezuma Creek, PRB, and bedrock margin of the aquifer) could be well defined by the investigation. The methods and results of the study are reported in detail in the 2009 annual groundwater report (DOE 2009c) and in *Monticello Mill Tailings Site Operable Unit III Remedial Design/Remedial Action Work Plan for Groundwater Remediation Expansion* (in preparation).

The April 2009 study, as documented in DOE 2009b, indicates that uranium contamination in this region is greater than previously characterized and so may account for the lack of restoration progress in this region. The results indicate that expansion of the groundwater treatment system between the mill site and PRB is feasible with regard to hydrogeologic conditions and uranium distribution. The maximum saturated thickness and uranium concentrations occur beneath the central portion of the floodplain. In this area, the water table is shallow (less than 10 ft), ground surface and bedrock surface topography is flat, and the base of the aquifer is uniformly about 15 ft below ground surface. These conditions suggest that the greatest volume of contaminated water and the greatest mass of contamination in this area is readily accessible for extraction. Results of the April 2009 study indicate further 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. Surface water was not expressed at the location of Seep 6 prior to mill site remediation. It is likely that OU II surface remediation removed a thin veneer of soil and shale residuum to expose shallow, pre-existing groundwater at this location.

High uranium concentrations at Seep 6 prompted DOE to investigate the source of the contamination and the source of the water to the seep in 2009. Following that investigation, DOE reported in detail that the likely source of contamination was mill tailings or ore present in the backfill of a buried irrigation water line (about 7 ft deep) or in an adjacent, more deeply buried, sanitary sewer line (20 ft deep) (DOE 2009b). These water utilities are located on private property within several hundred feet to the northwest of Seep 6. The locations of the utilities are provided in Figures 57 and 58 of the 2009 annual groundwater report (DOE 2009c).

Radiological contamination in the 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. The highest levels of contamination are associated with the sewer pipe backfill. This potential source of contamination is expected to remain in place until the water utilities are accessed for maintenance or replacement. Improved water quality at Seep 6 would depend on the extent and location of source removal in the corridor. The source of uranium contamination at Seep 6 is analogous to that of the uranium plume in OU III alluvial aquifer groundwater because in each case, residual uranium in the mill tailings (or ore) is available for release to the hydrologic system upon contact with percolating water.

The shallow groundwater expressed at Seep 6 is not associated with the alluvial aquifer. The water instead emanates from Mancos Shale that is exposed along the hill side. 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.

The source of water expressed at Seep 6 is suspected to be leakage from the sewer line or the irrigation line. Leakage from the sewer line is more likely the source because flow at Seep 6 is perennial whereas flow in the irrigation line is not. Leaking water from either of the utilities is suspected to become contaminated through contact with the backfill material (most likely in the sewer corridor). The contaminated water then flows southeast by way of fracture flow in the upper weathered zone of the Mancos Shale. The impact of Seep 6 on water quality in the alluvial aquifer, Wetland 2, and Montezuma Creek appears to be minimal. Relatively low-level uranium contamination in the alluvial aquifer in the area of Wetland 2 is likely associated with contamination derived from the Carbonate Tailings Pile that formerly overlaid this portion of the alluvial aquifer.

An additional study regarding the source of water and contamination at Seep 6 is not expected. DOE instead will manage radiologically contaminated material encountered in any excavation associated with maintenance or repair of the water utilities within the supplemental standards corridor in accordance with *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 exceeded the standard upstream of the Sorenson location but were also observed to similarly rise at the Sorenson location.

The historic (see DOE 1998a) and current trend is for uranium to decrease downstream of the Sorenson but to remain above the standard through the remainder of OU III. Concentrations decrease below the Sorenson location because of dilution caused by the discharge of uncontaminated groundwater from the Burro Canyon aquifer. Dilution does not occur below the contact between the Burro Canyon sandstone and the low-permeable mudstones of the Morrison Formation. Dilution occurs below the confluence with Vega Creek, a tributary to Montezuma Creek approximately 1.2 miles downstream of the Sorenson location, when flow is present in Vega Creek (see Figure 50 for location of Vega Creek). Additional discussion of creek and groundwater hydrology affecting contaminant levels in the creek is presented under Section 8.3.2.

DOE increased the scope of surface water monitoring for the October 1997 event to evaluate the cause for the increase in uranium in Montezuma Creek apparent at the Sorenson location. That event focused on collecting samples from the creek downstream of known localized areas of residual mill tailings in stream bank and floodplain deposits. The October 1997 surface water study occurred before the selective removal of contaminated soil and sediment in 1998 and 1999 along this section of the creek, designated as Upper, Lower, and Middle Montezuma Creek (see Figure 50 for designations). Section 8.3.1 further addresses soil and sediment remediation along Montezuma Creek. Results of the October 1997 monitoring event, reported in DOE 1998c, did not identify a correlation between localized deposits of mill tailings and increased uranium concentration in the creek. The results did suggest that the reach upstream of the Sorenson location between locations SW92-06 and SW97-01 (see Figure 50 for monitoring locations) was the likely region of uranium input to the creek.

8.3.1 Montezuma Creek Surface Remediation

Figure 50 shows the soil and sediment cleanup levels for the respective reaches of the creek. Remediation levels in Upper and Lower Montezuma Creek were based on scenarios of human health risk from gamma dose at ground surface. Upper Montezuma Creek was remediated to a more stringent standard (35 microRoentgens per hour [µR/hr]) because of a greater potential for human activity and therefore greater radiation exposure potential. Middle Montezuma Creek was not remediated because of its pristine value compared to potential human health risk. In Lower Montezuma Creek, areas to be remediated were defined by surface exposure rates of 80 µR/hr. Contaminated soil and sediment within these prescribed surface exposure rates areas in Upper and Lower Montezuma Creek were removed by excavation until the 15 pCi/g Ra-226 subsurface cleanup standard was achieved (this cleanup standard was not achieved at some locations). Lateral excavation beyond the respective ground-level exposure criteria was not pursued because the remediation was directed by a supplemental clean up standard based on the ground-level exposure rate (DOE 1999). Excavations were backfilled with clean material.

8.3.2 October 2009 Creek Sampling

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. Figure 50 shows the locations of the October 2009 surface water sampling locations and the corresponding concentration of uranium detected at that time in the creek within the respective reaches of the creek where supplemental cleanup standards were applied. Sample locations unique to the October 2009 events are prefixed SW10 (SW10-01 to SW10-07). Several of the locations sampled in 2009 were sampled in the 1997 study and are prefixed SW97 (SW97-01 to SW97-05). Locations SW92-06 and SW92-07, sampled in October 2009, were within the OU III monitoring network through 2000 but were discontinued because of access limitations (SW92-06) or data redundancy (SW92-07). Locations 0303, 0304, and 0305, sampled as part of the irrigation pond investigation reported in Section 8.4, are shown in Figure 50 because the data are relevant to evaluating uranium influx to the creek. The remaining locations shown in Figure 50 are within the established OU III monitoring network (SW01-02, SW01-03, SW00-02, SW01-01, SW01-02, Sorenson, SW00-04, SW92-08, SW92-09, and SW94-01).

8.3.2.1 Upper Montezuma Creek

Figure 50 shows that uranium concentrations in Montezuma Creek in October 2009 were low in the non-supplemental standards reach immediately downstream of the mill site (for example, locations SW00-02 and SW01-01). Uranium concentrations are then observed to increase significantly in Upper Montezuma Creek at the same locations identified in Section 7.2 where selenium concentrations increase (for example locations SW10-01, SW92-06, and 0303). As addressed in Section 7.2, Montezuma Creek transitions from a losing to a gaining stream in this area, as recognized in OU III creek flow measurement data and from direct field observation. The only source of increased creek flow in this area is the discharge of groundwater from the alluvial aquifer. Seasonally there is often little or no water in the creek upstream of this area. Groundwater discharge in this area can account for the observed increase in uranium in surface water because sufficient uranium is present in the local groundwater (350 to 690 µg/L in October 2009, wells P92-06 and 92-08, respectively; see Figure 50) compared to local surface water concentrations (430 and 130 µg/L, respectively, at locations SW10-01 and SW92-06), and because of the local baseflow contribution from groundwater discharge.

Concentrations of uranium then show a gradual decrease in the downstream reach of Upper Montezuma Creek. The decrease of uranium in the downstream reach of Upper Montezuma Creek is attributed to the discharge of uncontaminated groundwater from the Burro Canyon aquifer and subsequent dilution in the alluvial aquifer and in Montezuma Creek. In this reach, the upper bedrock transitions from the Dakota sandstone aquitard to the Burro Canyon aquifer. The approximate contact between the Dakota aquitard and the Burro Canyon aquifer is shown in Figure 50 as the Kd/Kbc contact. This dilution effect is apparent through the remainder of Upper Montezuma Creek and through Middle Montezuma Creek.

8.3.2.2 Middle Montezuma Creek

Figure 50 illustrates further that uranium concentration in the creek did not increase through Middle Montezuma Creek, where no soil or sediment remediation occurred. Furthermore, the

special sample locations for October 2009 in Middle Montezuma Creek (SW97-03 and SW10-05) were situated at known locations of residual mill tailings but showed no increase in uranium concentration.

8.3.2.3 Lower Montezuma Creek

Most of the sampled locations in Lower Montezuma Creek were intentionally situated adjacent to or immediately downstream of unremediated hot spots. Concentrations of uranium in Montezuma Creek were shown to be unaffected by this sampling strategy, remaining nearly consistent at about 180 µg/L through Lower Montezuma Creek. These results again suggest that the residual mill tailings are not a significant source of uranium to the creek. Dilution of uranium in the creek is not expected in Lower Montezuma Creek above the confluence of Vega Creek because there are no additional surface water inputs and because the upper bedrock (low-permeability mudstones of the Morrison Formation) is non-water bearing or draws water downward from the alluvium or creek (see Figure 50 for the approximate location of the Burro Canyon/Morrison Formation contact [Kbc/Jm]). Vega Creek (see Figure 50) was dry during the October 2009 sampling event and so there is no evidence of dilution at location SW94-01.

8.3.3 Summary of October 2009 Creek Sampling

The October 2009 results indicate that there is no apparent correlation between residual soil and sediment contamination and elevated uranium concentration in Montezuma Creek. 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. Groundwater contamination in this portion of the aquifer is considered to be contiguous with the remnant uranium plume that originated at the former mill site before remedial action at the mill site (source removal) was completed. Residual mill tailings in sediments and soil adjacent to the creek are not indicated to be a significant source of uranium to the 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 or is remediated.

Selenium, molybdenum, and nitrate exhibit a similar pattern of increased concentrations at the identified groundwater discharge zone, with subsequent dilution downstream by Burro Canyon groundwater discharge. Concentrations of these COCs also show no apparent contribution by residual mill tailings. Nitrate may not be a reliable indicator of the presence or absence of residual mill tailings because it is not expected to remain with tailings that were transported in the creek; also, agricultural sources of nitrate are present locally. Selenium and molybdenum would not be similarly affected; however, selenium concentrations in groundwater and surface water may be influenced by local bedrock sources. Arsenic, manganese, and vanadium have no effect on water quality in Montezuma Creek at the discharge location because local groundwater concentrations are too low. These COCs also show no impact to water quality associated with contaminated deposits in Upper, Middle, and Lower Montezuma Creek.

8.4 Surface Water Diversion to Irrigation Pond

DOE, in consultation with EPA and UDEQ, collected two water samples from an irrigation pond on a peripheral property (property MP-00990-CS) located downstream of the mill site on October 6, 2009, 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 consists of diverting water from Montezuma Creek by the landowner 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 run-off, 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 (see Figure 50). 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 50). Evaporative concentration of uranium in Adams Pond is therefore not significant and so 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 extended to 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. The pond will be sampled again in mid-summer 2010 during the later part of the irrigation season to confirm the October 2009 results.

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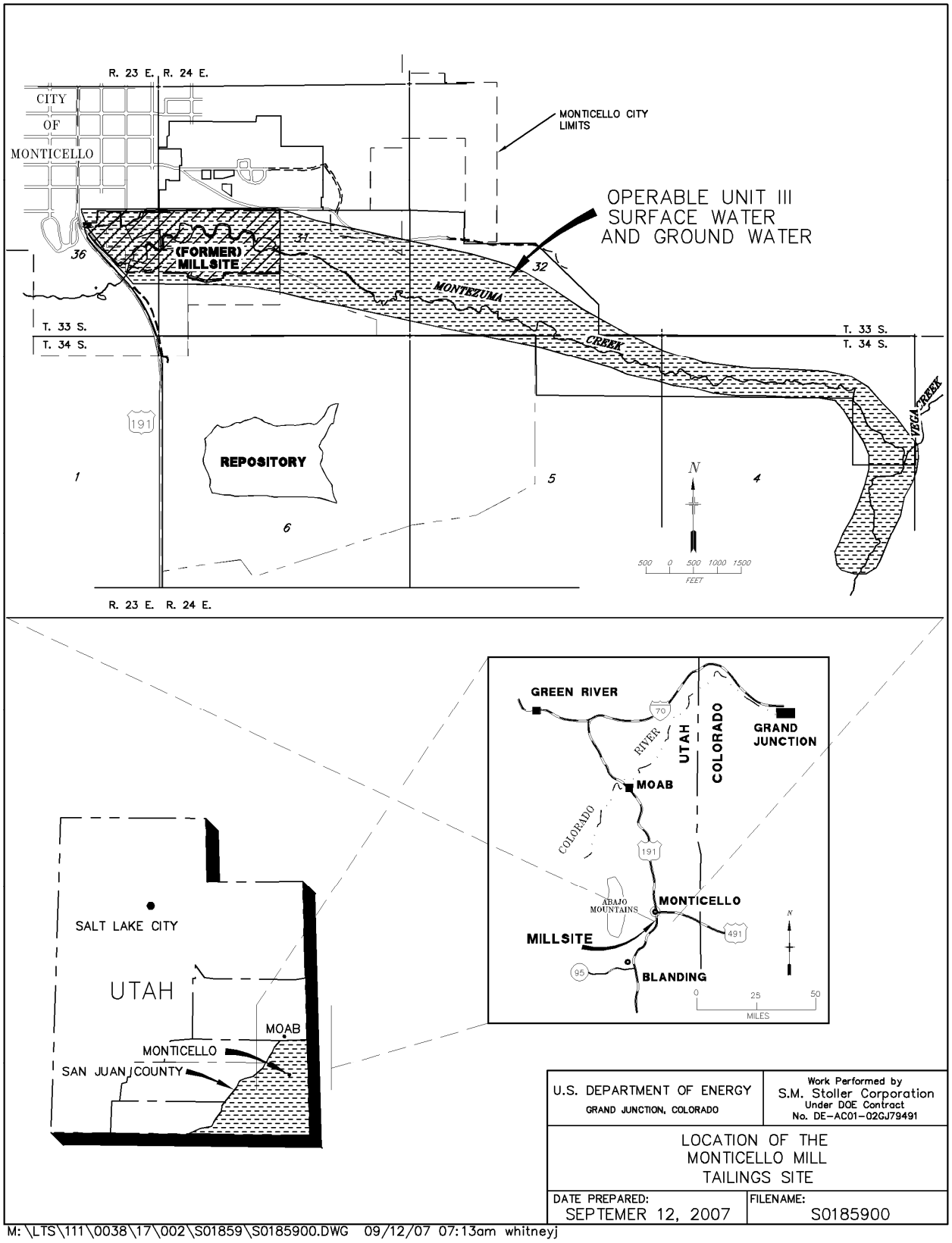

Figure 1. Location of the Monticello Mill Tailings Site

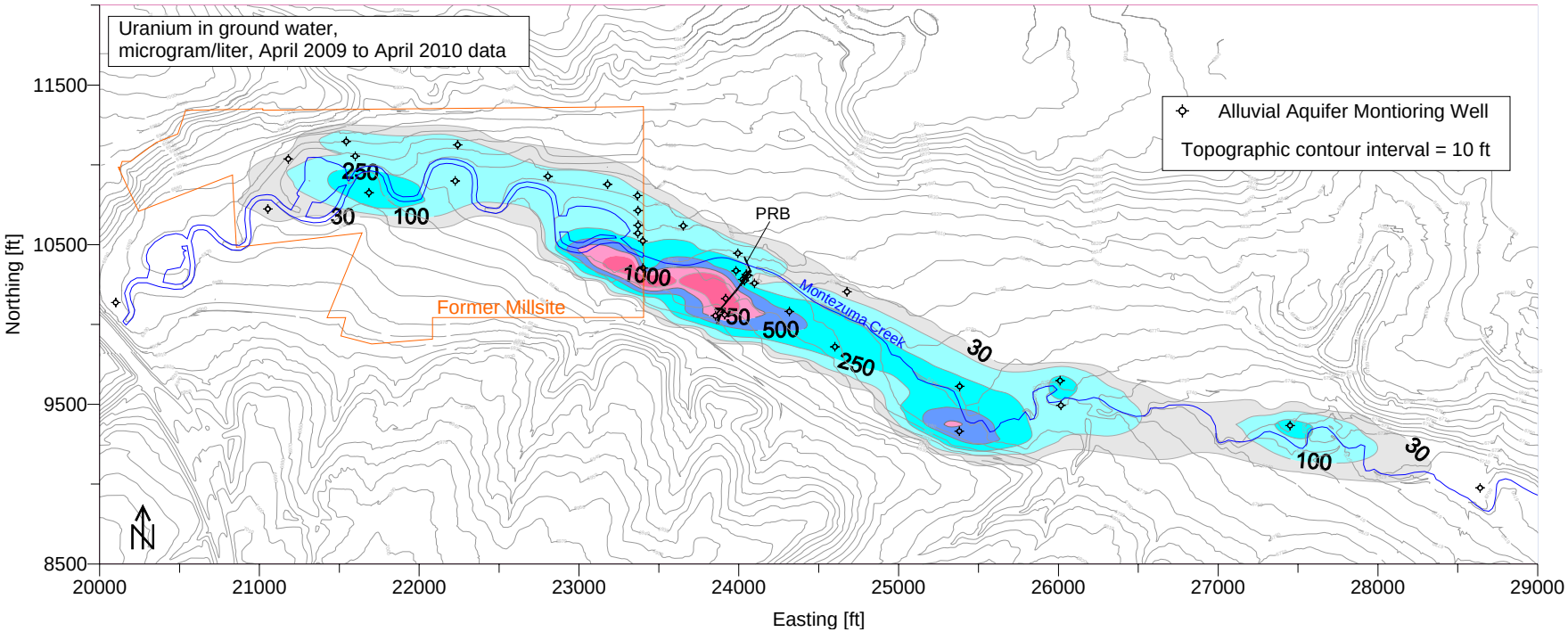

Figure 2. Uranium Groundwater Plume—October 2009−April 2010 Data

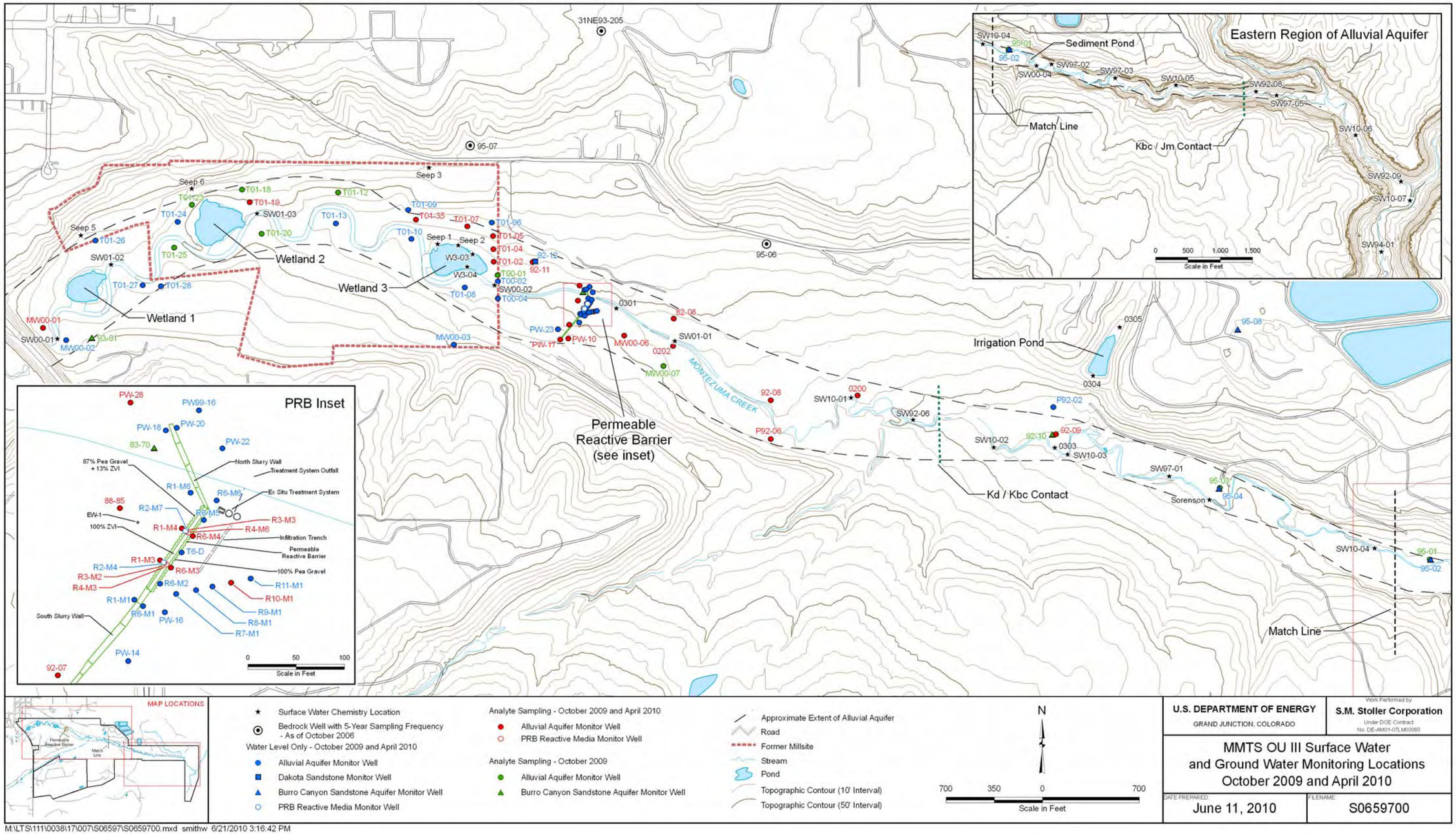

Figure 3. Reference Map for OU III Water Quality Monitoring Locations

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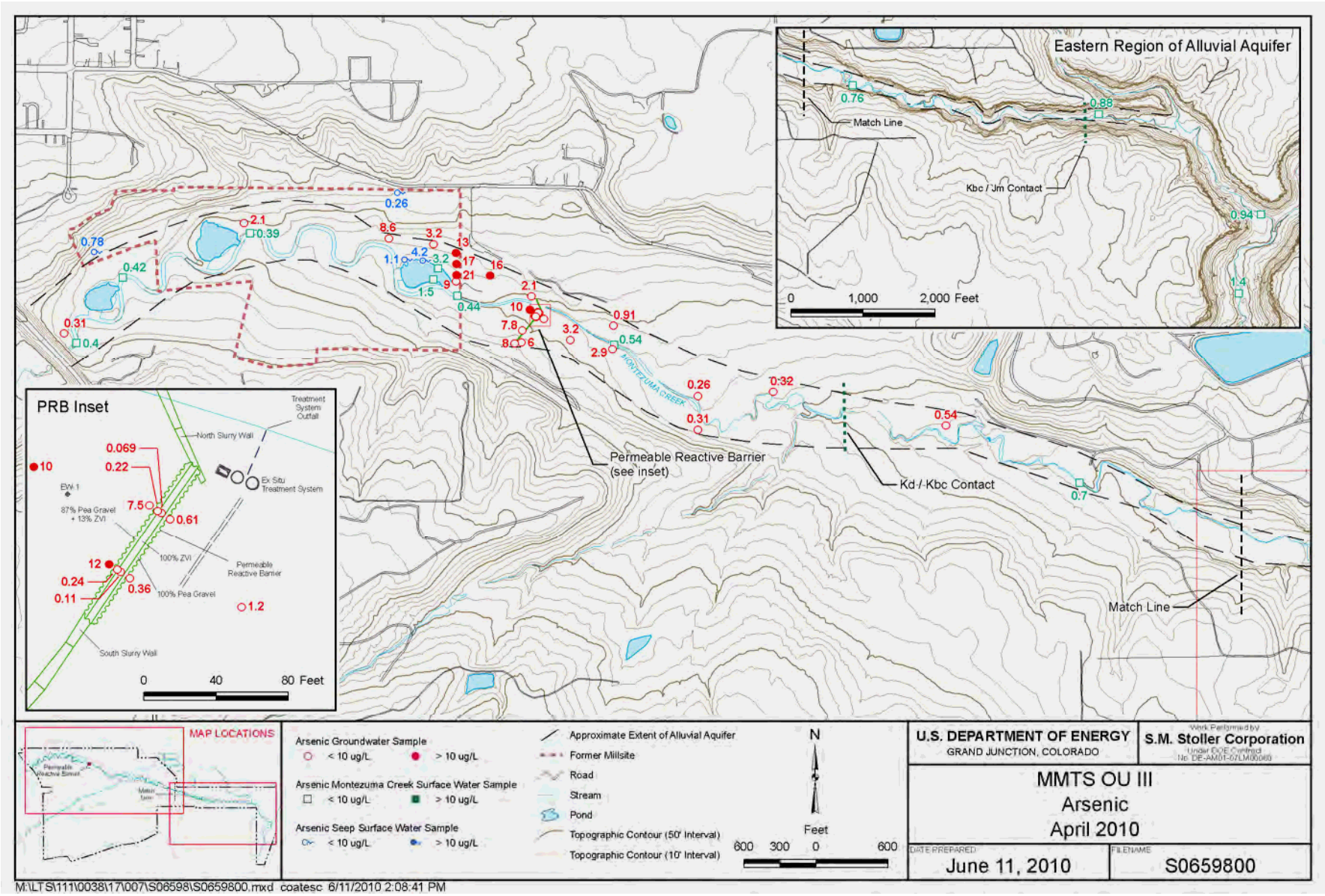

Figure 4. Distribution of Arsenic in Surface Water and Alluvial Aquifer Groundwater, April 2010

