LMS/MNT/S05072

Monticello Mill Tailings Site Operable Unit III Water Quality Compliance Strategy

December 2009

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1.0 Introduction

1.1 Statement of Purpose

This water quality compliance strategy, prepared by the U.S. Department of Energy (DOE) Office of Legacy Management (LM), in concurrence with the U.S. Environmental Protection Agency (EPA) and the Utah Department of Environmental Quality (UDEQ), presents the activities that will be implemented to evaluate the contingency remedy defined in *Explanation of Significant Difference for the Monticello Mill Tailings (USDOE) Site, Operable Unit III, Surface Water and Ground Water, Monticello, Utah* (ESD), March 2009.

The original remedy for Operable Unit (OU) III, monitored natural attenuation (MNA) with institutional controls (in *Record of Decision* [ROD] *for the Monticello Mill Tailings (USDOE) Site Operable Unit III, Surface Water and Ground Water, Monticello, Utah*, June 2004), did not meet ROD-specific performance criteria and was determined unlikely to meet OU III remedial action objectives (RAOs) for water quality restoration. A contingency remedy was therefore implemented under the ESD that includes a pump-and-treat enhancement to MNA. The ESD also adopted the protection standard for uranium in surface water recently enacted by the State of Utah.

This water quality compliance strategy identifies the scope of work, data use objectives, and schedule that DOE will implement to evaluate the feasibility, relative risk reduction, and cost of the contingency remedy in meeting OU III RAOs. The scope of work focuses on evaluating the performance of pump-and-treat technology and evaluating factors that have limited the progress of natural attenuation compared to the initial expectations. Table 1 summarizes the main elements of the compliance strategy and the corresponding scope, data use objectives, and schedule for evaluating the OU III contingency remedy. DOE will conduct this work in a phased approach so that successive tasks can be refined as new information is obtained.

1.2 Background Information

OU III is one of three OUs that constitute the Monticello Mill Tailings Site (MMTS), located in Monticello, Utah. MMTS was placed on the National Priorities List in 1989, and remedial actions have proceeded pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). MMTS is the site of a former uranium- and vanadium-ore processing mill (mill site) that operated from 1942 to 1960. The MMTS ROD, signed in August 1990, designated OUs I and II for remediating radiologically contaminated soil, sediment, and debris on the mill site (OU I) and on the peripheral properties (OU II). Those remedial actions were completed in 1999. All OU I and II wastes are encapsulated at the engineered repository located 1 mile south of the former mill site and operated by LM.

Table 1. Compliance Strategy Key Work Elements

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

The MMTS ROD also designated OU III to address mill-related contamination of surface water and groundwater, stipulating that remedy selection would follow the completion of a CERCLA Remedial Investigation (RI) and Feasibility Study to characterize the nature and extent of contamination in the hydrologic environment, to establish baseline risk assessments, and to evaluate groundwater remedial action alternatives. OU III occupies the valley of Montezuma Creek from and including the mill site to a distance of approximately three miles downstream (east) of the mill site. The primary focus of OU III is the shallow alluvial aquifer and Montezuma Creek, a small perennial stream that flows through the site. Figure 1 illustrates important features of OU III.

The RI report was issued in September 1998 (*Monticello Mill Tailings Site Operable Unit III Remedial Investigation*, September 1998); however, the companion Feasibility Study report was not completed beyond draft status because of ongoing OU I and OU II remedial actions that would significantly and unpredictably impact groundwater and surface water. This status precluded an accurate forecast of risk associated with these media, thereby deferring selection of a remedy for OU III. EPA and UDEQ instead concurred with DOE to implement interim measures under an interim remedial action (IRA) ROD (in *Record of Decision for an Interim Remedial Action at the Monticello Mill Tailings Site, Operable Unit III—Surface and Ground Water, Monticello, Utah,* August 1998.) and to complete the Feasibility Study at a later date when site conditions had stabilized.