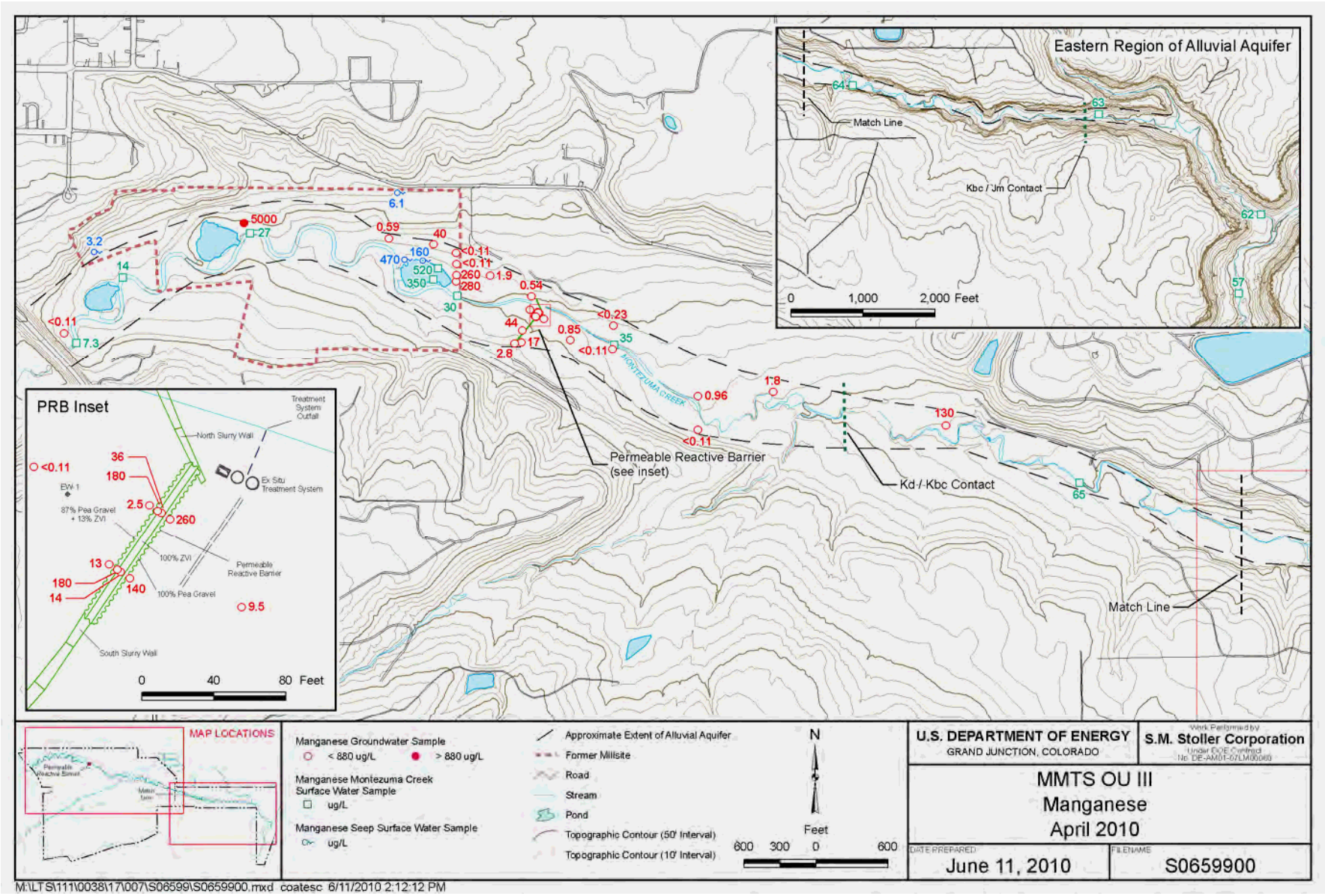

Figure 5. Distribution of Manganese in Surface Water and Alluvial Aquifer Groundwater, April 2010

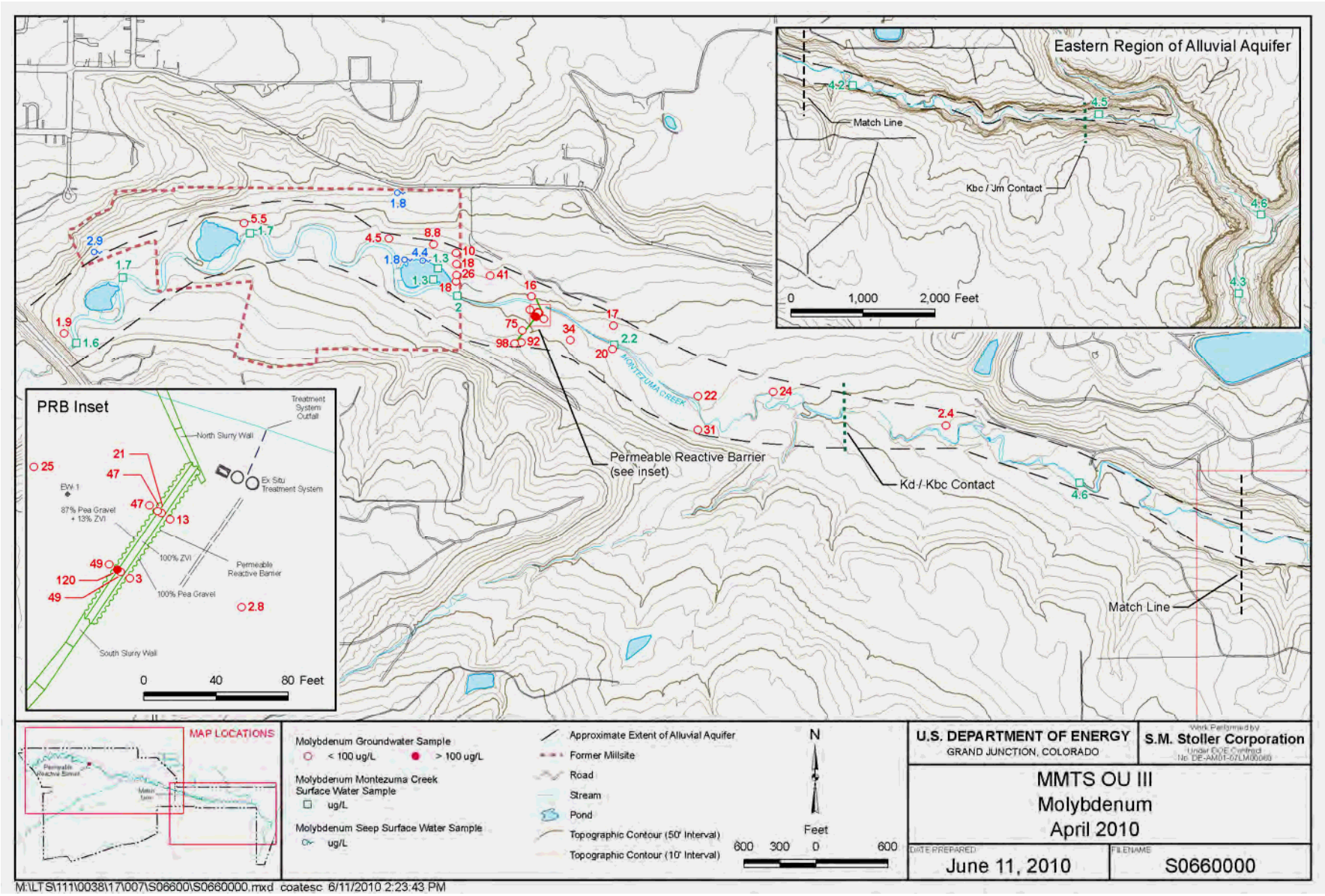

Figure 6. Distribution of Molybdenum in Surface Water and Alluvial Aquifer Groundwater, April 2010

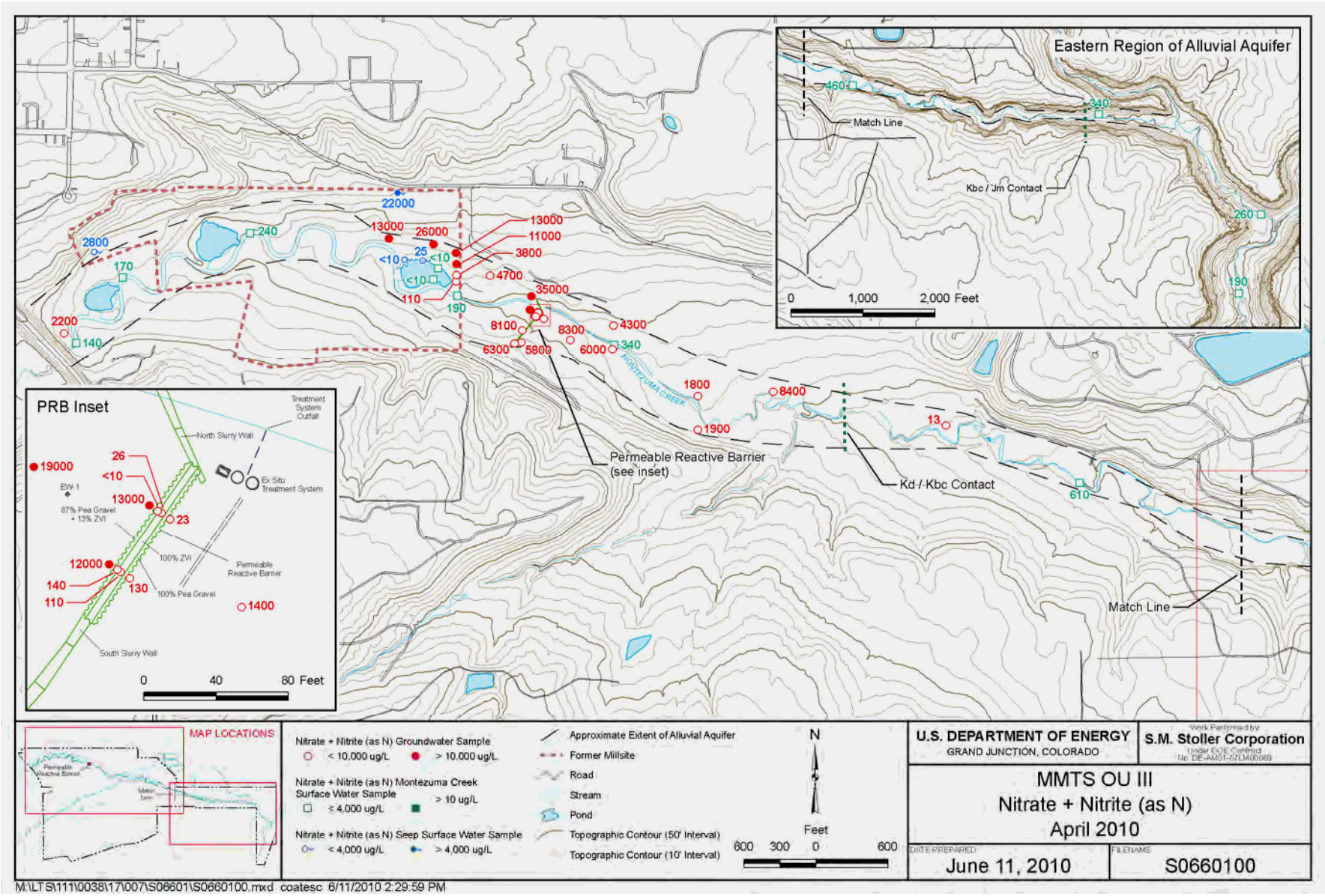

Figure 7. Distribution of Nitrate (as Nitrogen) in Surface Water and Alluvial Aquifer Groundwater, April 2010

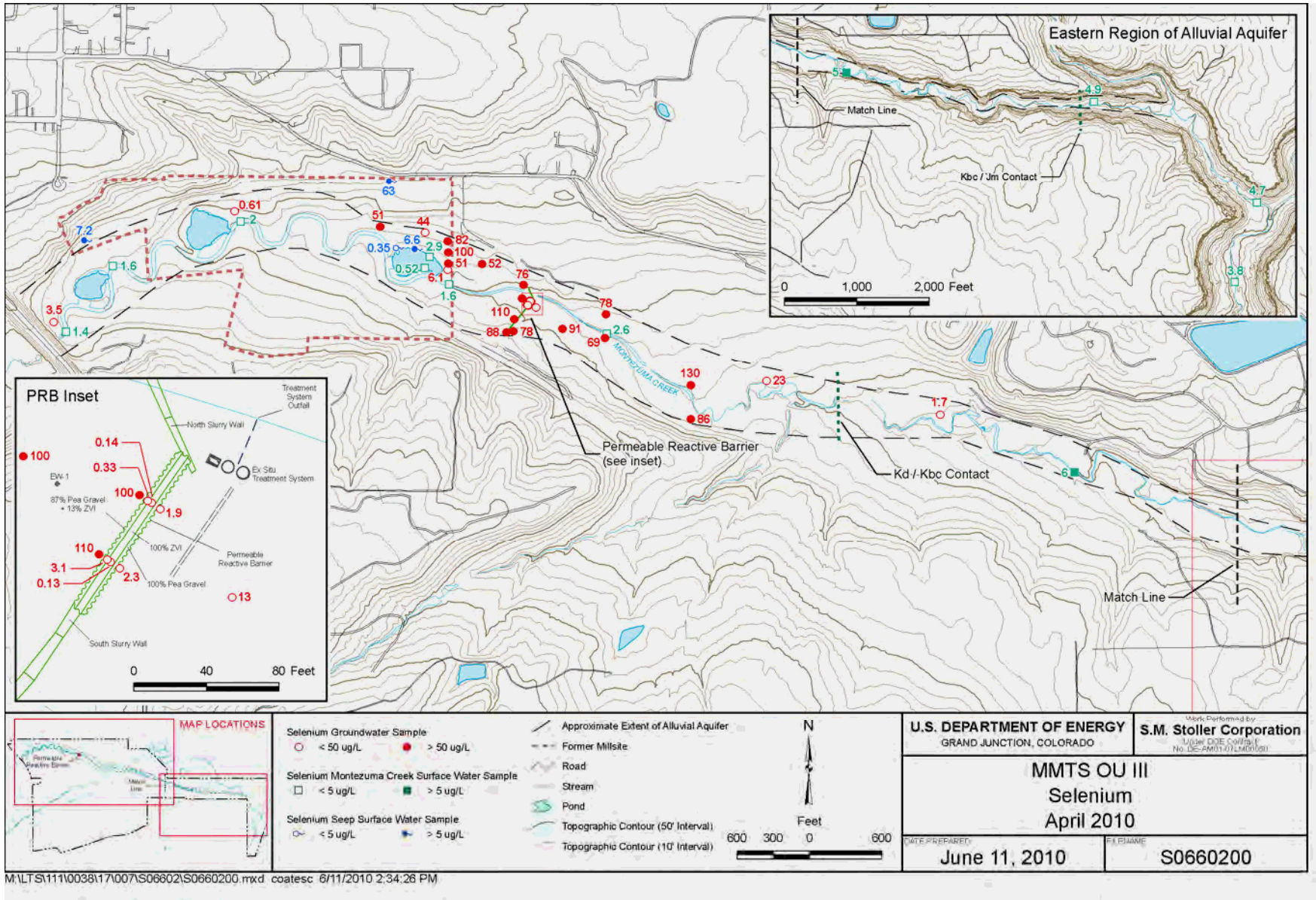

Figure 8. Distribution of Selenium in Surface Water and Alluvial Aquifer Groundwater, April 2010

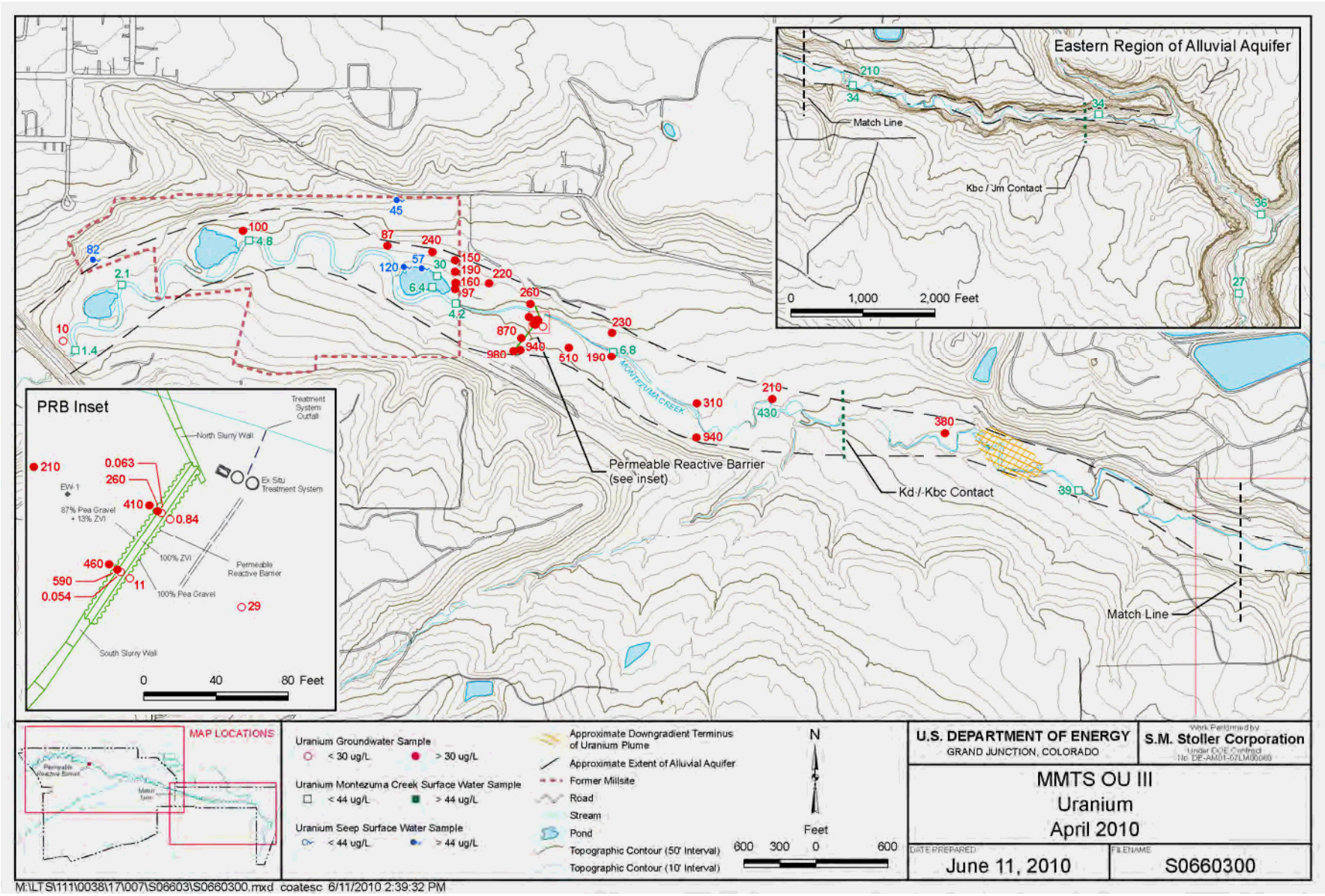

Figure 9. Distribution of Uranium in Surface Water and Alluvial Aquifer Groundwater, April 2010

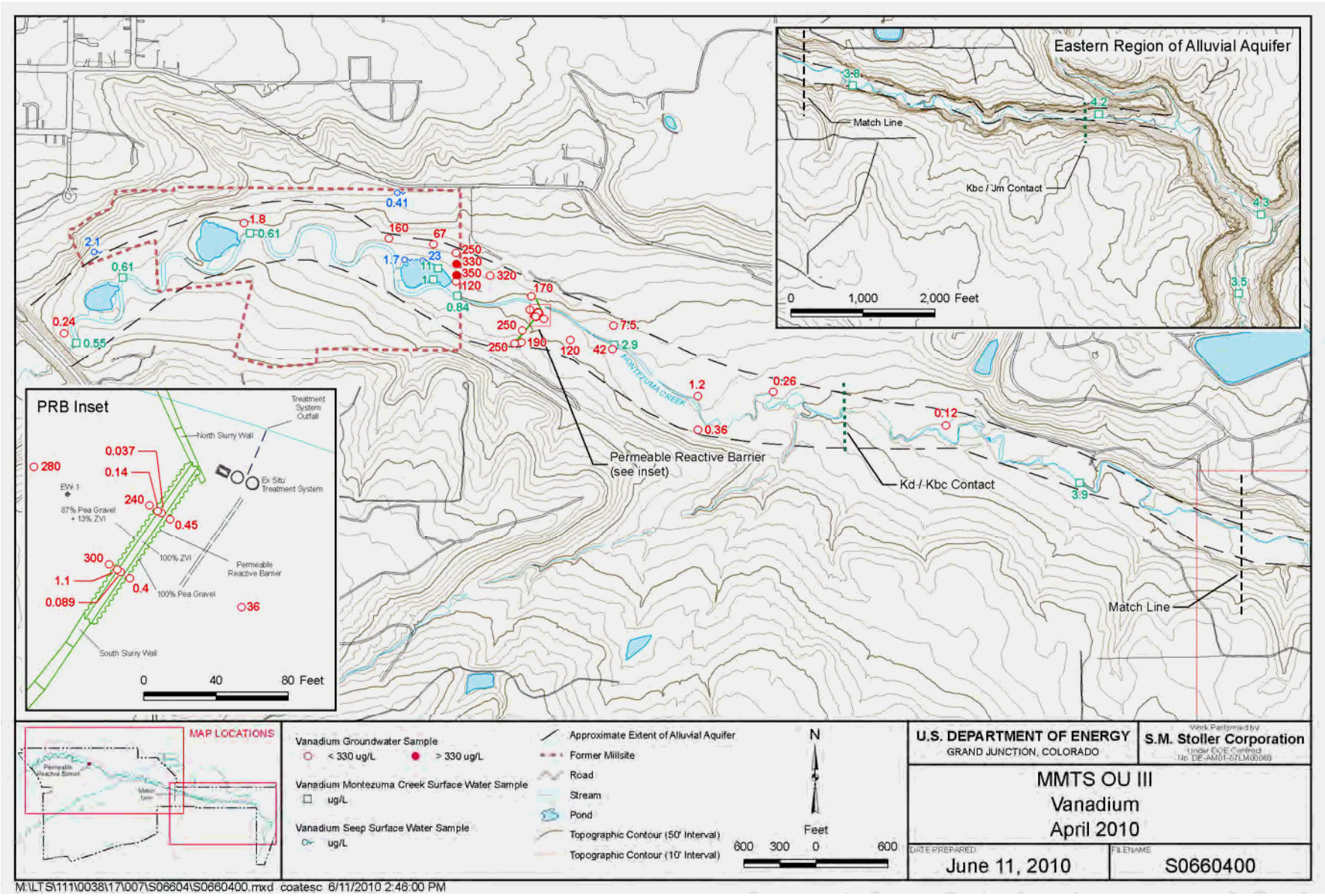

Figure 10. Distribution of Vanadium in Surface Water and Alluvial Aquifer Groundwater, April 2010

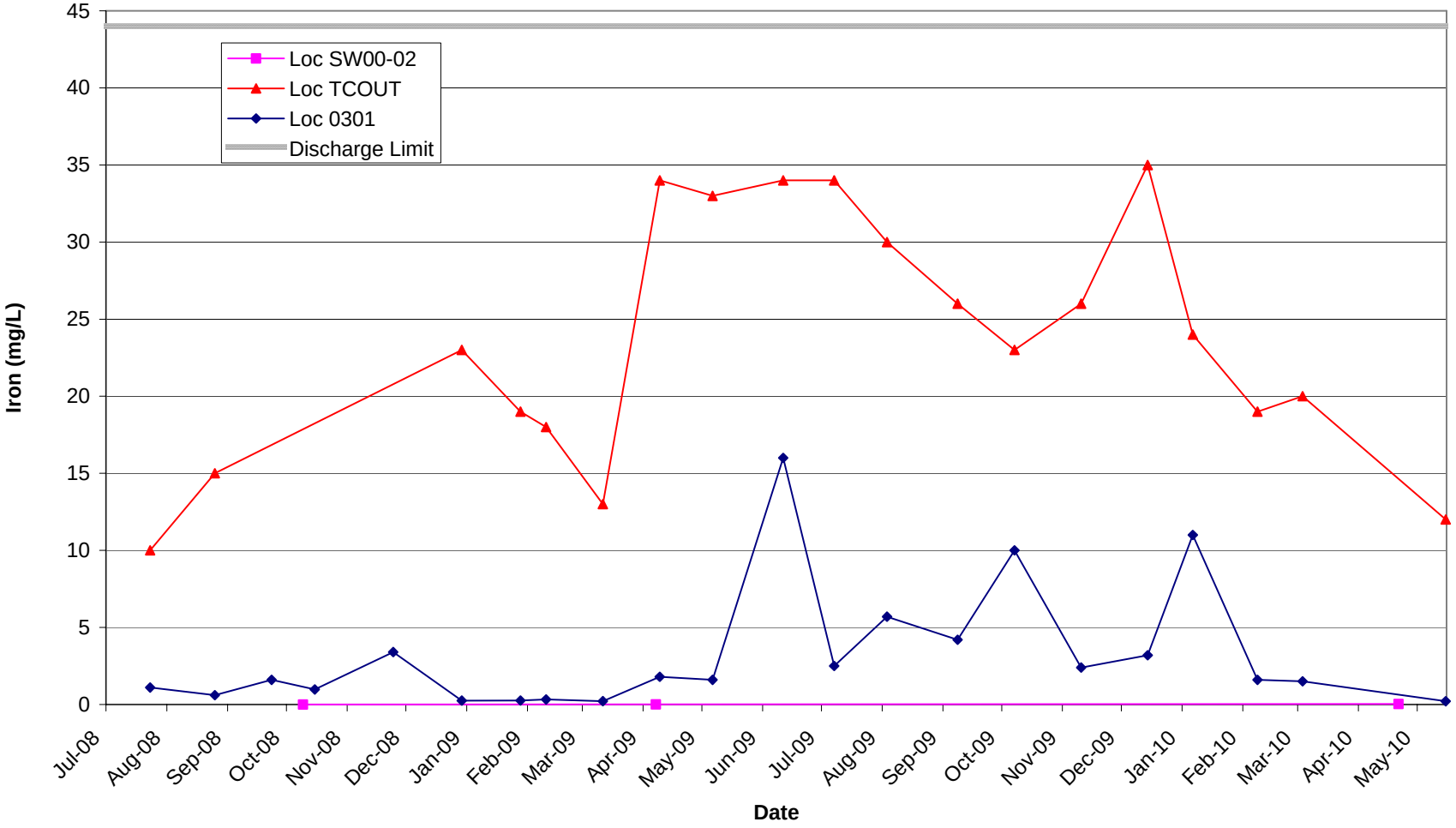

Figure 11. Ex Situ Treatment System Monitoring Results, Iron

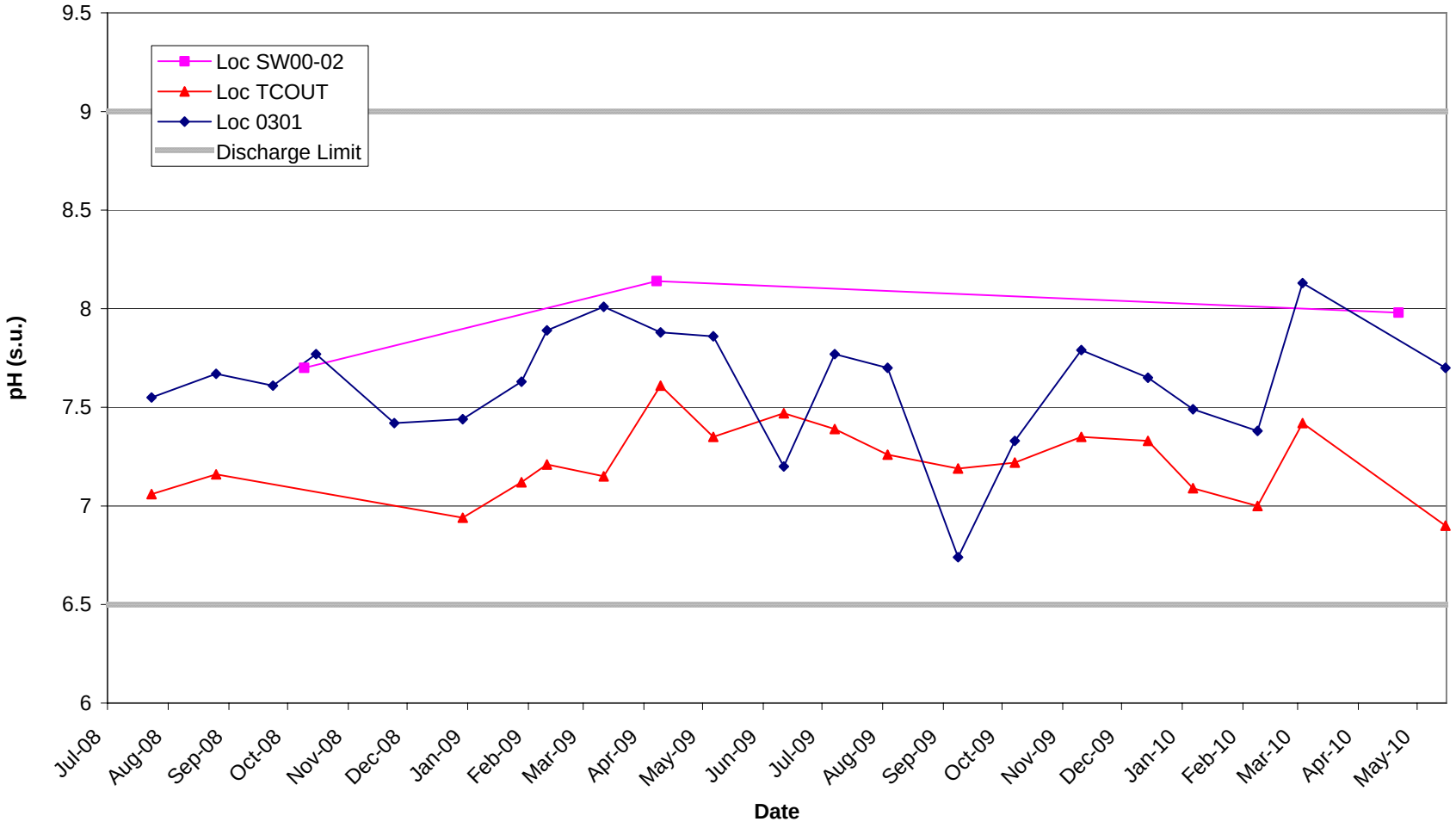

Figure 12. Ex Situ Treatment System Monitoring Results, pH

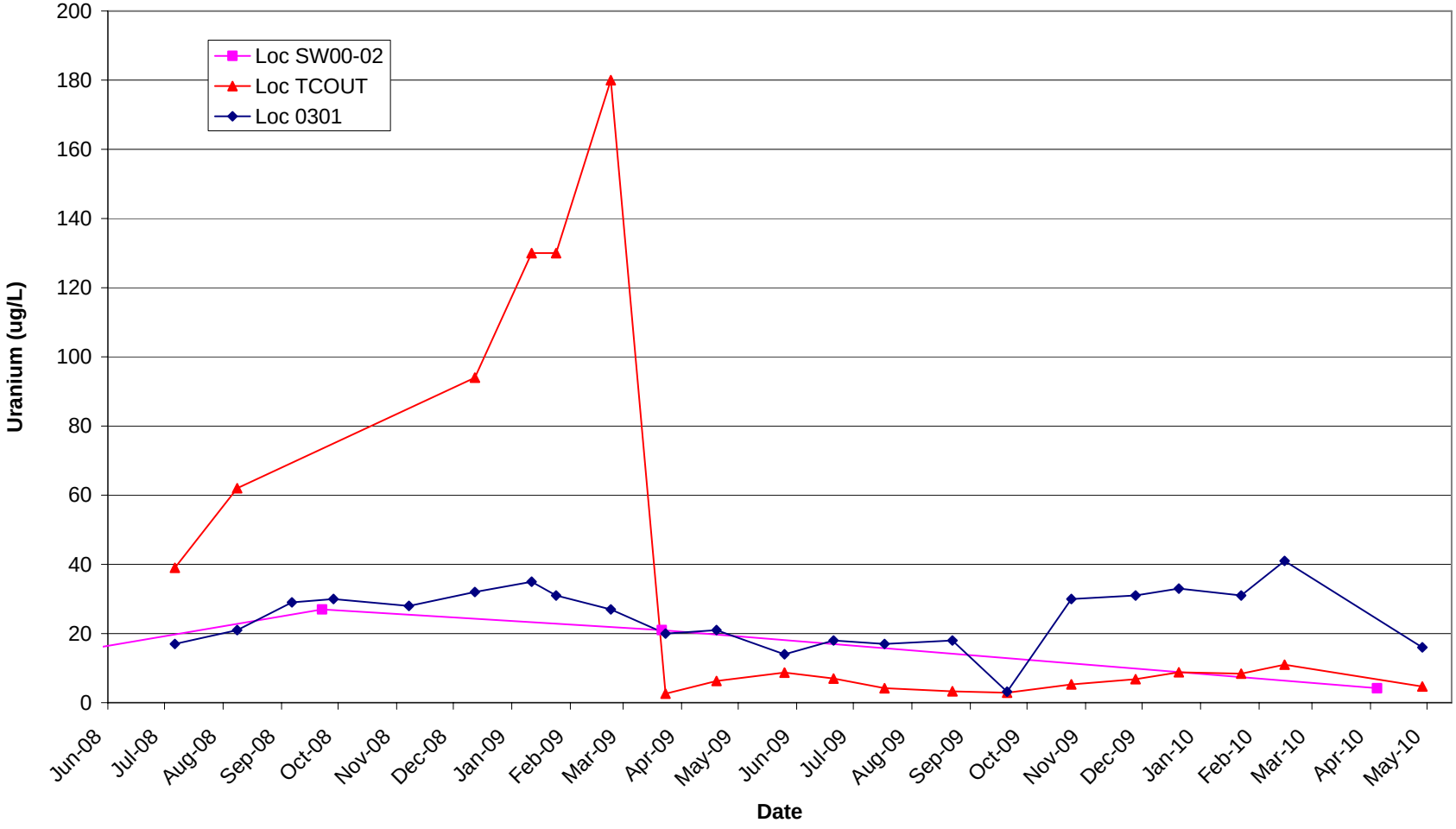

Figure 13. Ex Situ Treatment System Monitoring Results, Uranium

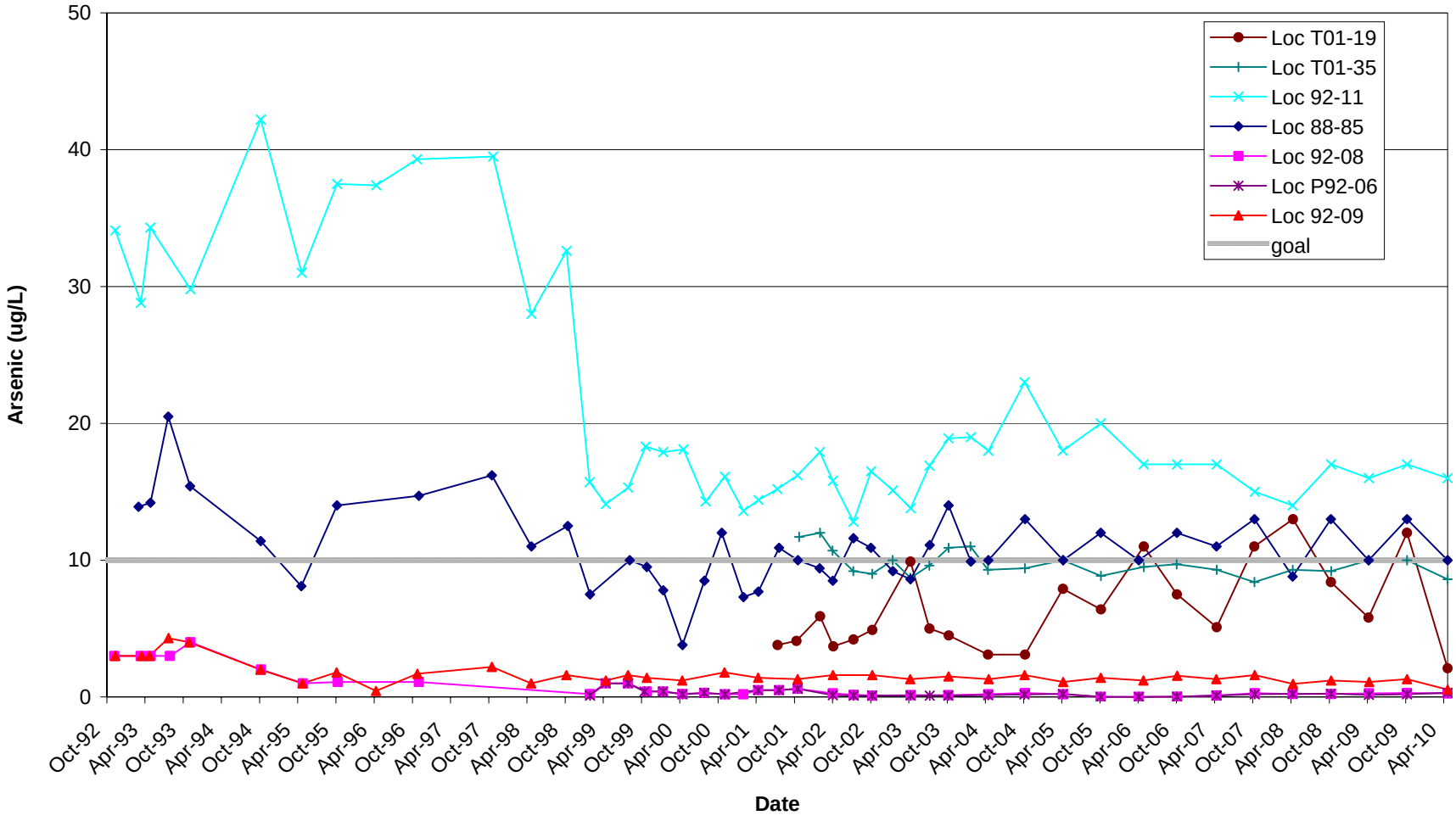

Figure 14. Arsenic Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

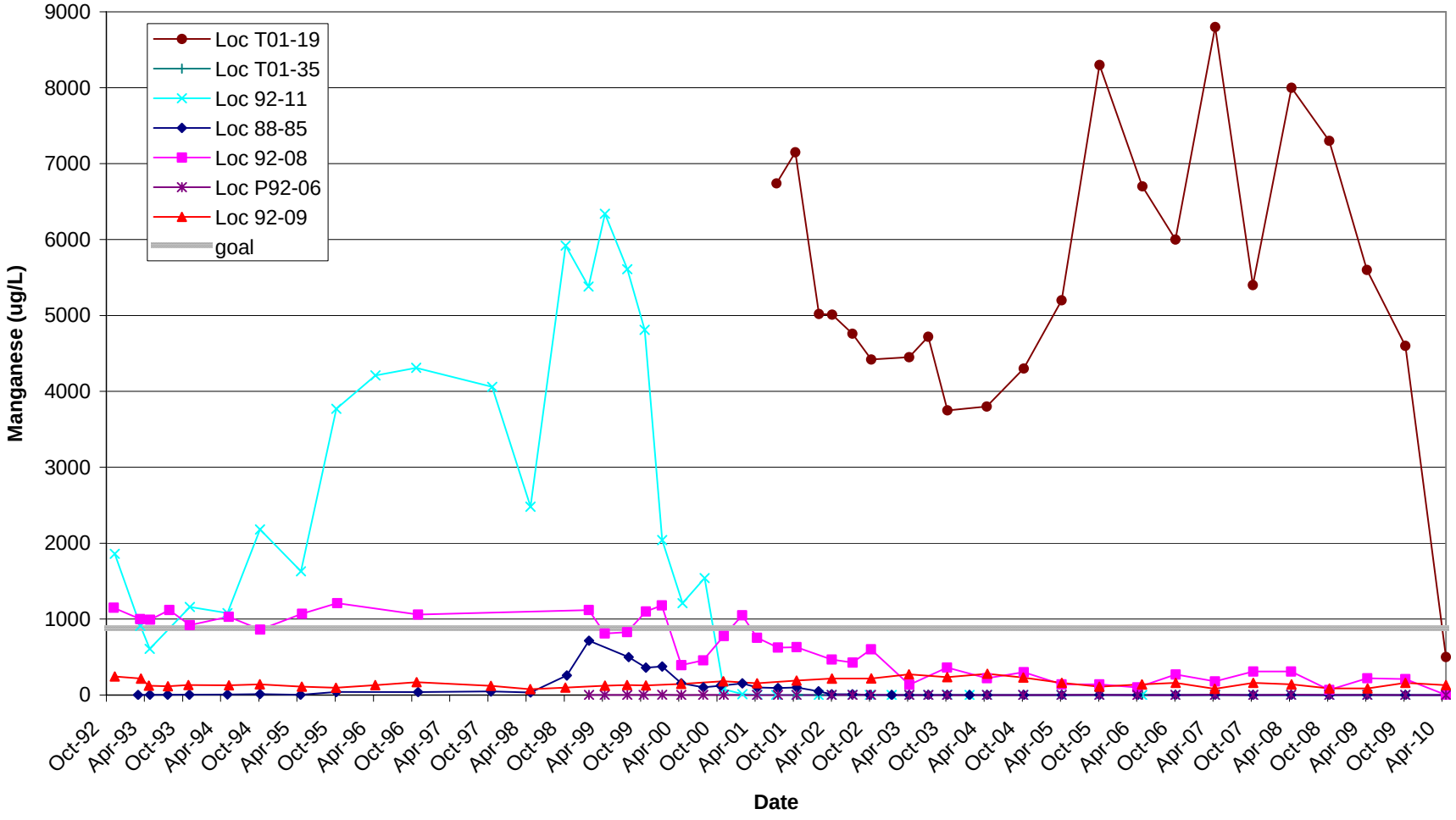

Figure 15. Manganese Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

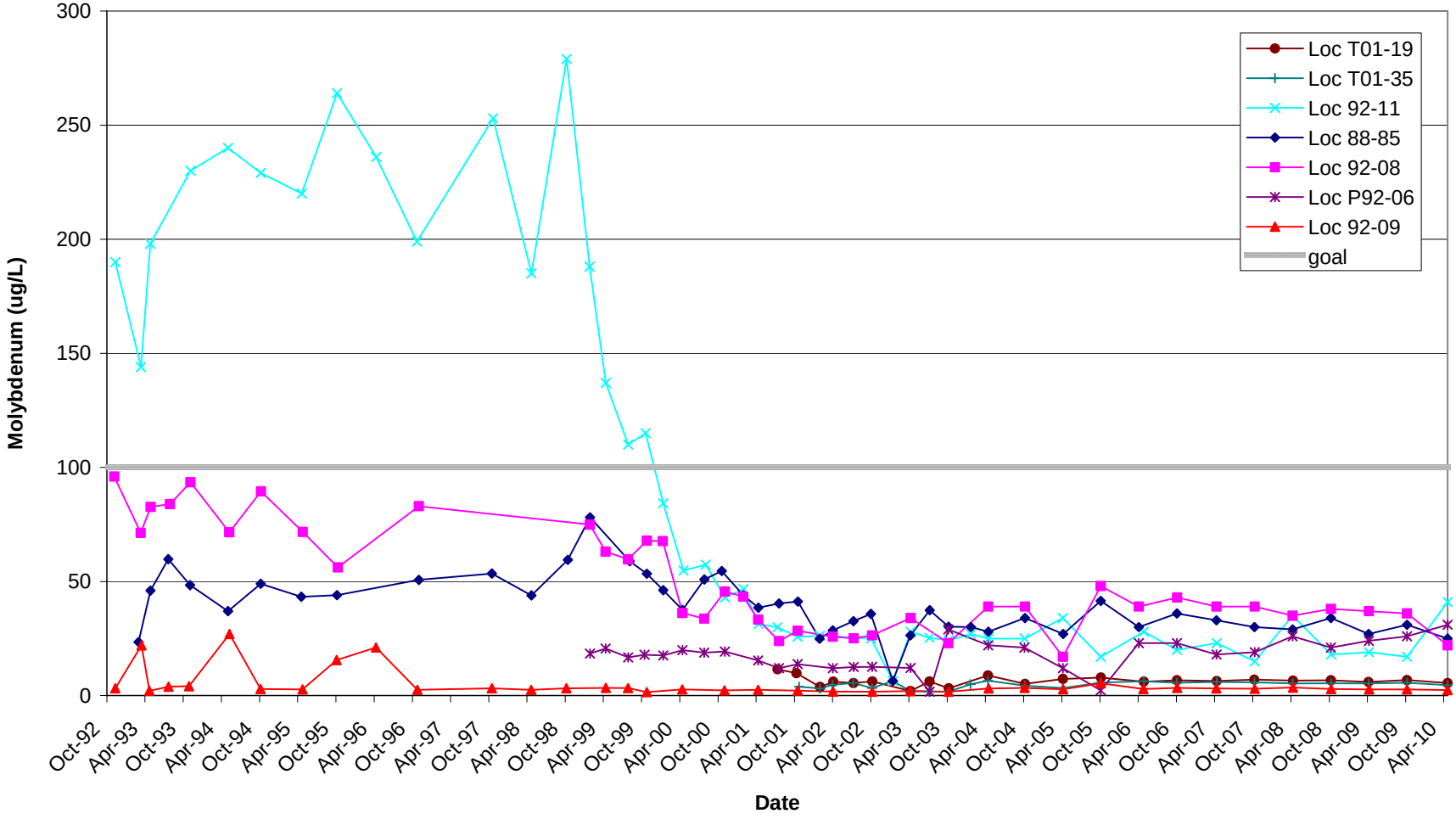

Figure 16. Molybdenum Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

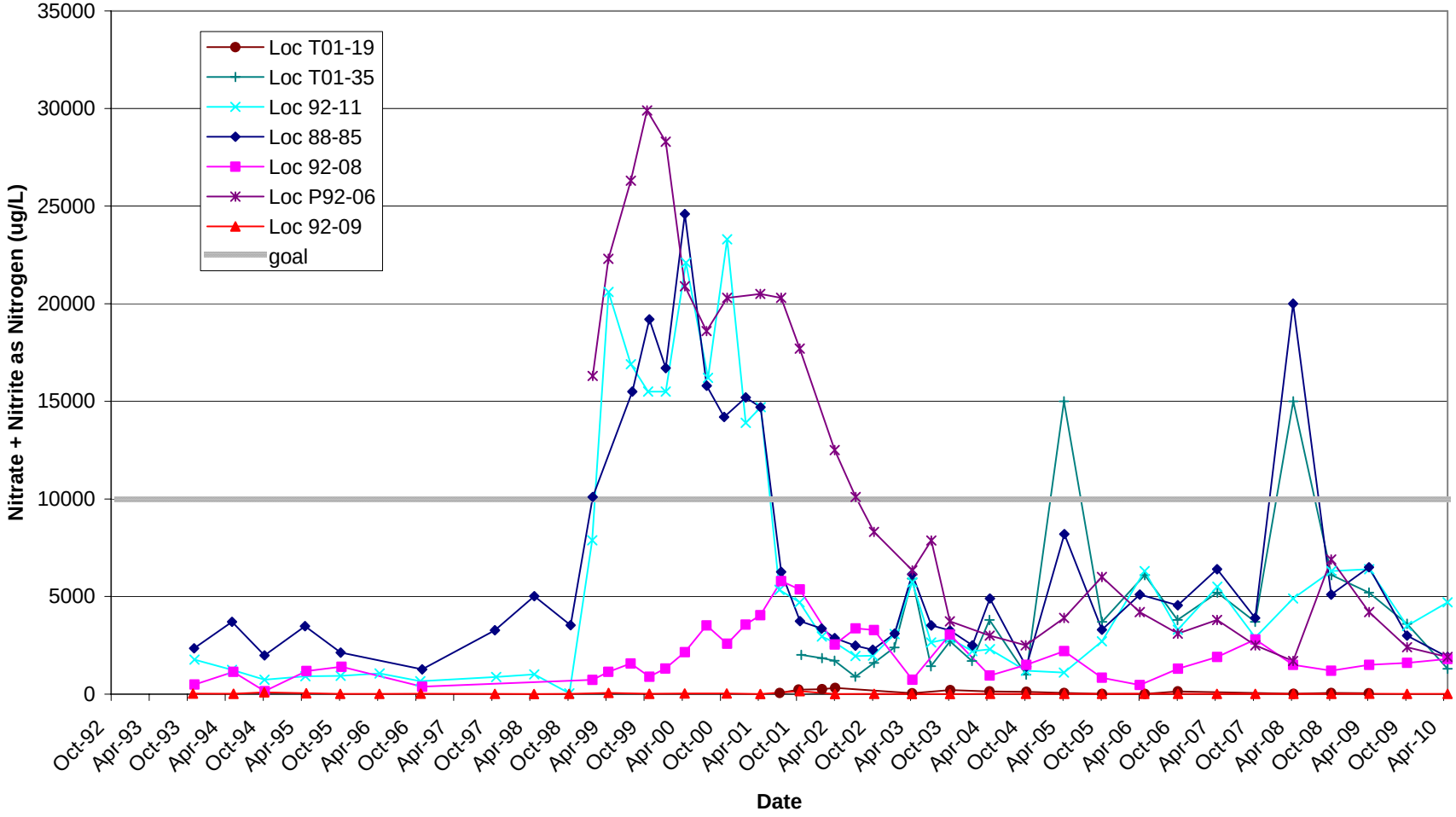

Figure 17. Nitrate (as Nitrogen) Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