The interim measures included implementing institutional controls to restrict use of contaminated groundwater, continued characterization of hydrogeologic conditions and the nature and extent contamination, study of hydrologic and geochemical factors that affect fate and transport of contaminants at OU III, and implementing a treatability study of in situ permeable reactive barrier (PRB) technology using zero-valent iron (ZVI) as the treatment medium. The site groundwater model and the human health and ecological risk assessments were also 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* (RIA/FFS), January 2004. The updated groundwater model predicted a restoration period by natural processes of 42 years, beginning in 2002. This outcome, in conjunction with source removal completed under OUs I and II, and no reasonable exposure scenario identified in the risk update, provided the technical basis in selecting the MNA remedy.

1.2.1 Basis of Contingency Remedy

DOE is implementing the ESD contingency remedy because the progress of water quality improvement does not meet the performance criteria specified in the ROD. Appendix B of the ROD (*Performance Evaluation Plan for MNA at Monticello Mill Tailings Site Operable Unit III*) stipulates a specific analytical method for comparing observed uranium concentrations to those predicted by the OU III groundwater model as a measure of restoration progress. For that method, the aquifer is conceptually divided into five regions distinguished by contaminant distribution and hydrogeology. Appendix B of the ROD and the subsequent ROD-specified annual groundwater reports describe the aquifer regions and method of trend evaluation in detail.

The ROD further states that as of October 2004, if observed uranium concentrations, averaged for each region, significantly exceed the corresponding model-predicted average over three consecutive sampling events, aquifer restoration is not progressing as expected. This condition was first recognized and reported in *Monticello Mill Tailings Site Operable Unit III Annual Ground Water Report October 2005 through April 2006*, September 2006. As required by the ROD, DOE then reanalyzed water quality data using formal statistical methods, which confirmed that despite measurable progress in some regions of the aquifer, groundwater restoration would likely require much more time than the 42-year period allowed by the ROD (in *Monticello Mill Tailings Site Operable Unit III Analysis of Uranium Trends in Ground Water*, August 2007).