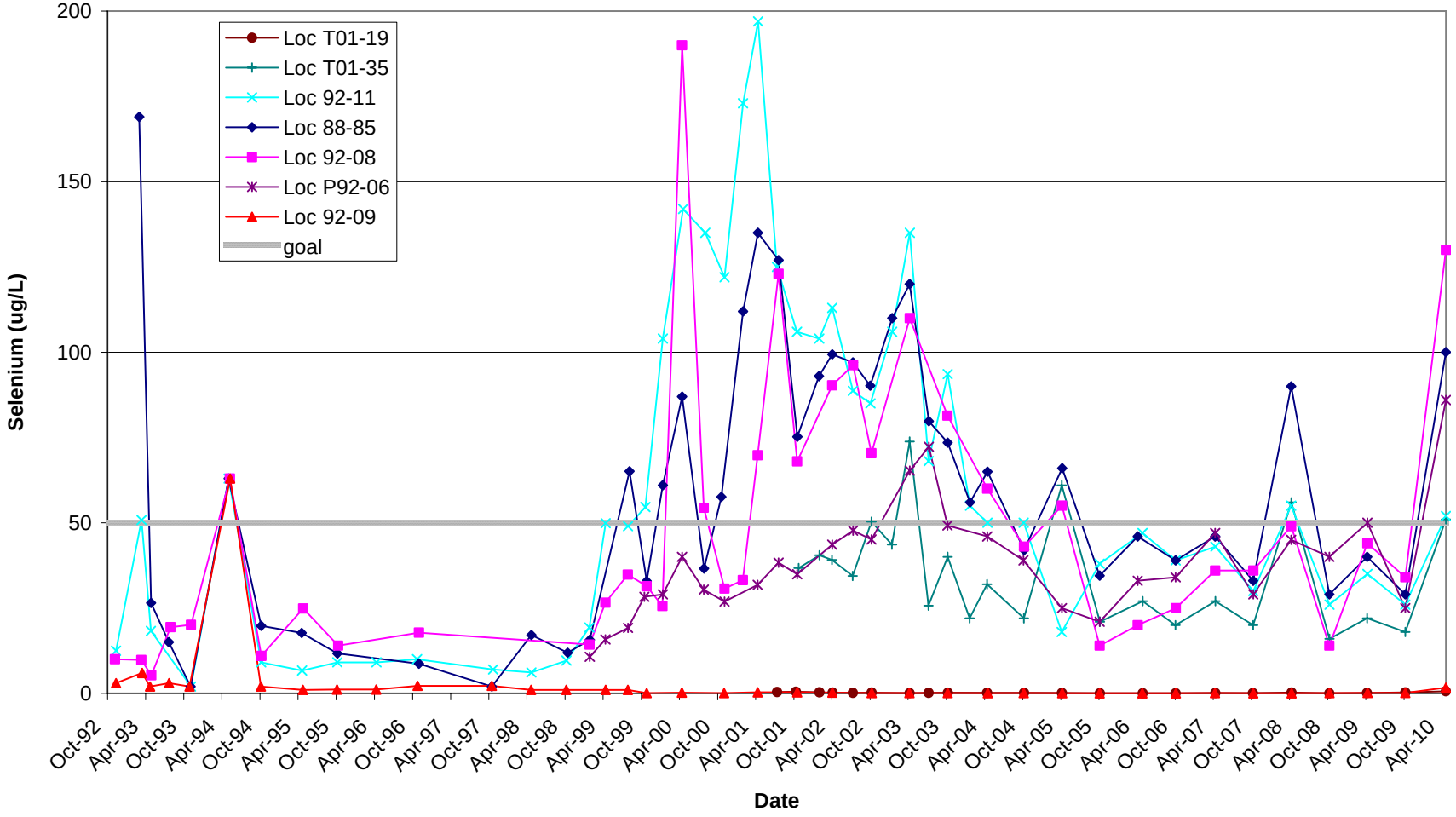

Figure 18. Selenium Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

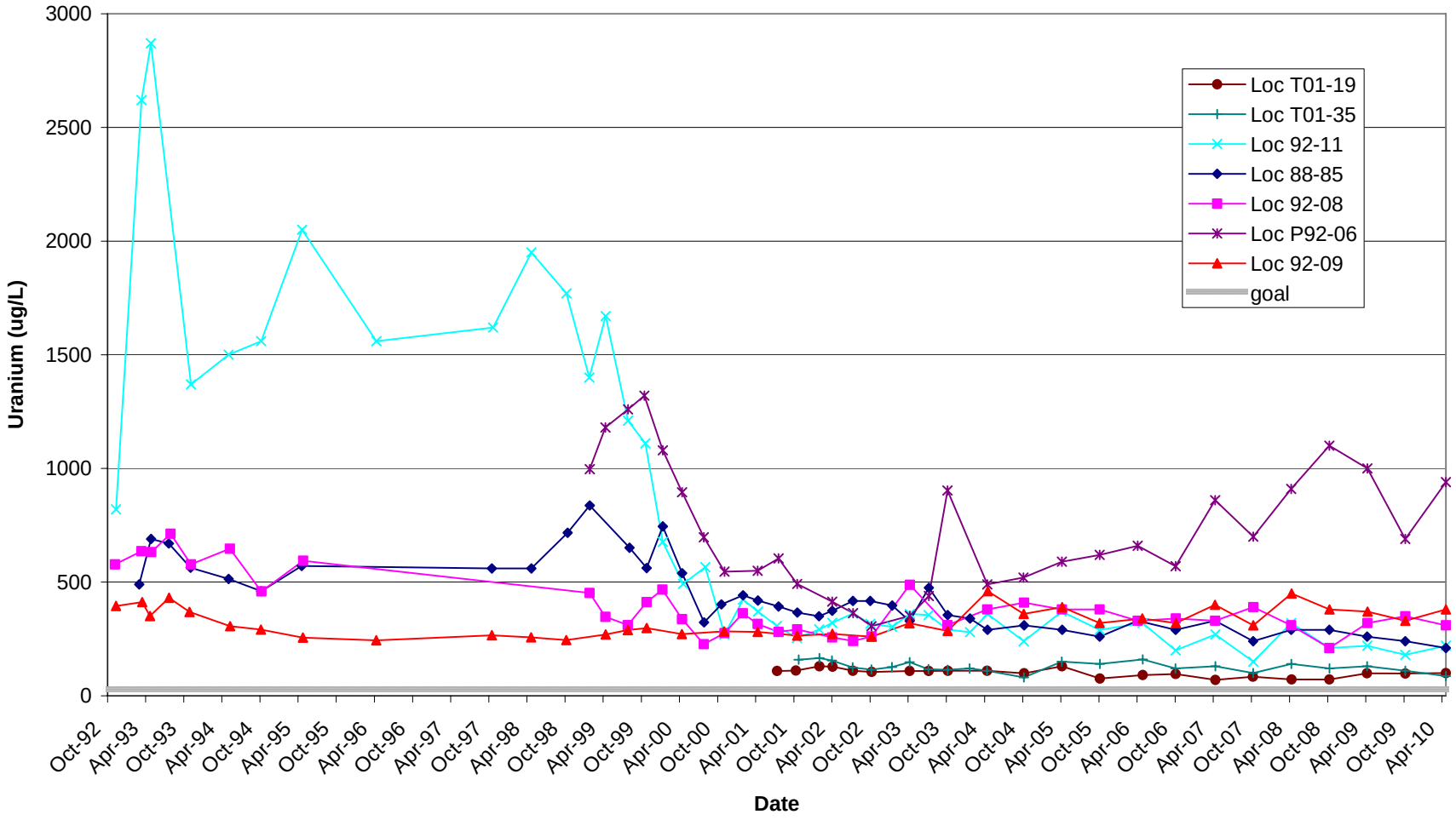

Figure 19. Uranium Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

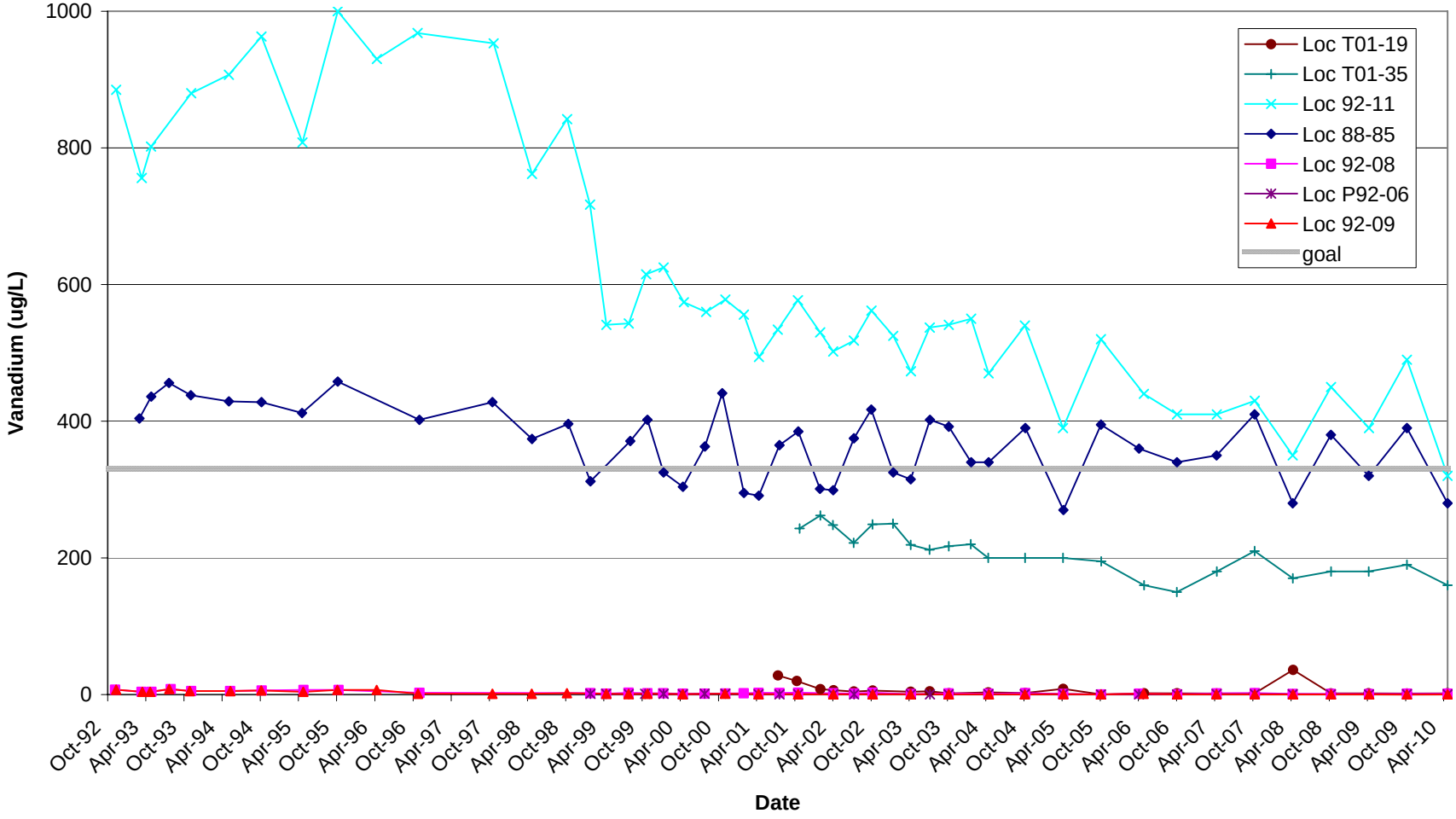

Figure 20. Vanadium Concentration Over Time at Selected Alluvial Aquifer Monitoring Wells

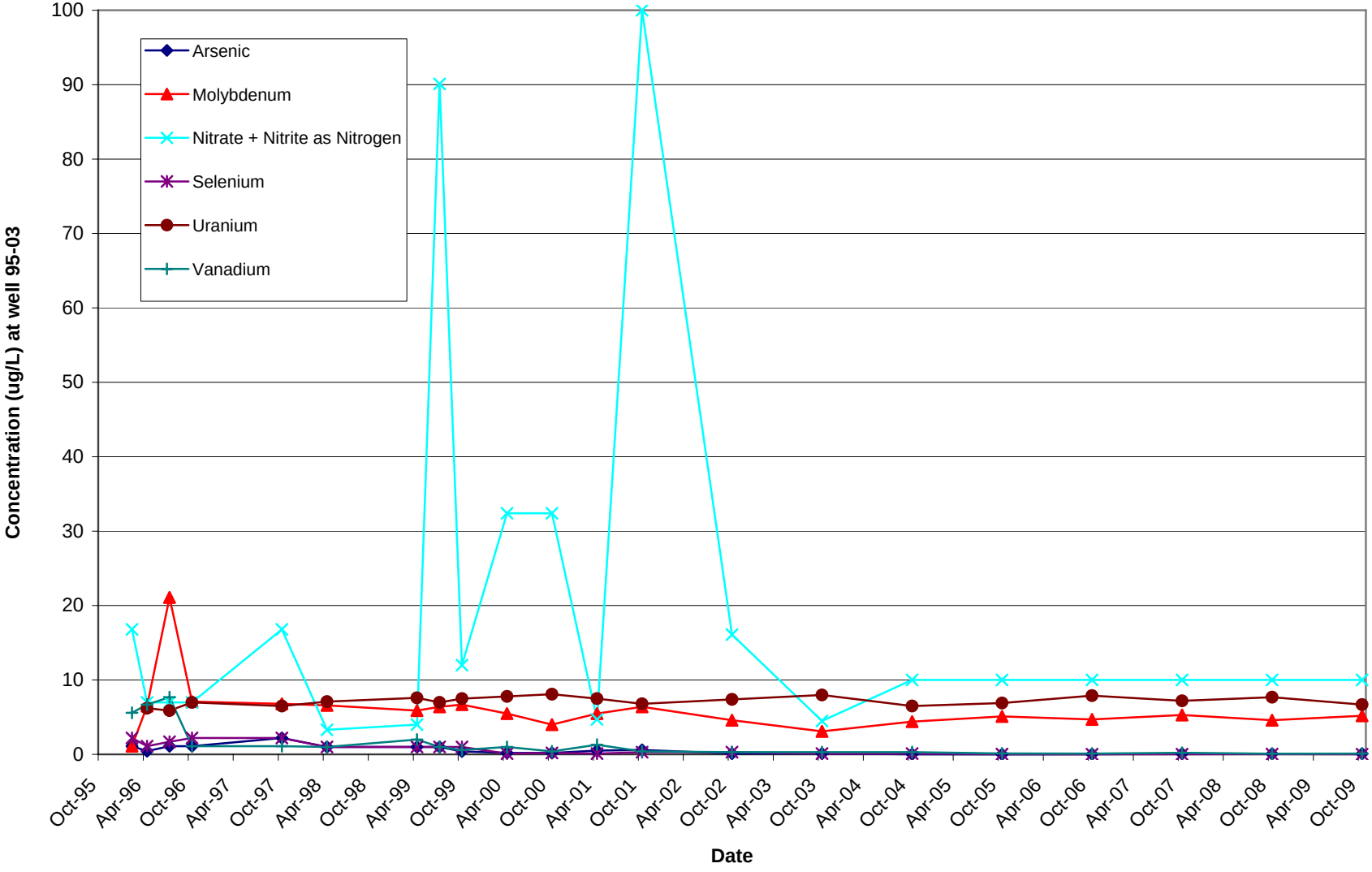

Figure 21. Contaminant Concentrations Over Time at Sentinel Well 95-03

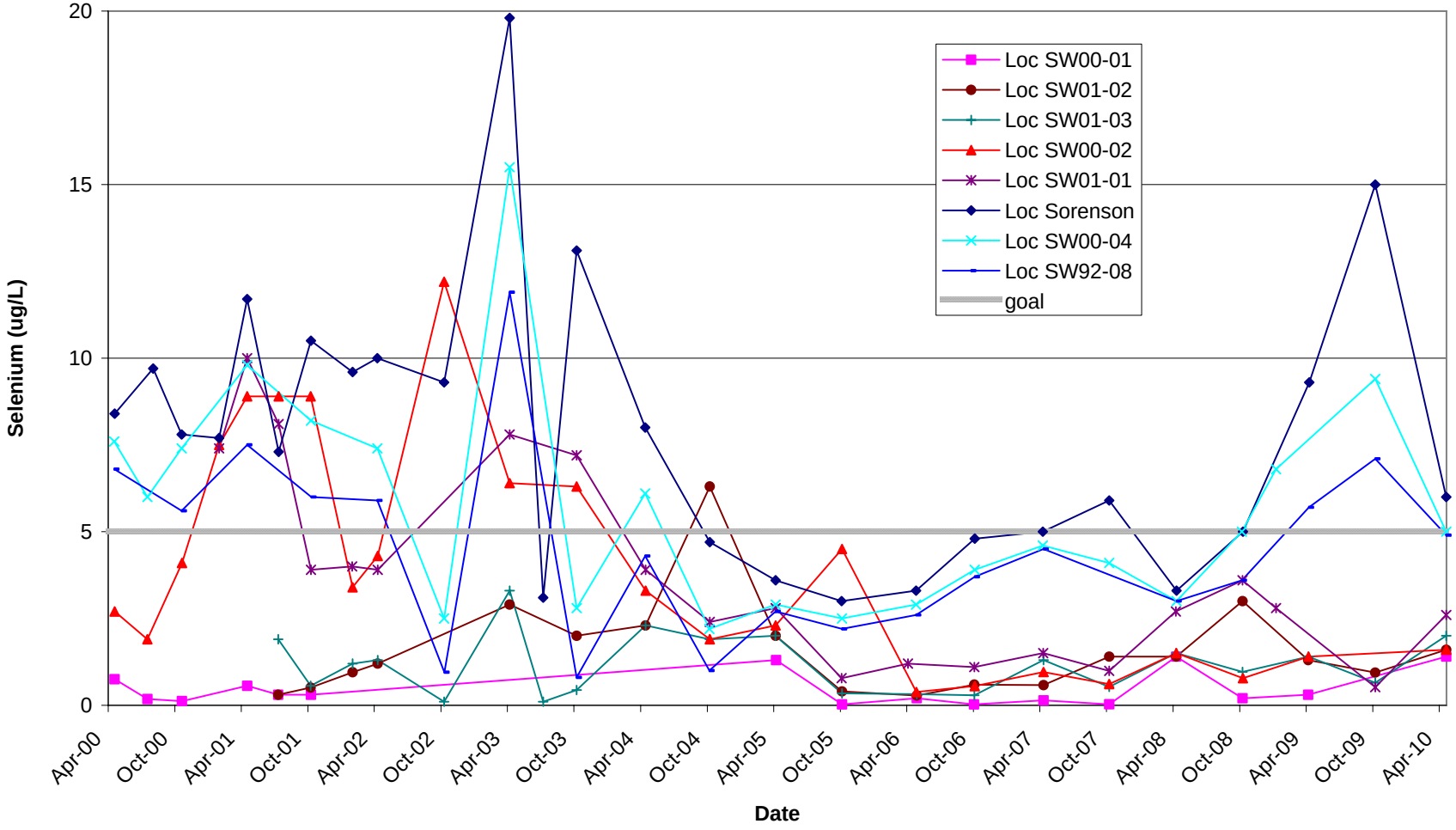

Figure 22. Selenium Concentration Over Time in Montezuma Creek

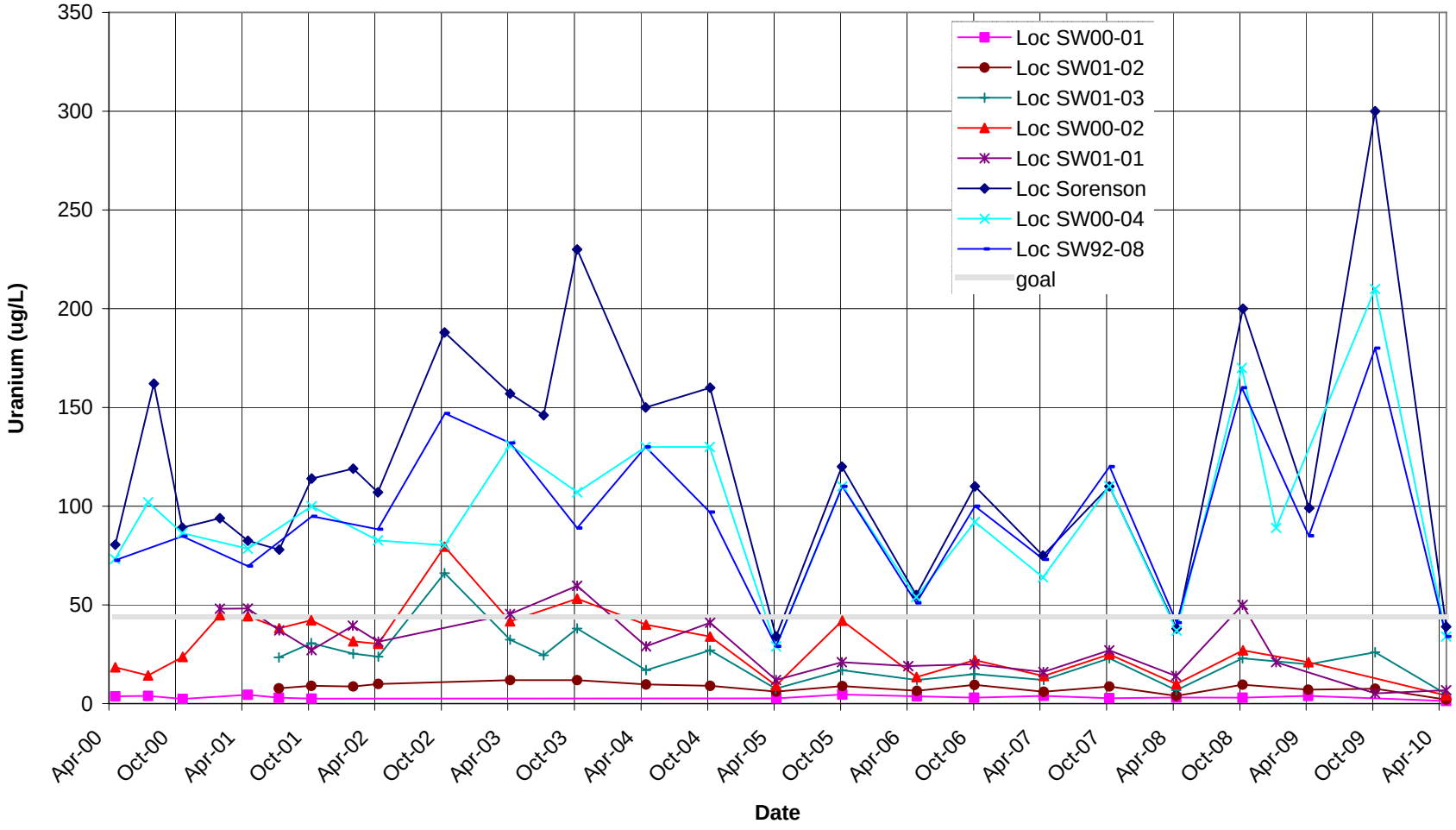

Figure 23. Uranium Concentration Over Time in Montezuma Creek

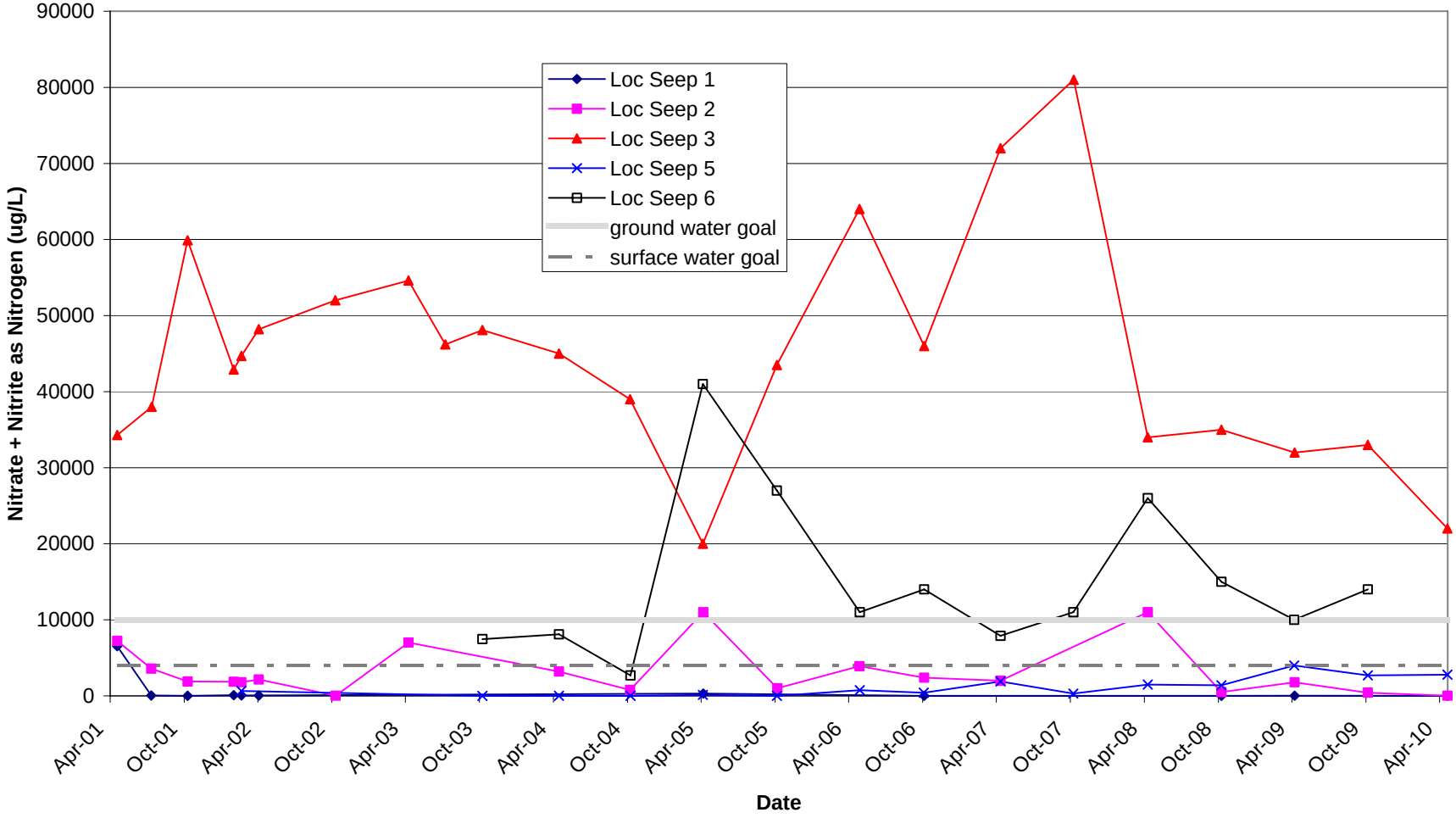

Figure 24. Nitrate (as Nitrogen) Concentration Over Time at Selected Seep Locations

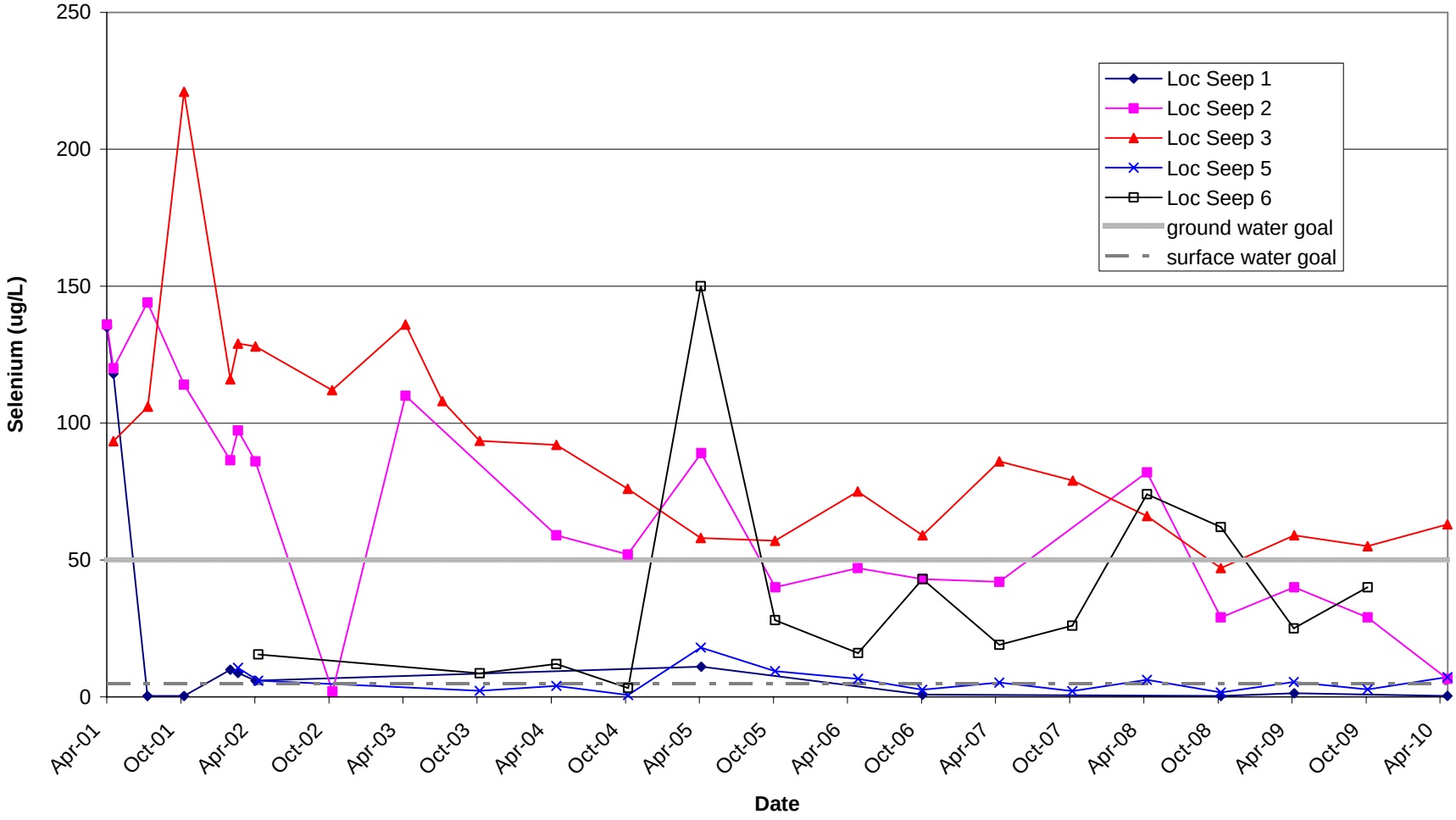

Figure 25. Selenium Concentration Over Time at Selected Seep Locations

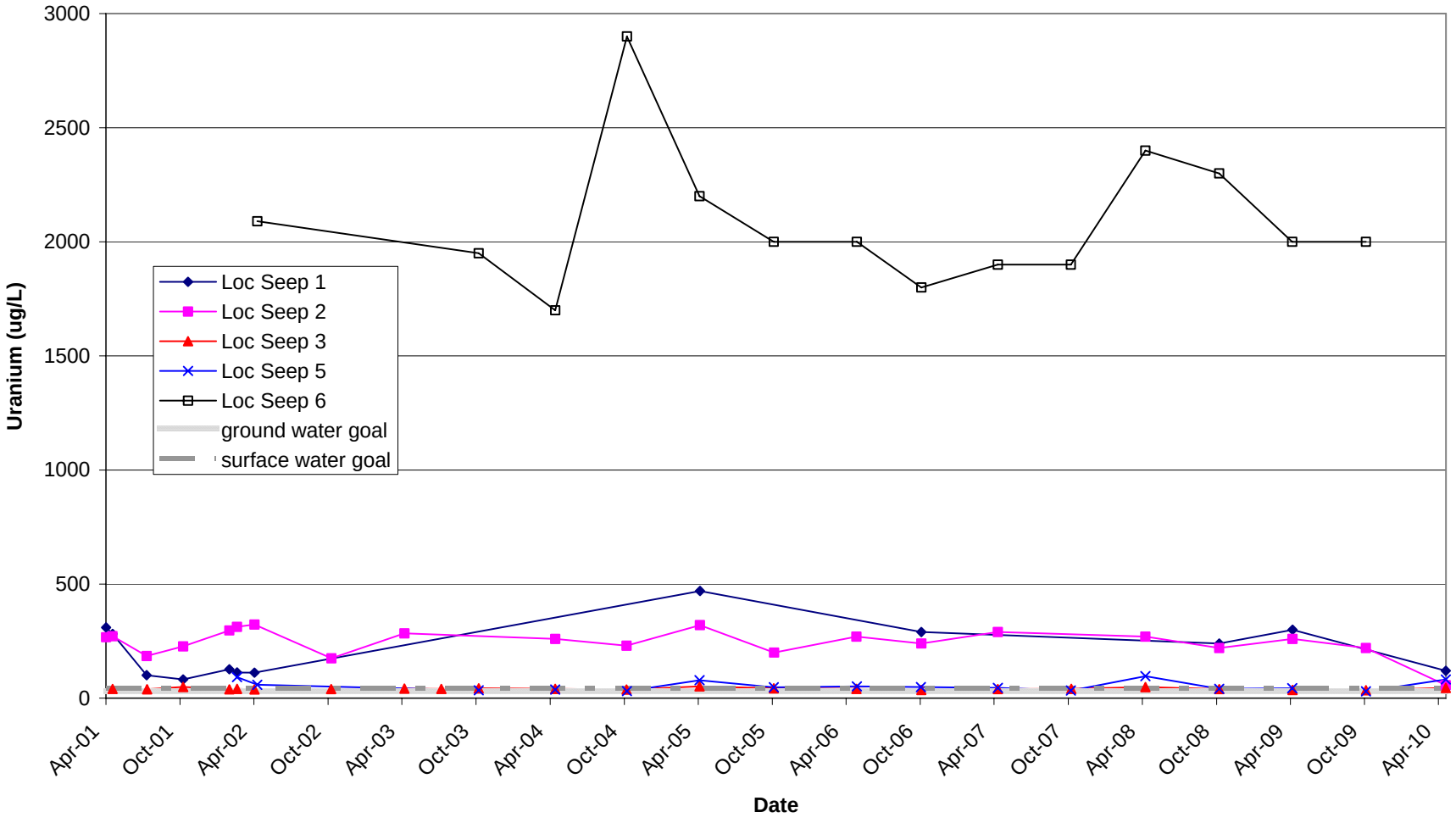

Figure 26. Uranium Concentration Over Time at Selected Seep Locations

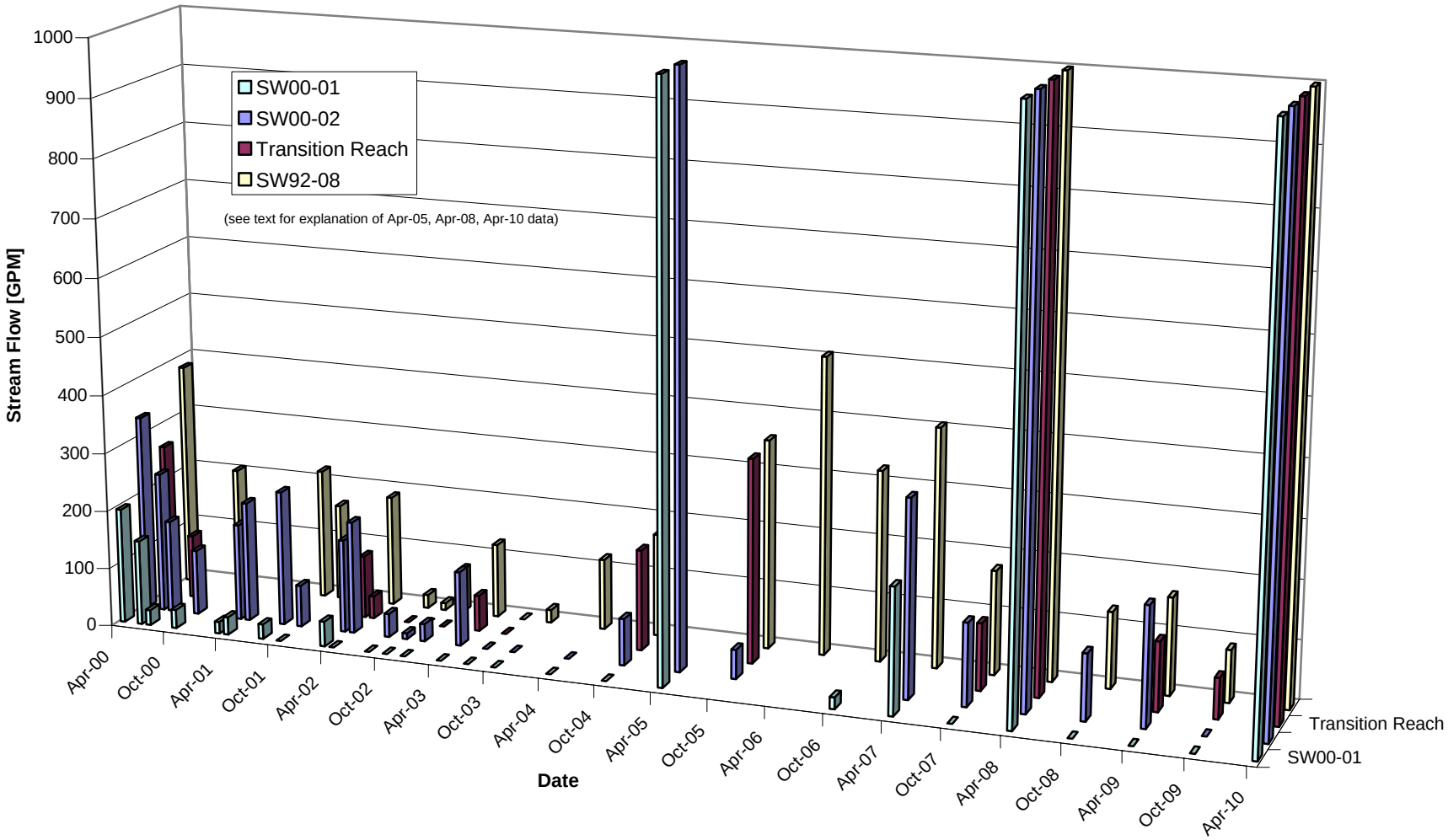

Figure 27. Stream Flow Hydrographs for Selected Sites on Montezuma Creek

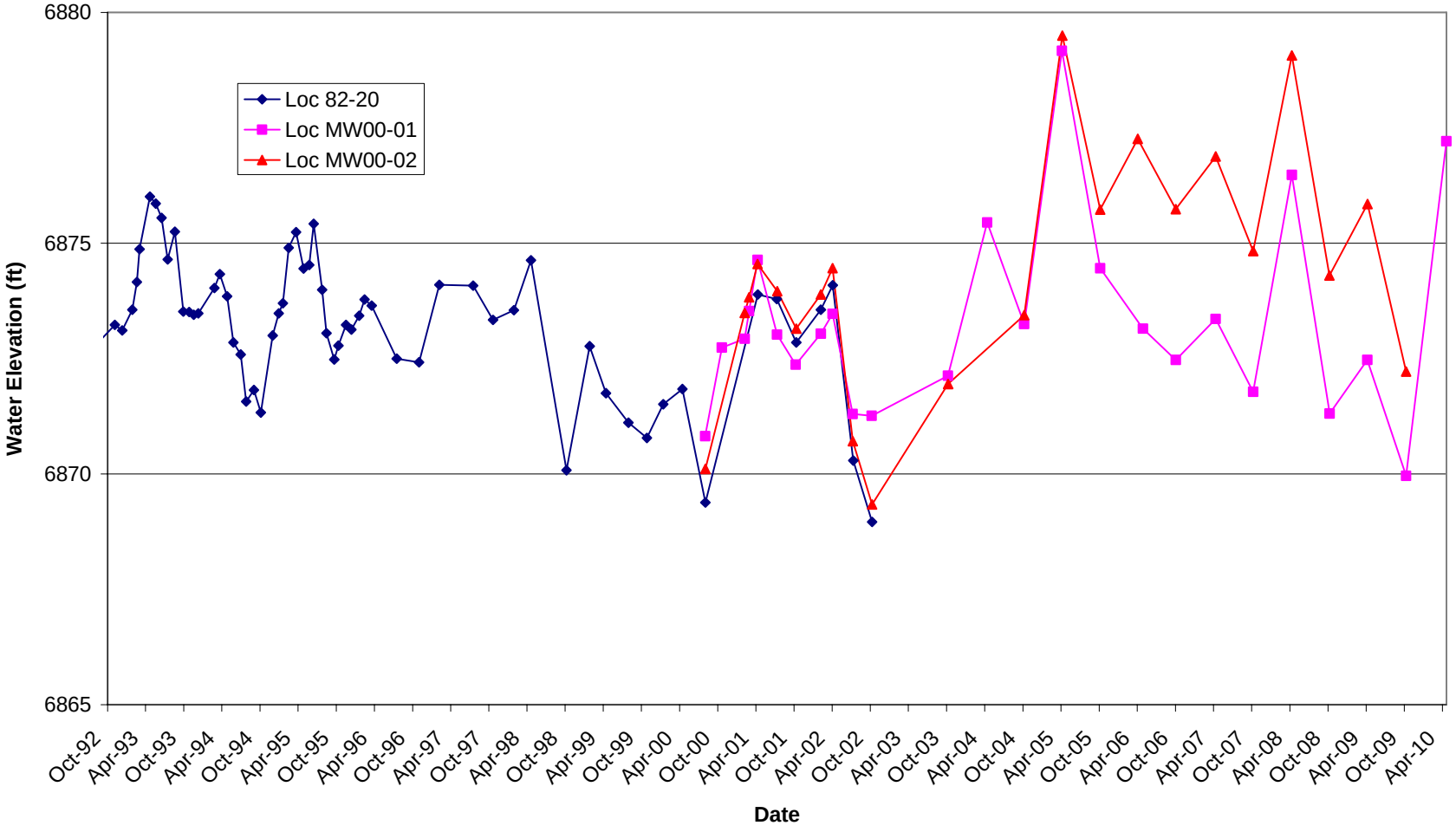

Figure 28. Water Level Hydrographs for Upgradient Alluvial Wells

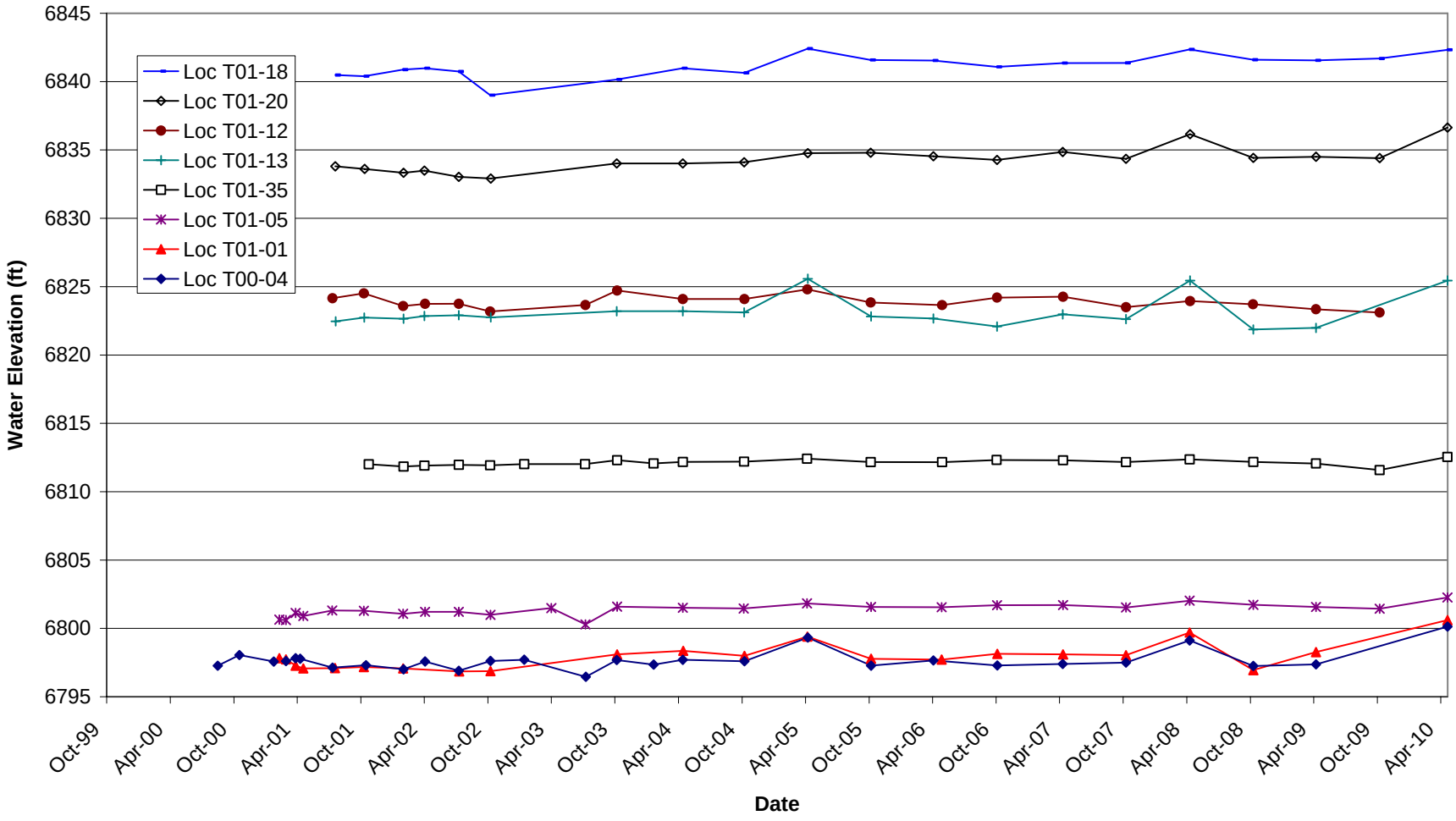

Figure 29. Water Level Hydrographs for Selected Mill Site Alluvial Wells

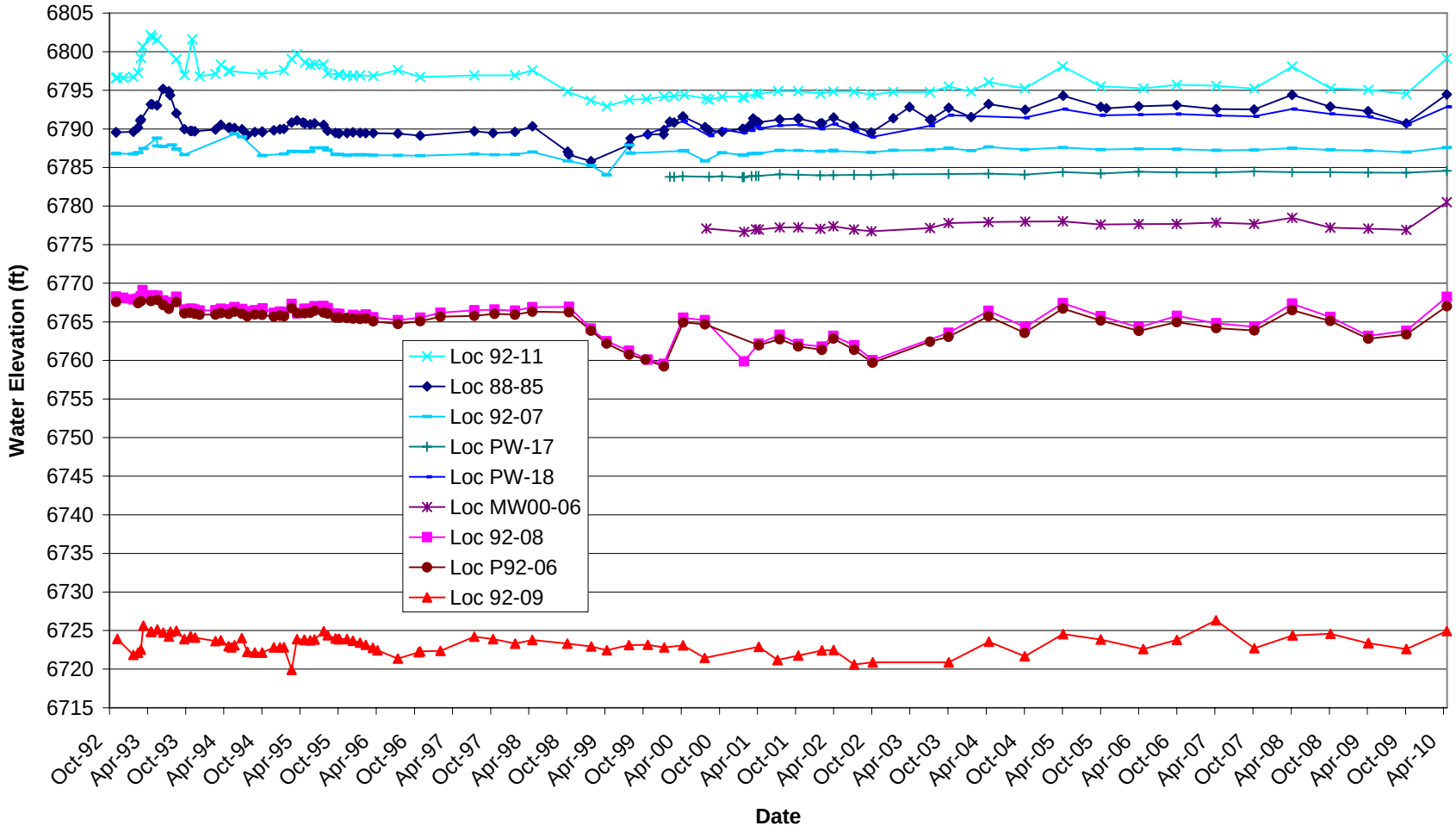

Figure 30. Water Level Hydrographs for Downgradient Wells

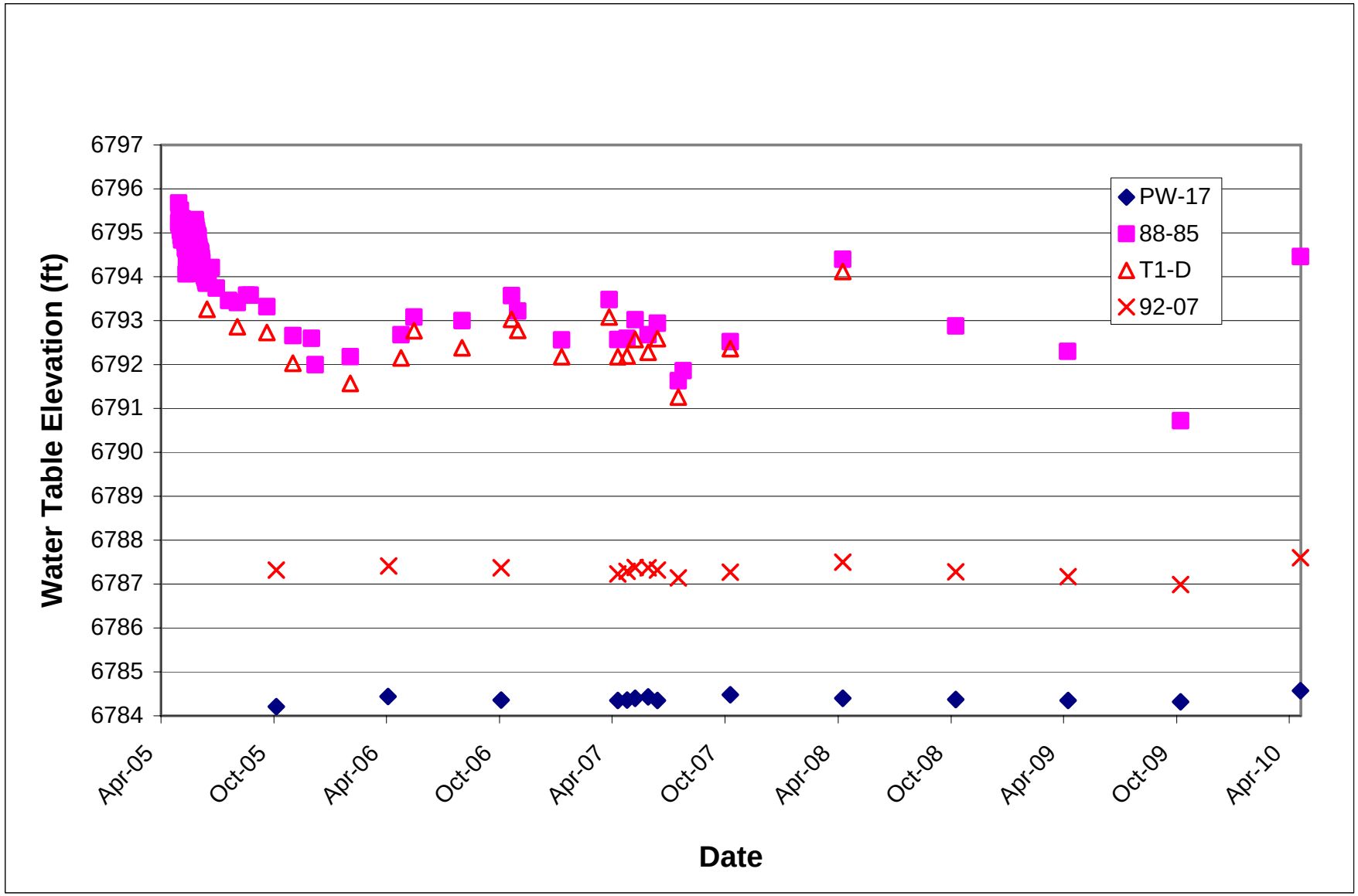

Figure 31. Water Table Trends Near the PRB

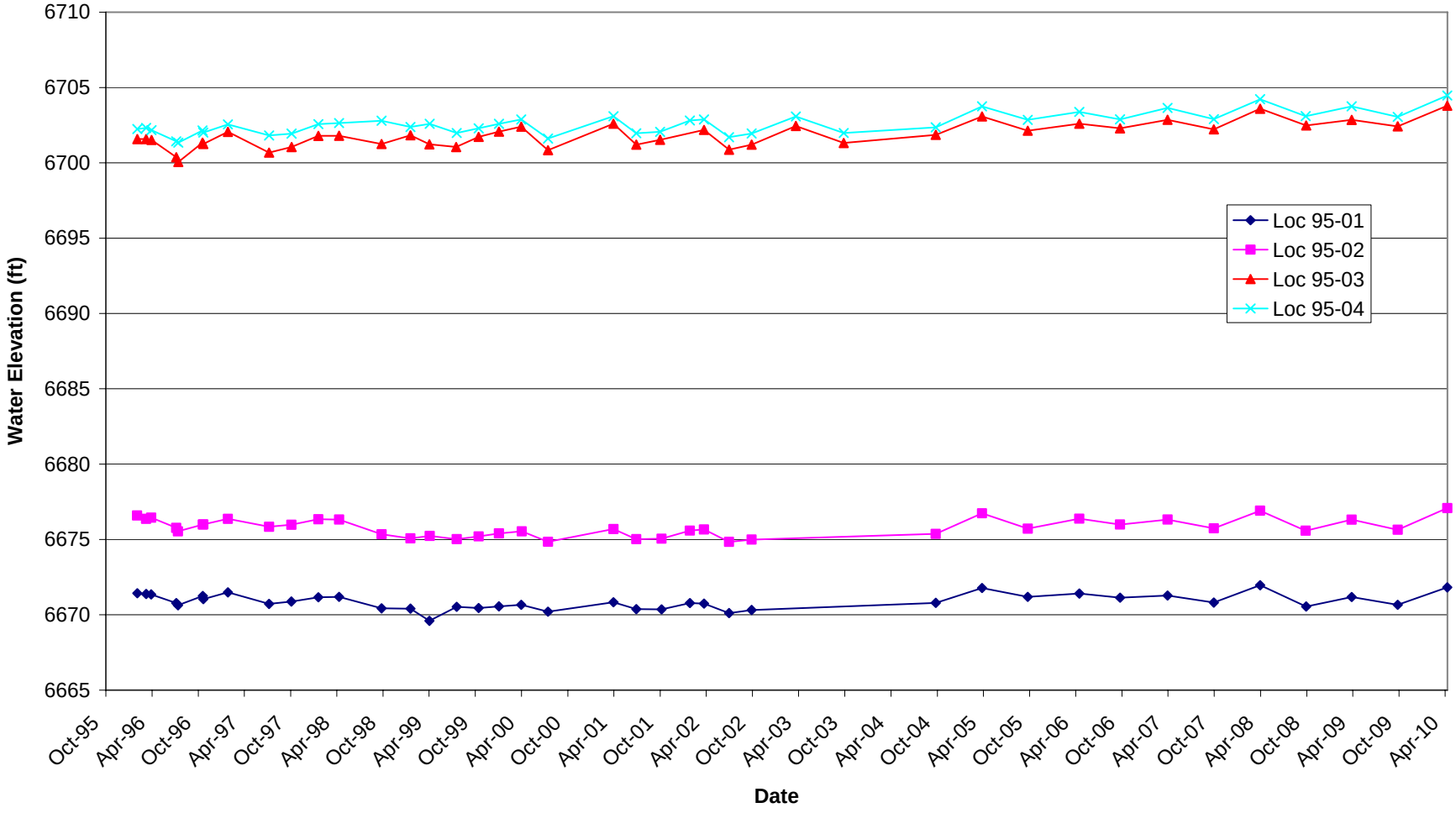

Figure 32. Water Level Hydrographs for Alluvial/Burro Canyon Well Pairs 95-01/95-02 and 95-03/95-04

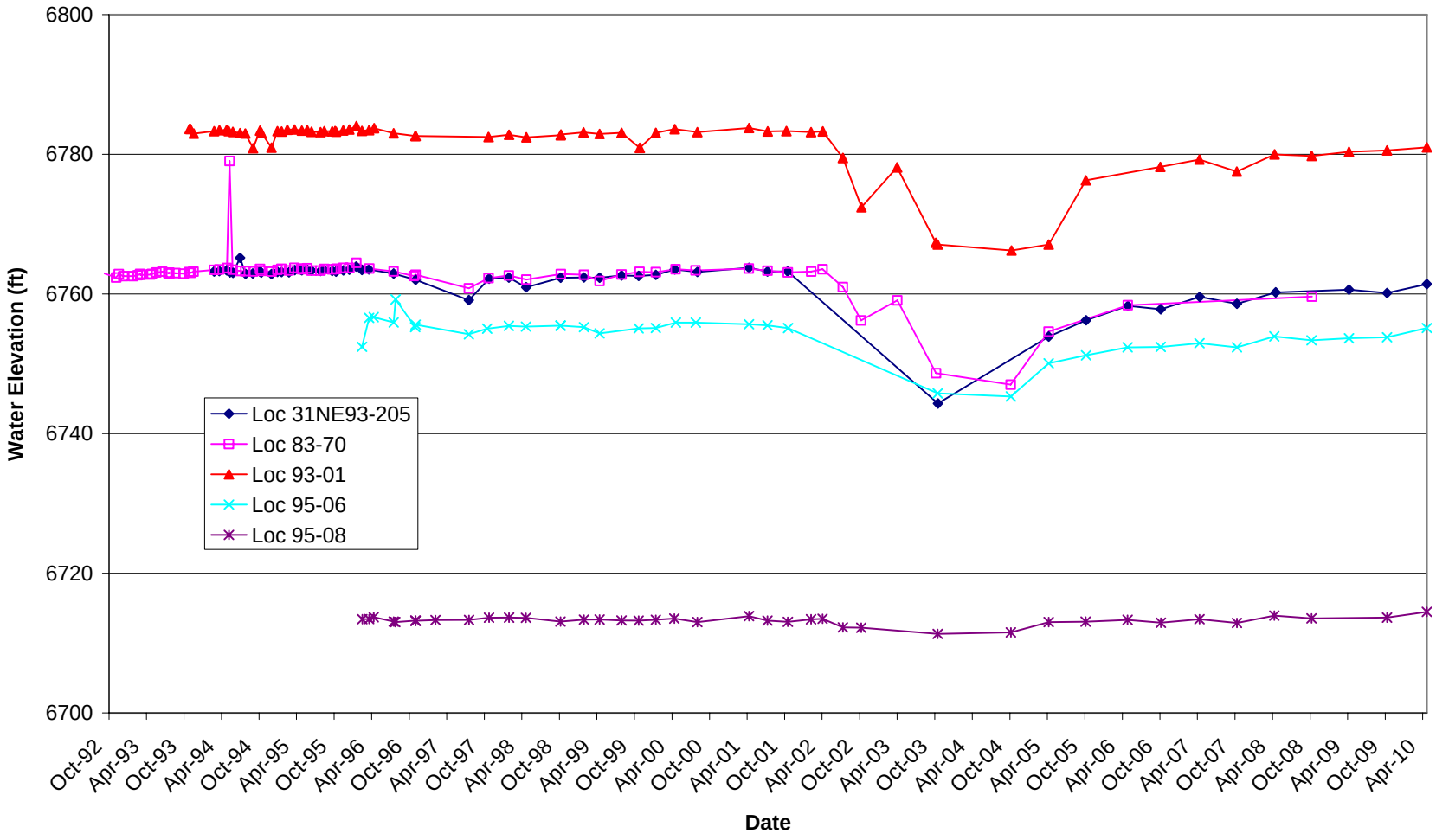

Figure 33. Water Level Hydrographs for Selected Burro Canyon Aquifer Wells

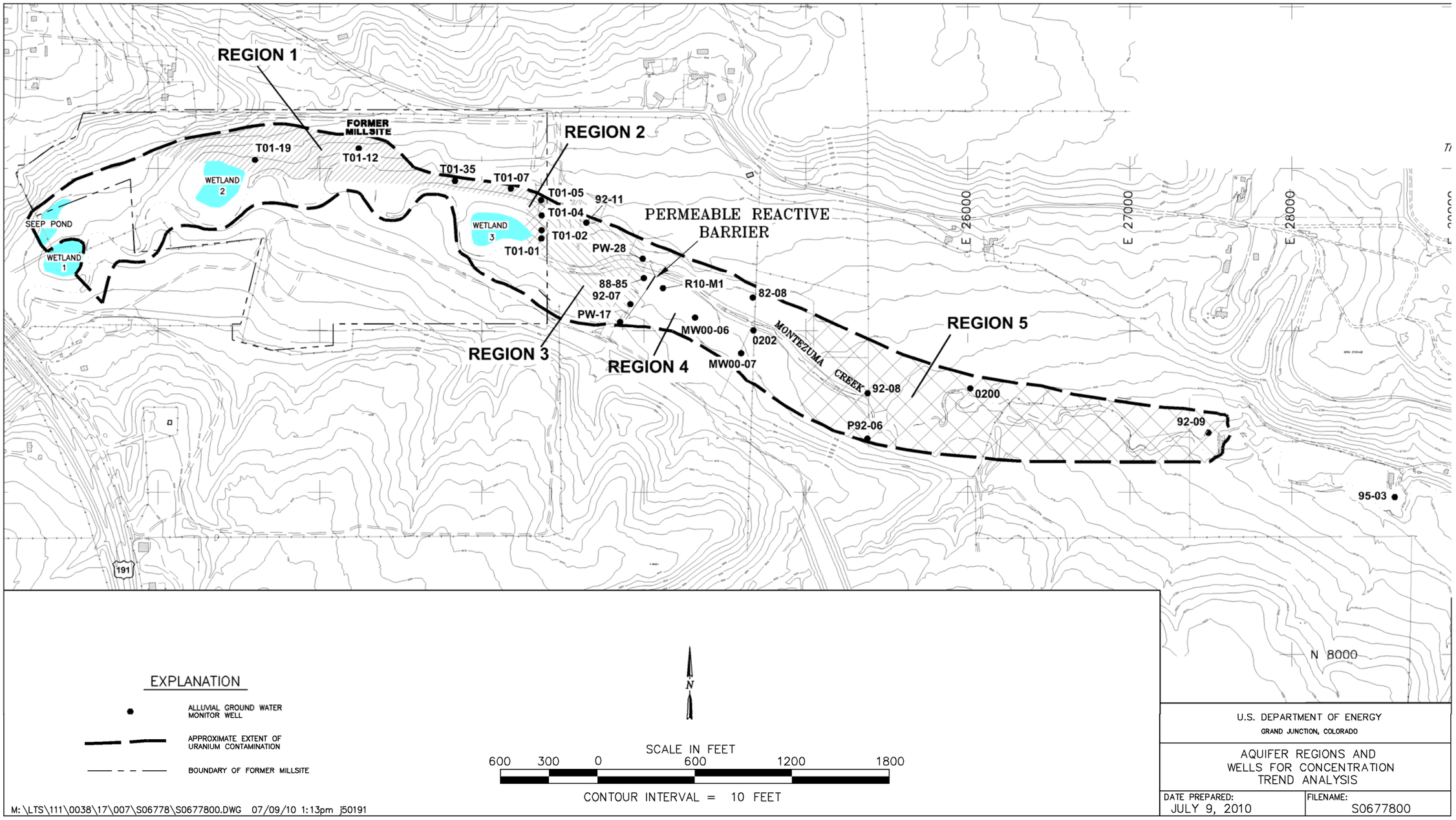

Figure 34. Aquifer Regions and Monitoring Wells Selected for Concentration Trend Analysis

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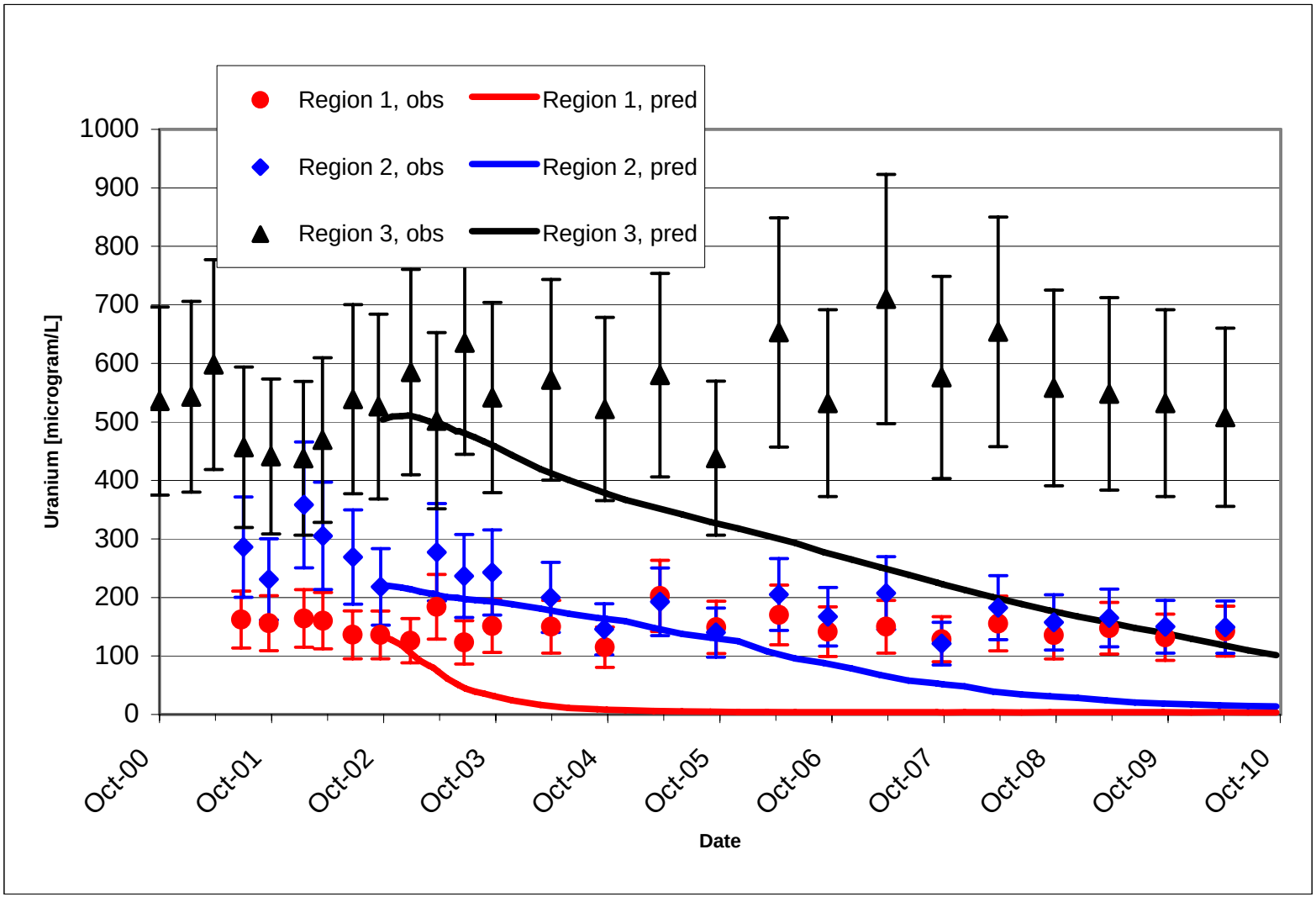


Figure 35. Comparison of Model Prediction to Observed Restoration Progress—Aquifer Regions 1 to 3

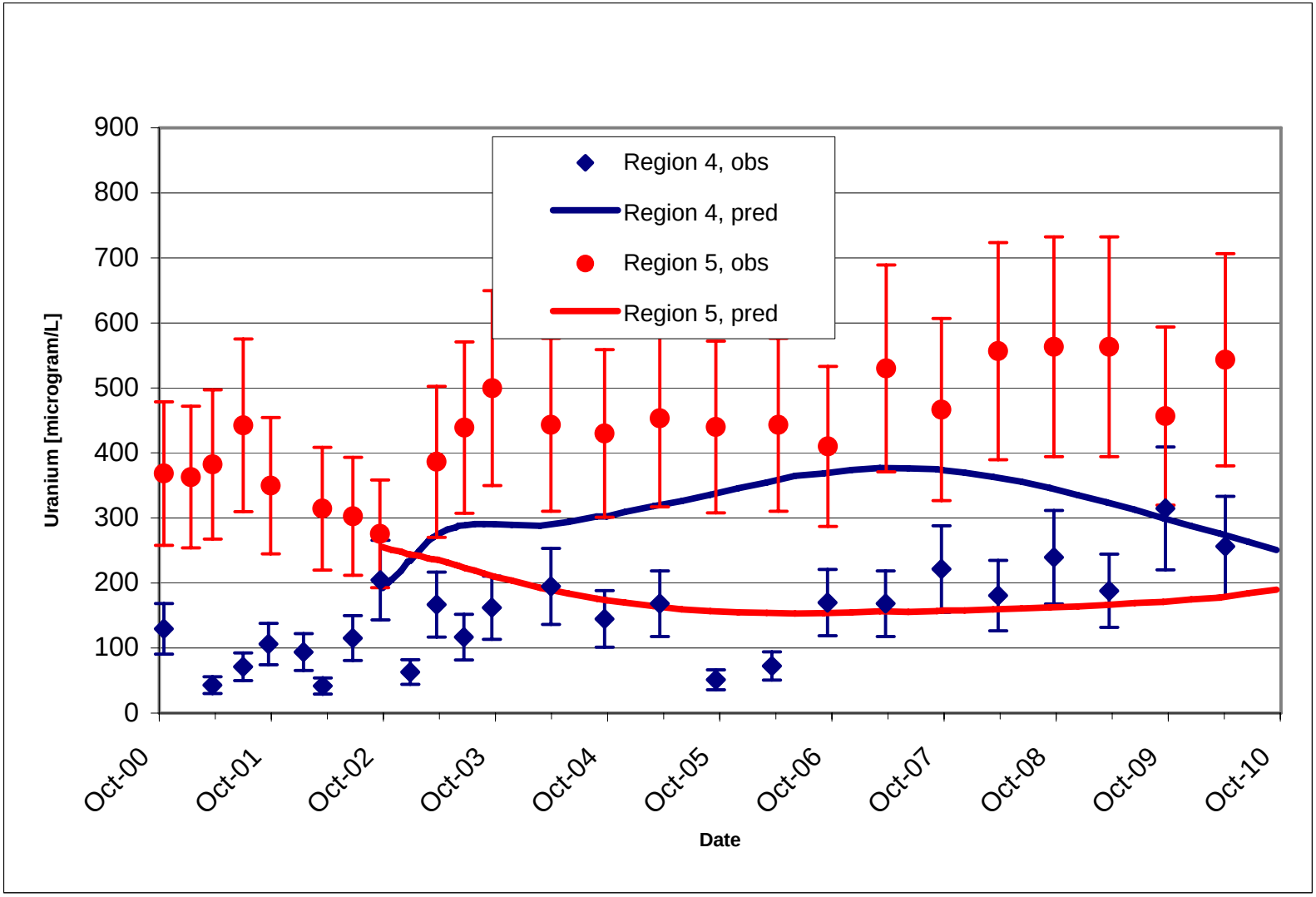


Figure 36. Comparison of Model Prediction to Observed Restoration Progress—Aquifer Regions 4 and 5

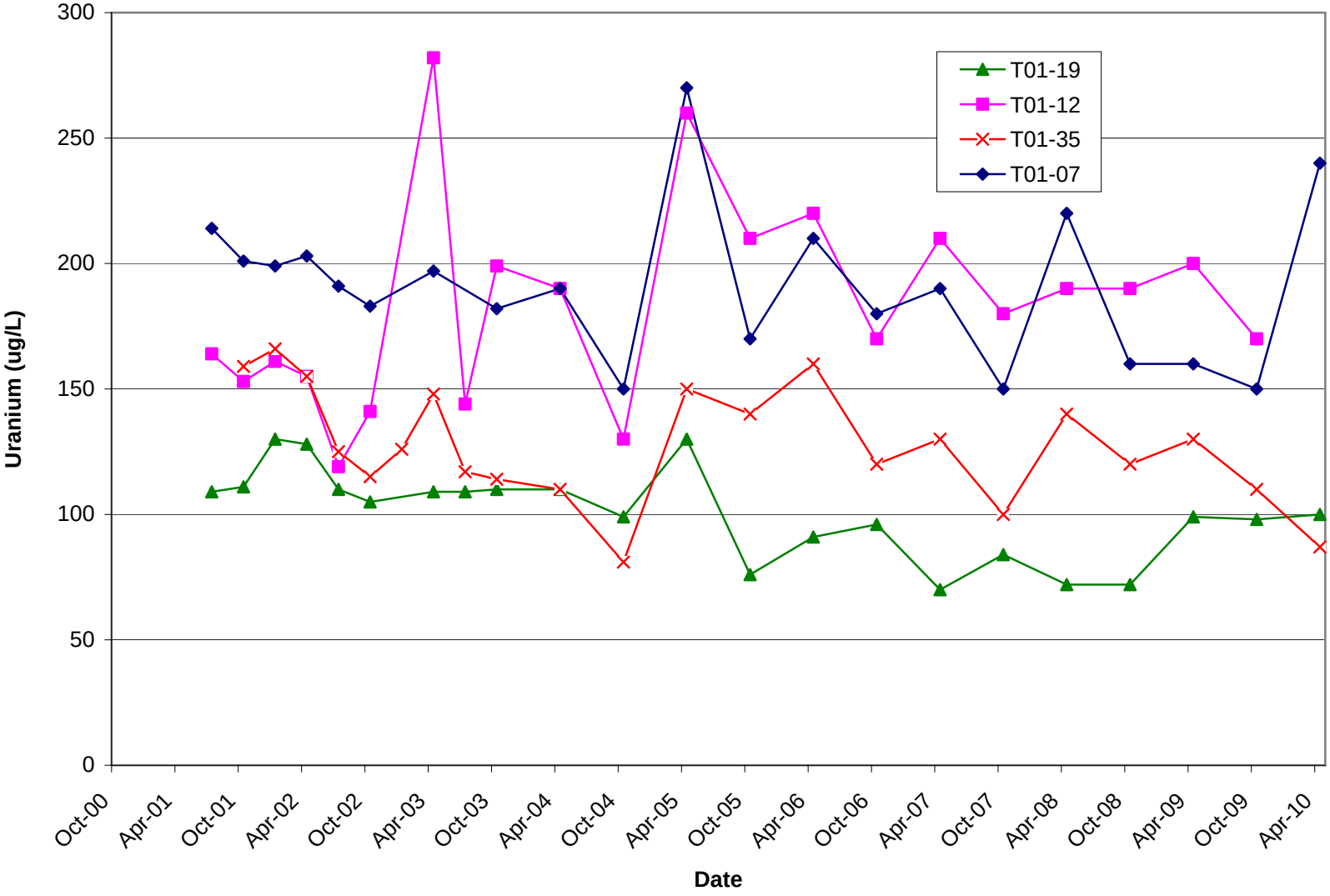


Figure 37. Region 1 Uranium Concentration Trends in Groundwater

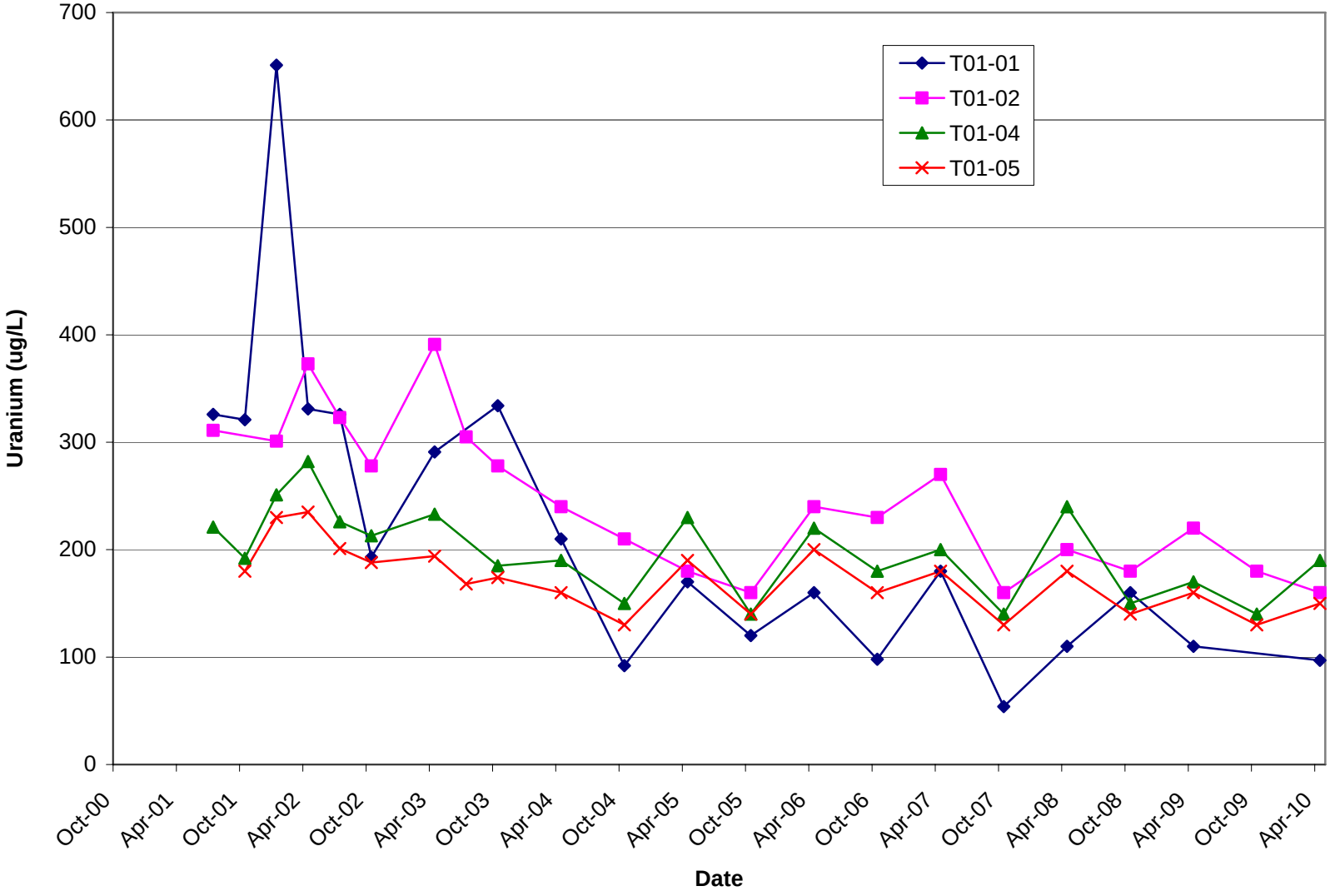


Figure 38. Region 2 Uranium Concentration Trends in Groundwater

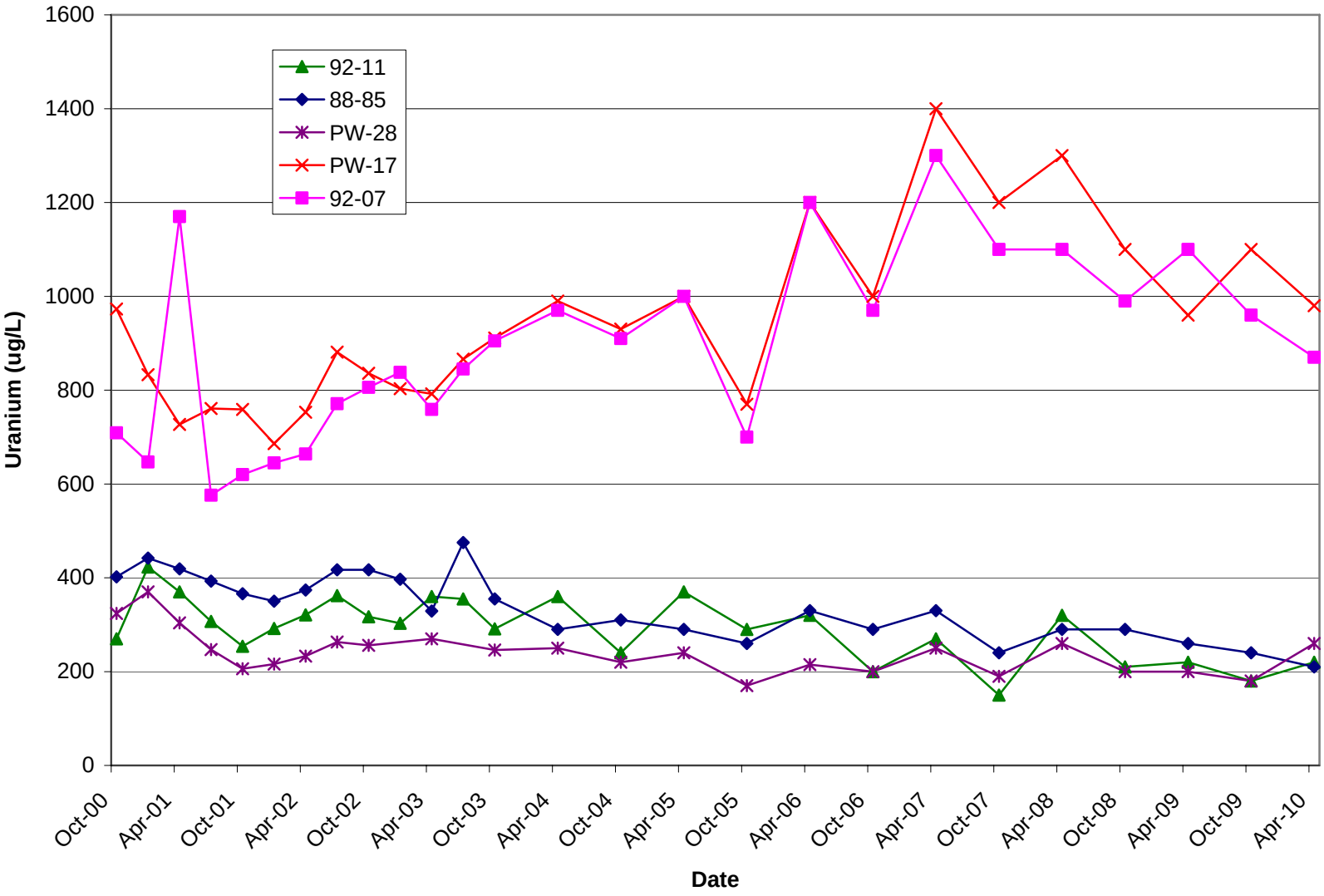


Figure 39. Region 3 Uranium Concentration Trends in Groundwater

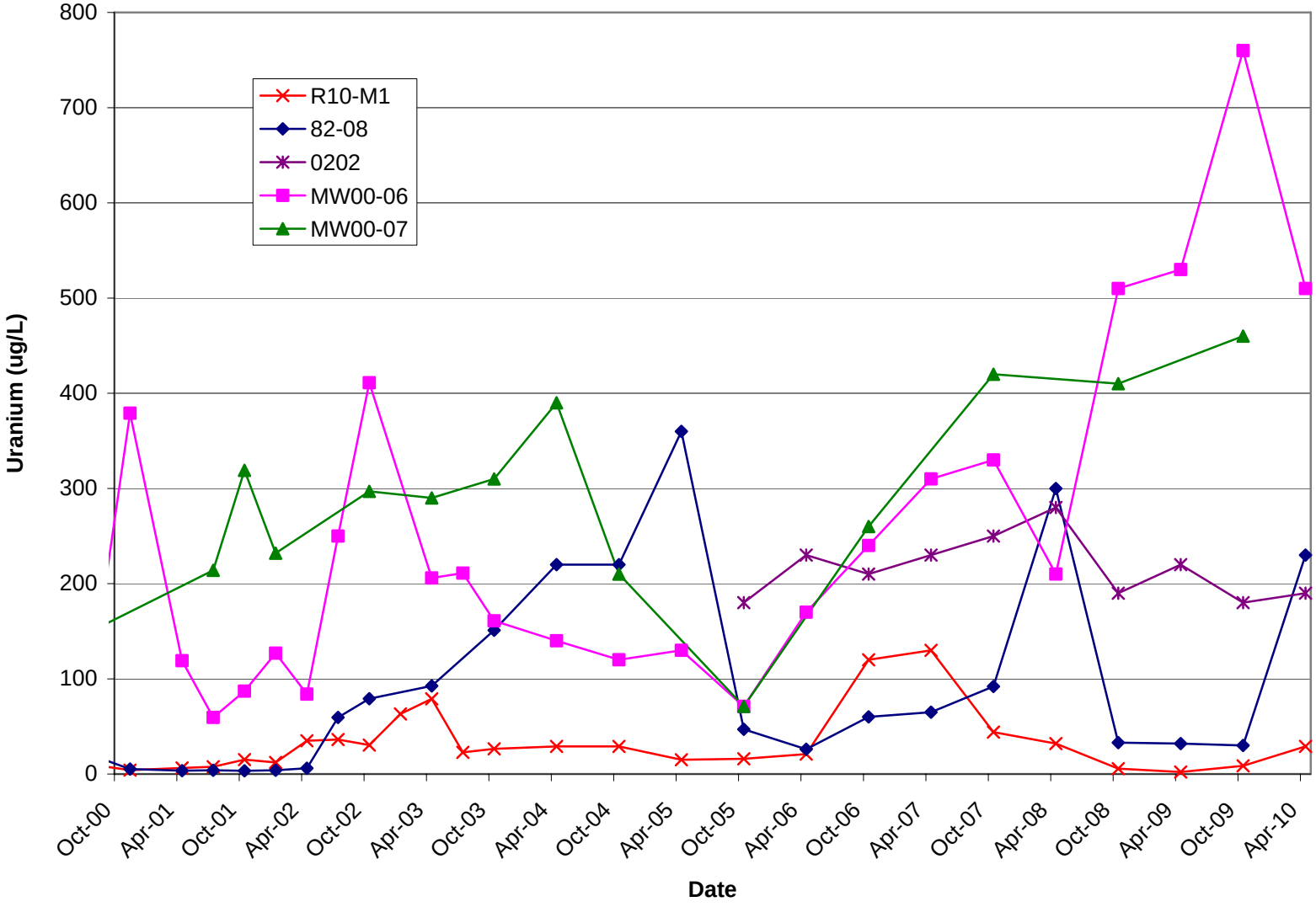


Figure 40. Region 4 Uranium Concentration Trends in Groundwater

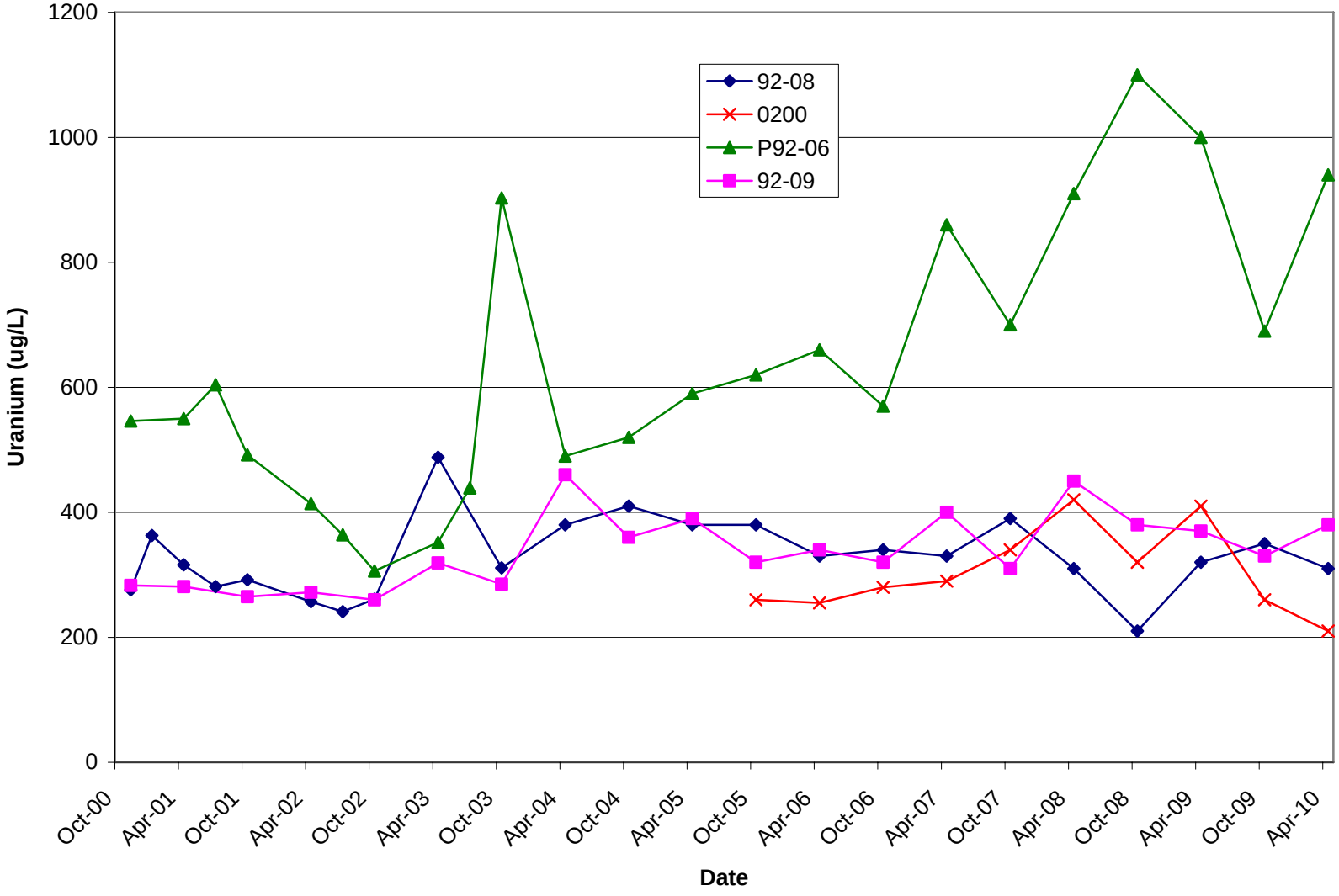


Figure 41. Region 5 Uranium Concentration Trends in Groundwater

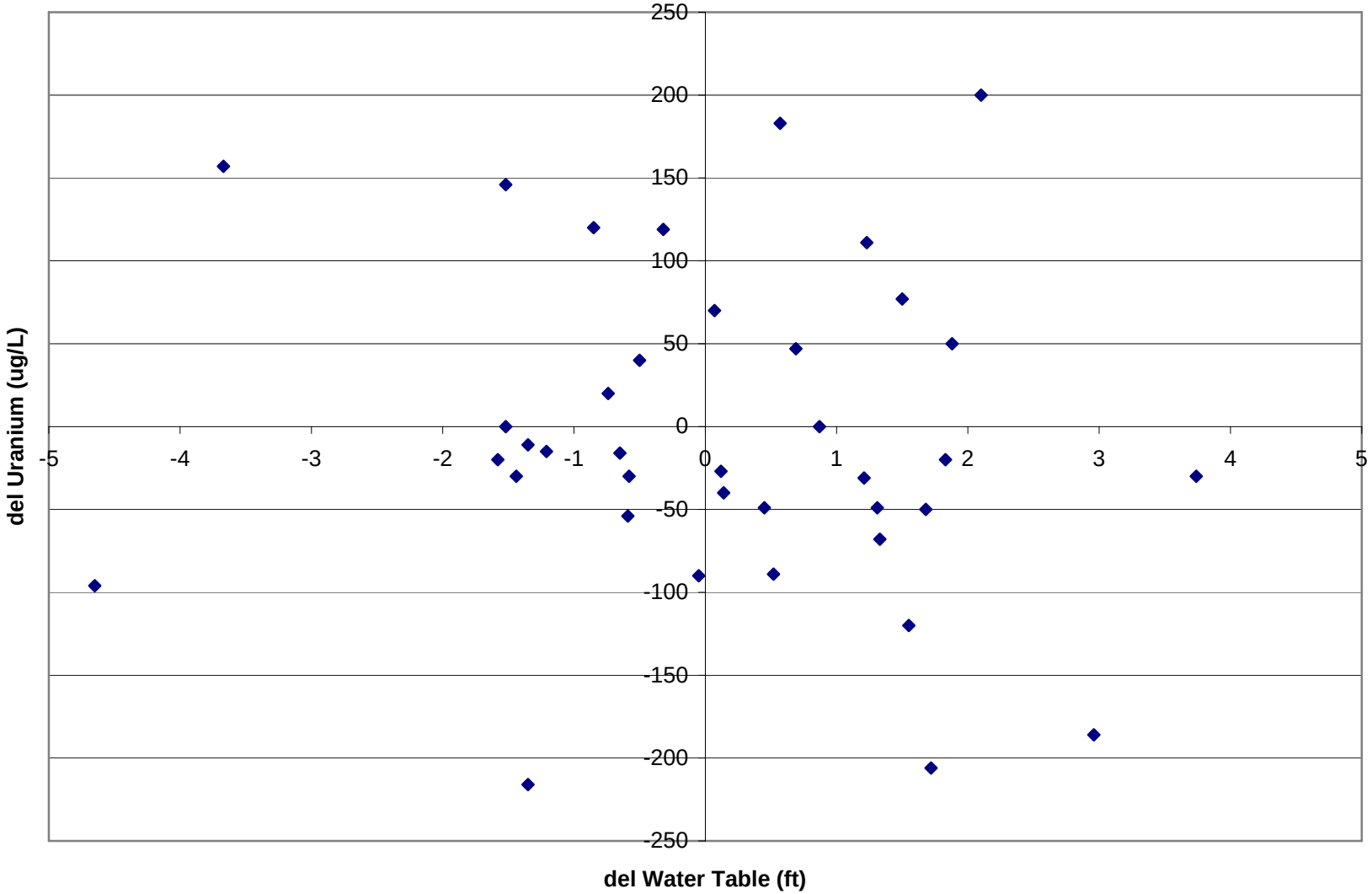


Figure 42. Uranium Concentration vs. Water Table Elevation, Well T01-01

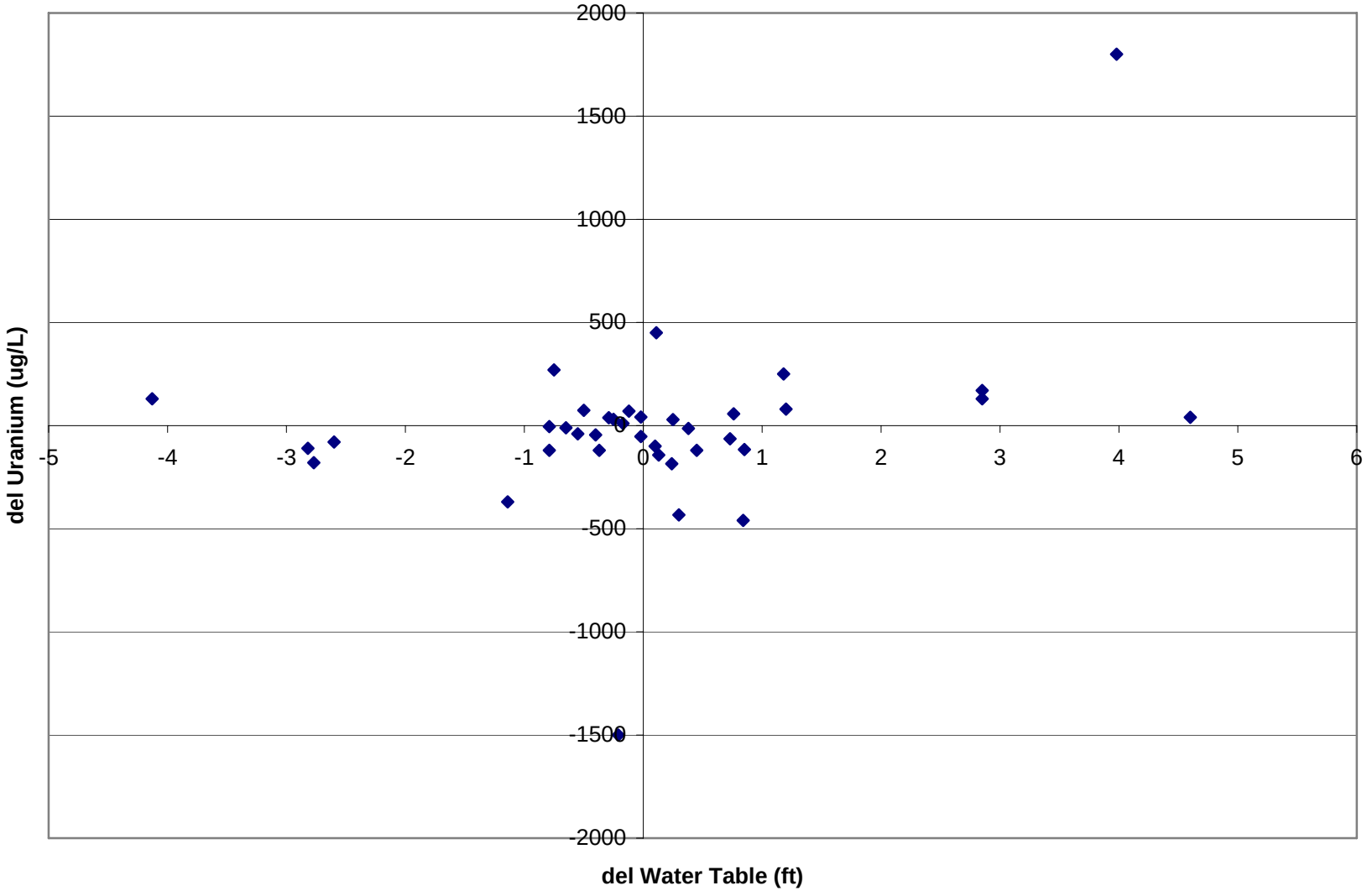


Figure 43. Uranium Concentration vs. Water Table Elevation, Well 92-11

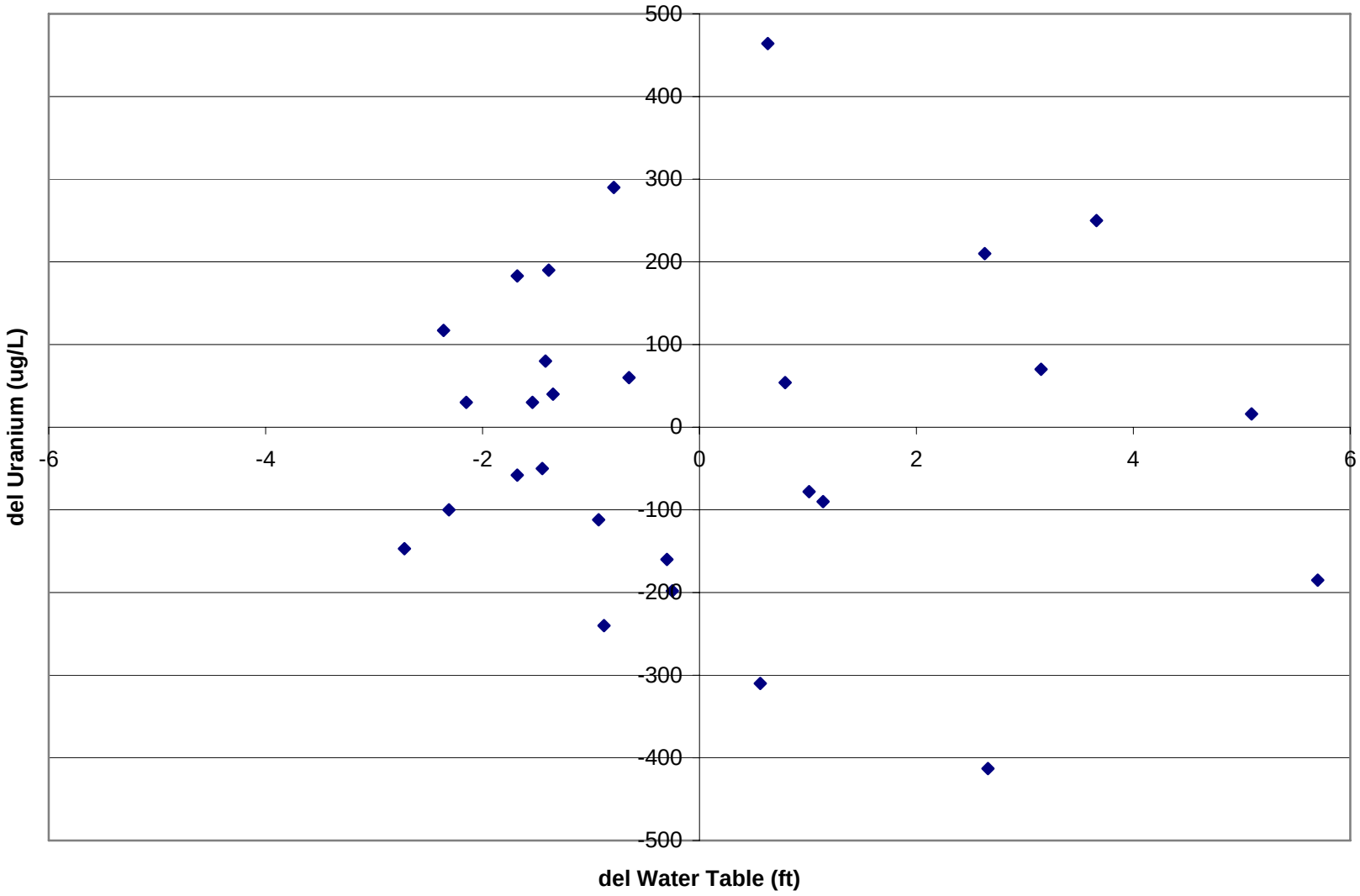


Figure 44. Uranium Concentration vs. Water Table Elevation, Well 88-85

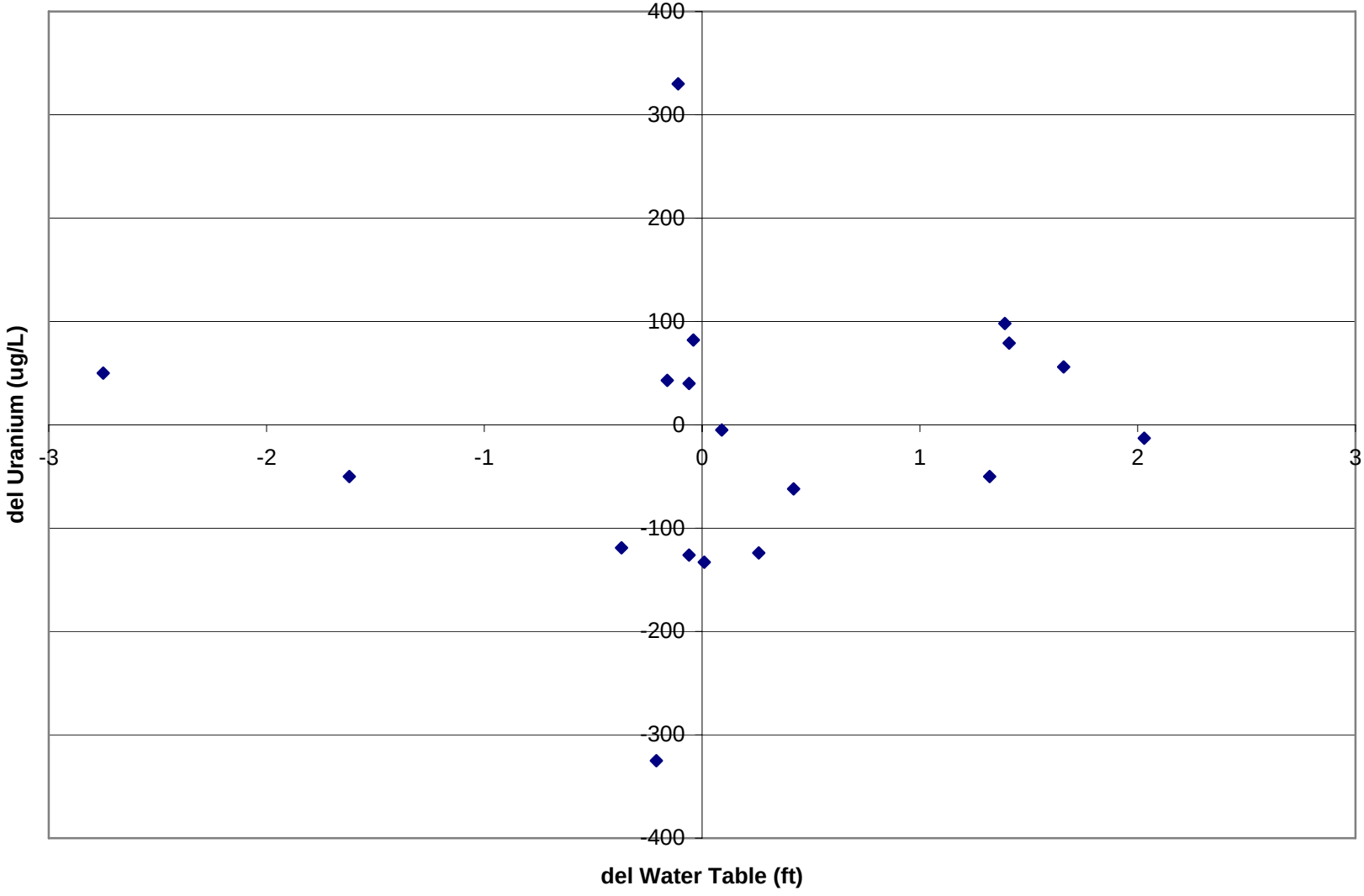


Figure 45. Uranium Concentration vs. Water Table Elevation, Well P92-06

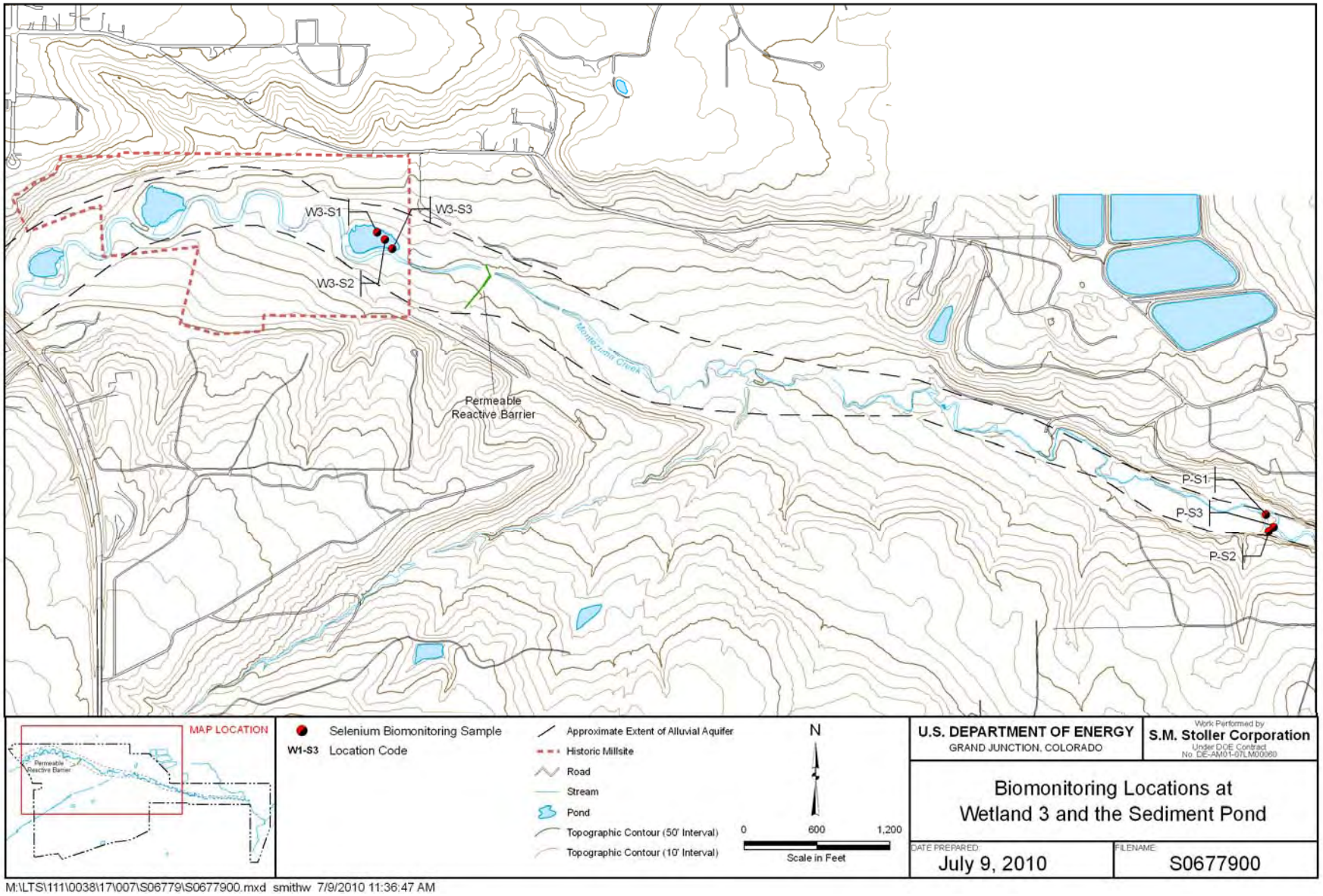
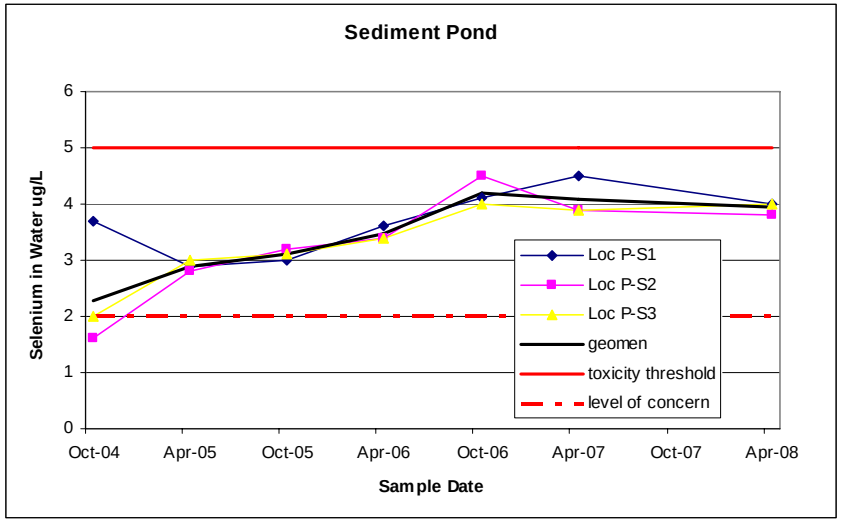
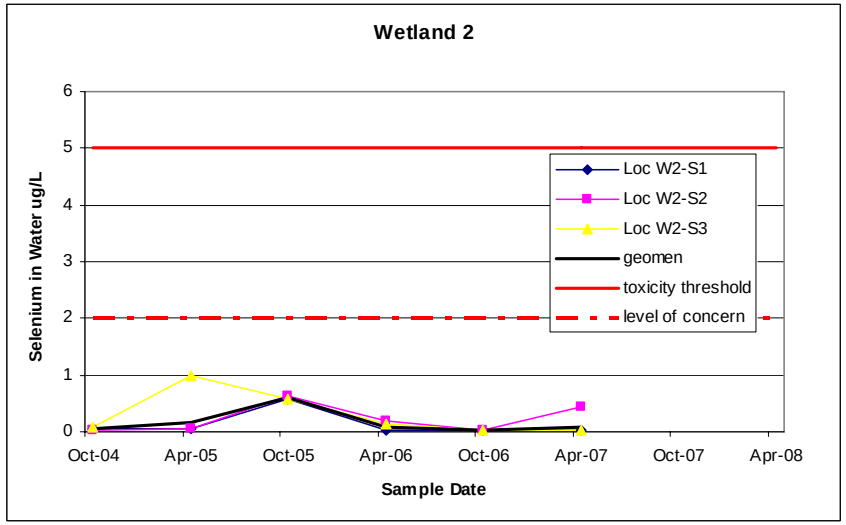
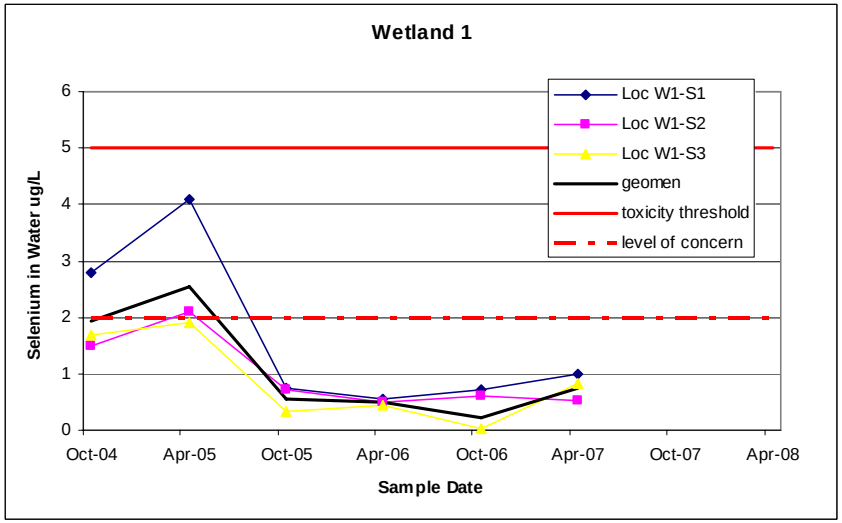


Figure 46. Biomonitoring Locations at Wetland 3 and the Sediment Pond







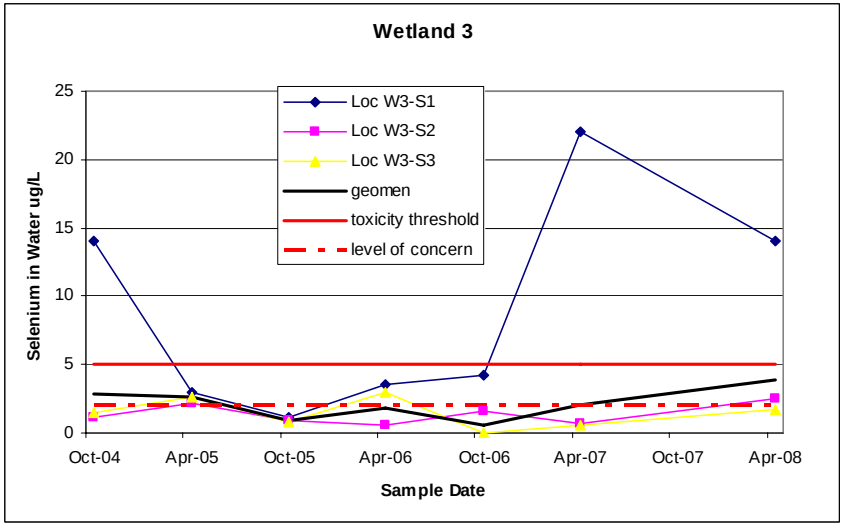
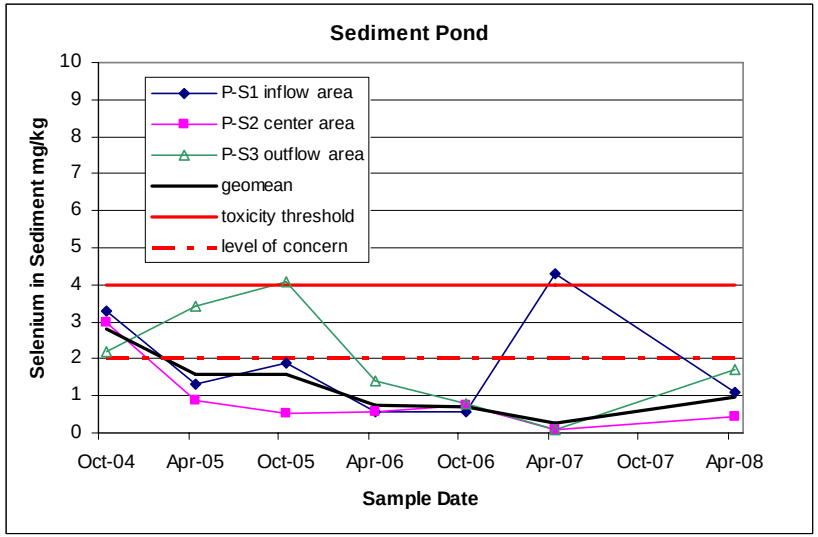
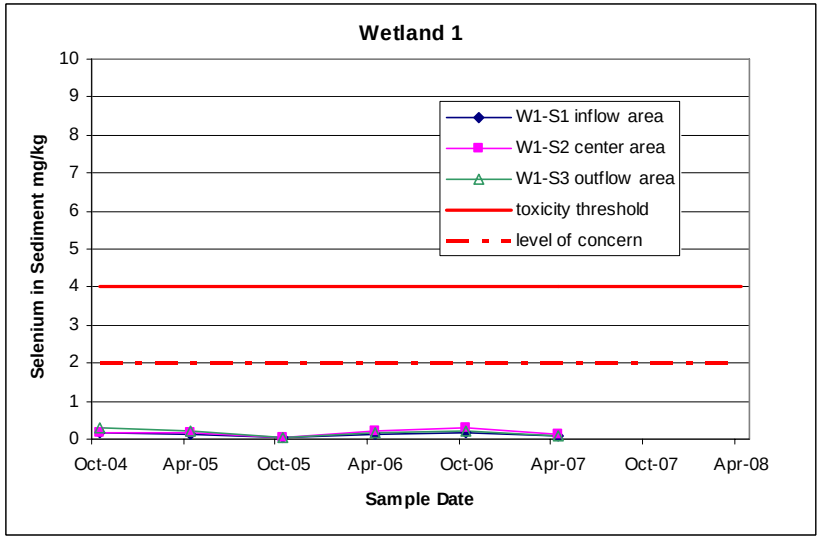
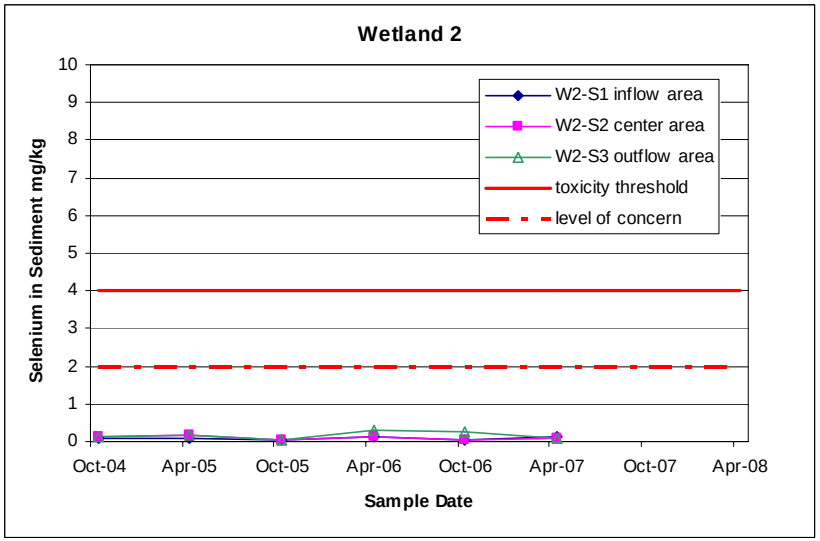


Figure 47. Selenium Concentrations in Surface Water







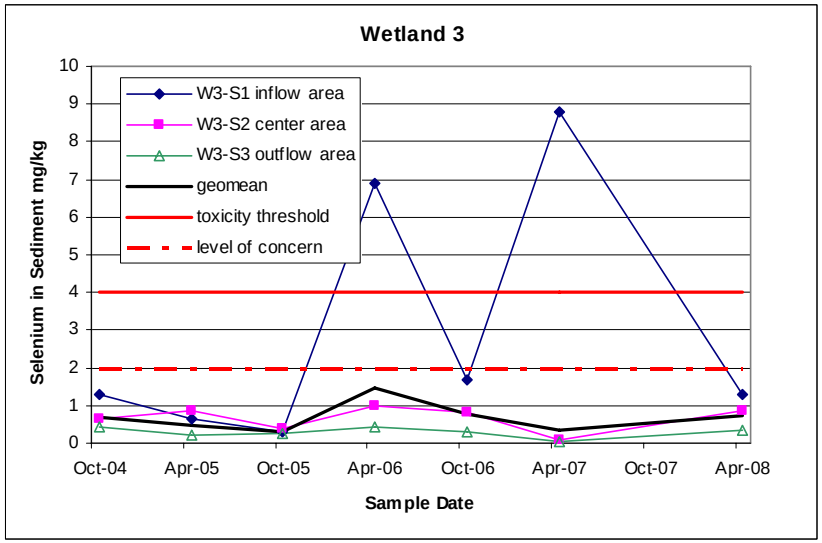
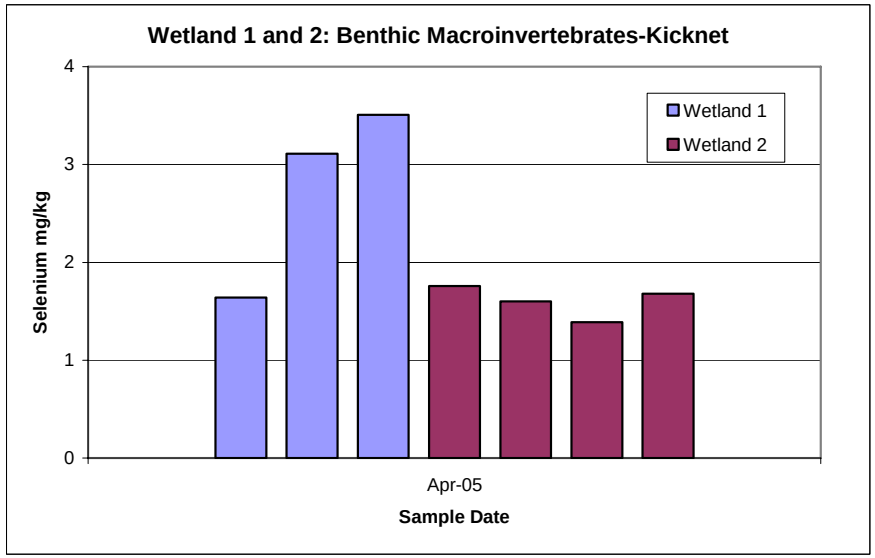
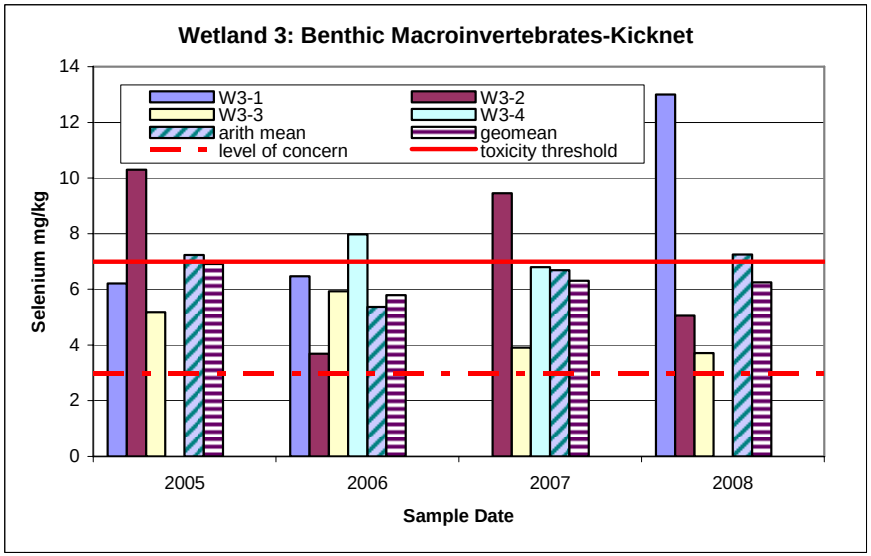
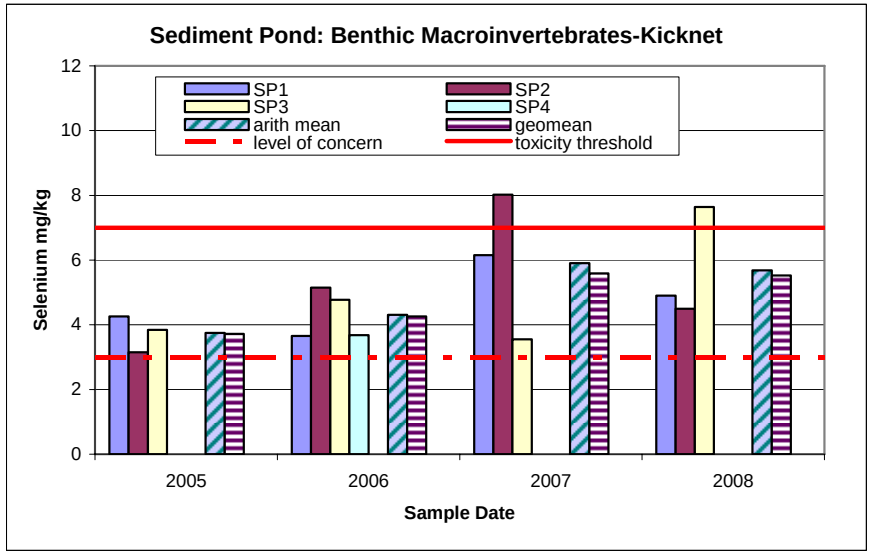


Figure 48. Selenium Concentrations in Sediment







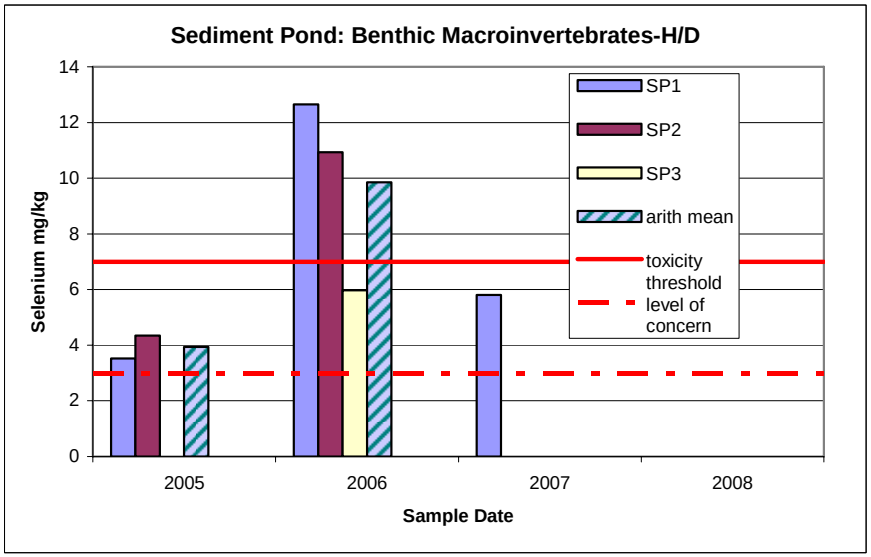


Figure 49. Selenium Concentrations in Aquatic Macroinvertebrate Tissue

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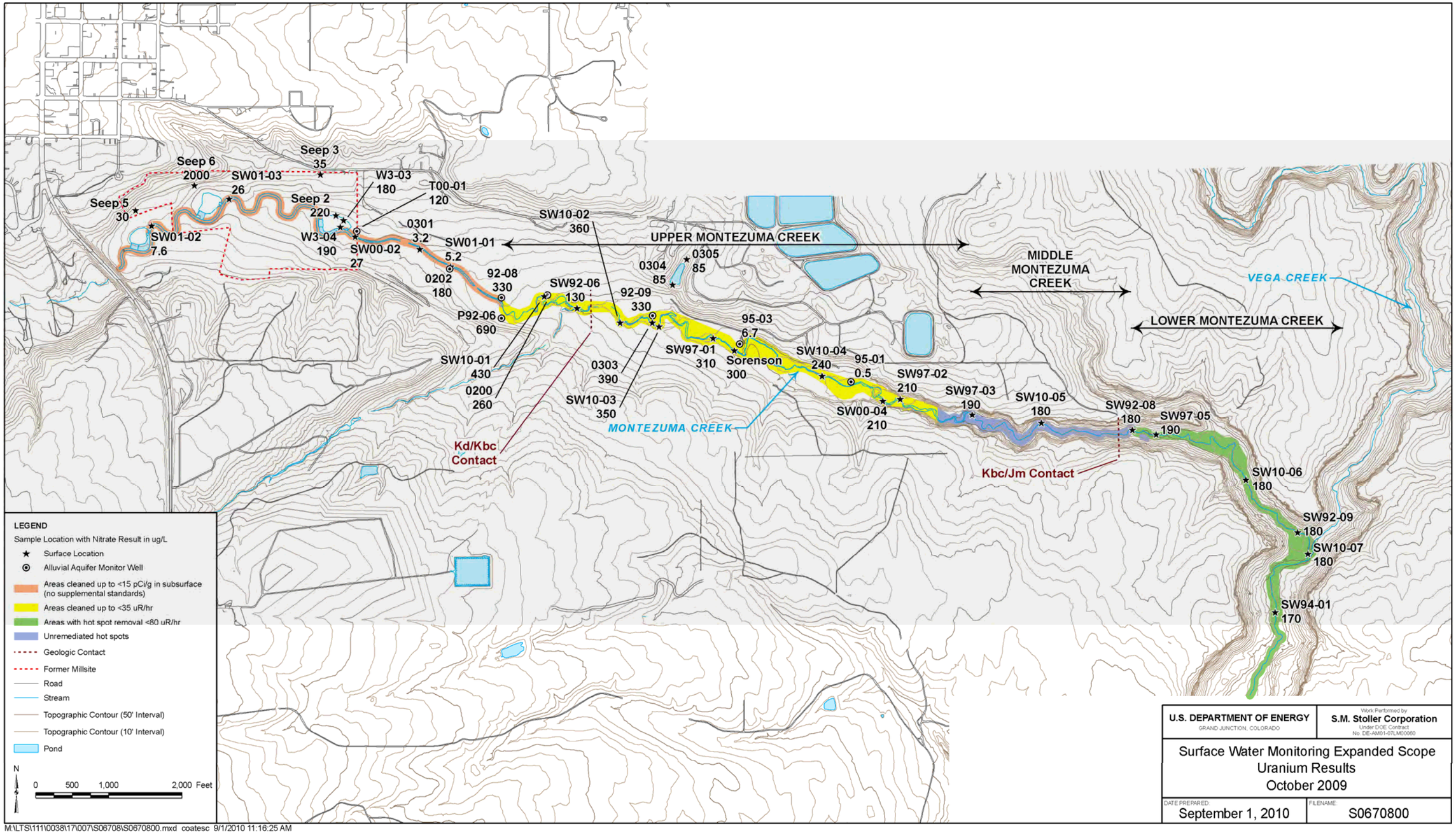

Figure 50. October 2009 Expanded Monitoring Scope—Uranium Results

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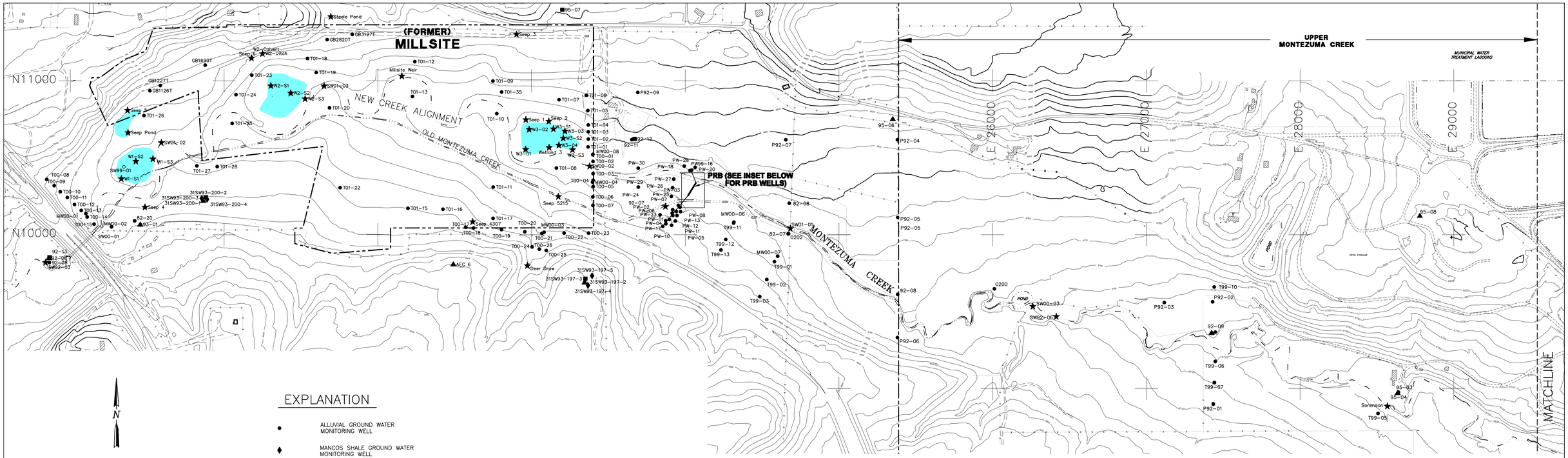
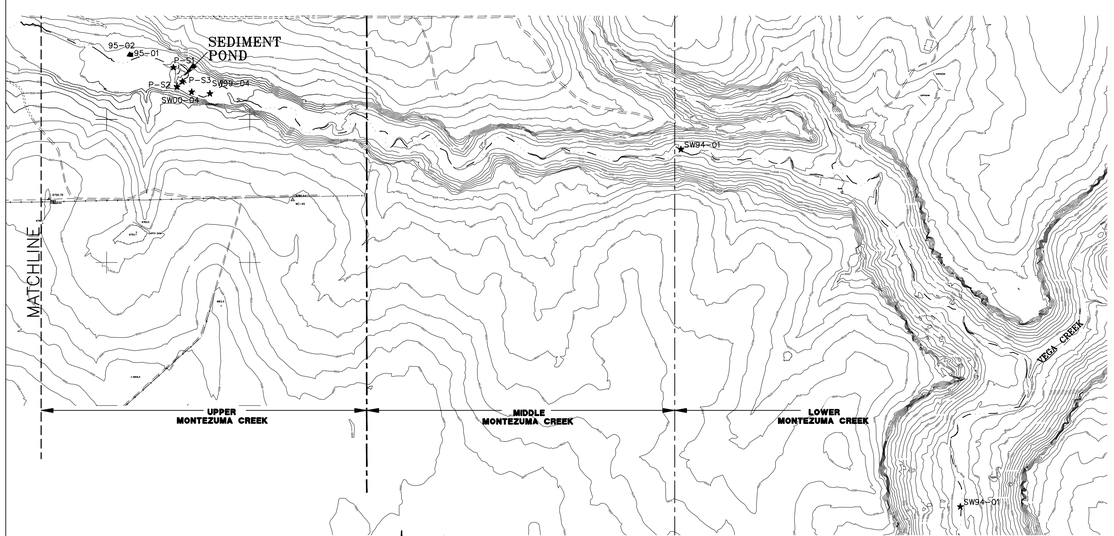


EXPLANATION

- 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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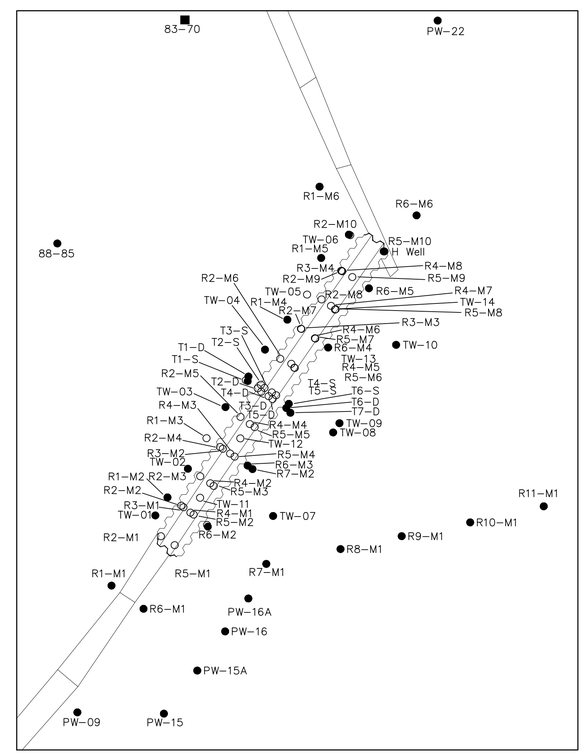
CONTOUR INTERVAL 10 FEET



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

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