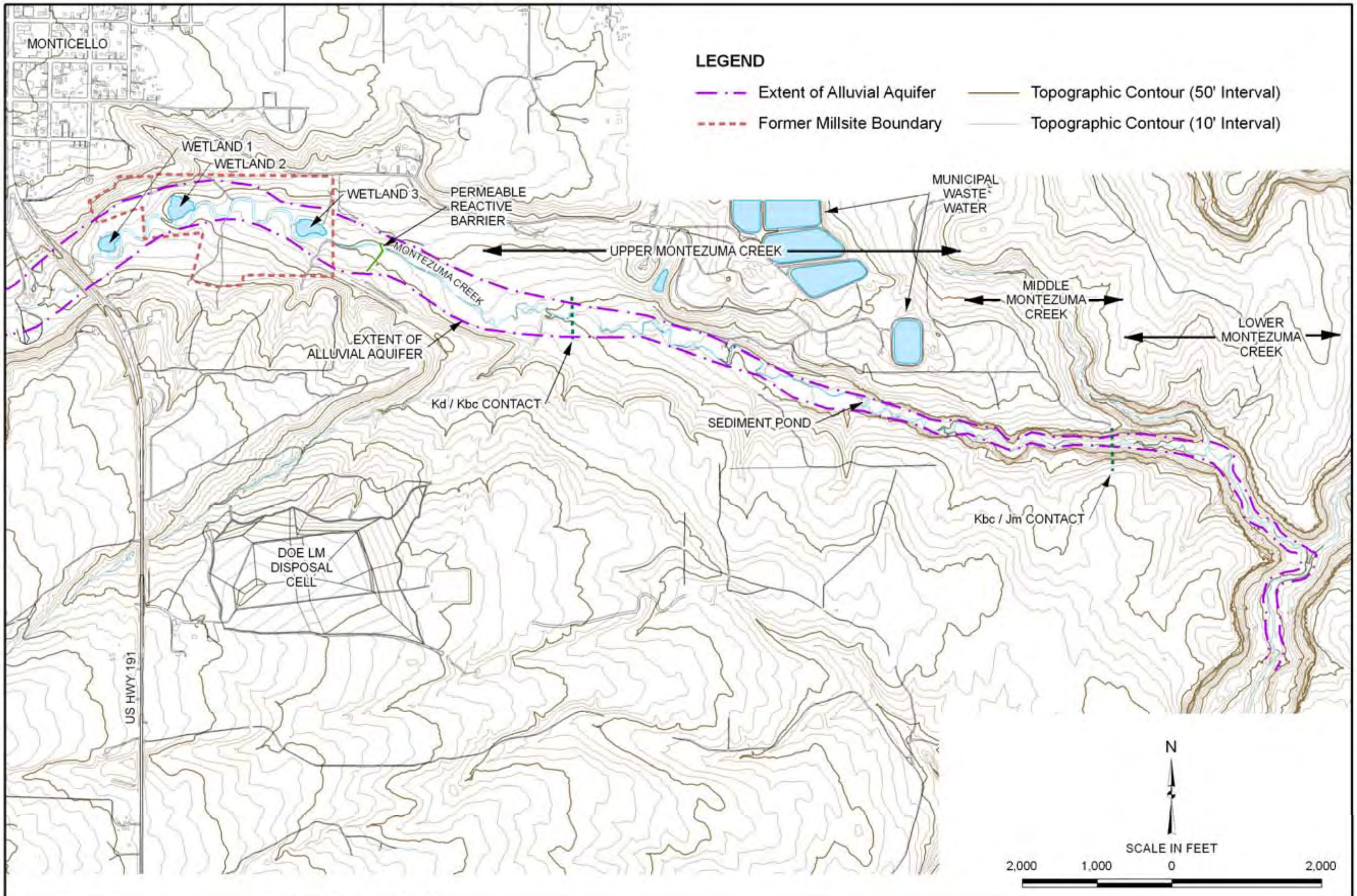

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Figure 1. Features of the Monticello Mill Tailings Site

Based on that finding, and in accordance with the contingency plan provided in the ROD, DOE then proposed response actions at the Federal Facilities Agreement (FFA) meeting in March 2008. These discussions lead to adopting the pump-and-treat contingency remedy that is documented in the ESD and to a DOE commitment to further evaluate natural attenuation factors at OU III.

1.3 Physical Setting and Site Conditions

Activities to characterize hydrologic conditions and the nature and extent of contamination associated with the former mill began in 1982. Among more recent efforts, comprehensive studies of the groundwater/surface water system are documented in the RI and the RIA/FFS. The following descriptions of site conditions are summarized from the RI and RIA/FFS. This information is also provided in the annual groundwater reports.

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. The population of Monticello is about 2,000 permanent residents. 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 at the site 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-pine and juniper trees, sagebrush, and rabbit brush. Willow thickets and other phreatophytes line much of the riparian zone of Montezuma Creek.

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

1.3.1 Surface Water and Groundwater Hydrology

Montezuma Creek forms at the confluence of North and South Creeks about one-quarter mile west of the mill site. The valley of Montezuma Creek is underlain by a shallow, thin aquifer composed of channel-fill silt, sand, and gravel (alluvial aquifer). Bedrock beneath the valley floor is generally within 10 to 15 ft of ground surface, and the saturated thickness of the alluvial aquifer averages about 5 ft. Groundwater flow is west to east following the slope of the valley. Where contaminated, the alluvial aquifer is underlain by low-permeability, variably saturated bedrock of the Dakota Sandstone. Contaminated water in the alluvial aquifer does not migrate to the deeper Burro Canyon Sandstone aquifer.

Montezuma Creek is strongly gaining on the mill site, resulting from the discharge of alluvial aquifer groundwater. There are three constructed wetlands on the mill site that are hydraulically connected to the creek; these wetlands are also strong groundwater sinks. On the former mill site, the alluvial aquifer is recharged by underflow from the west and from suspected leakage of water lines (secondary and sanitary sewer) known to traverse the north margin of the valley. DOE monitors several prominent seeps (Seeps 3, 5, and 6; Figure 2) that are expressed in a conspicuous spring zone downslope of the water utilities.

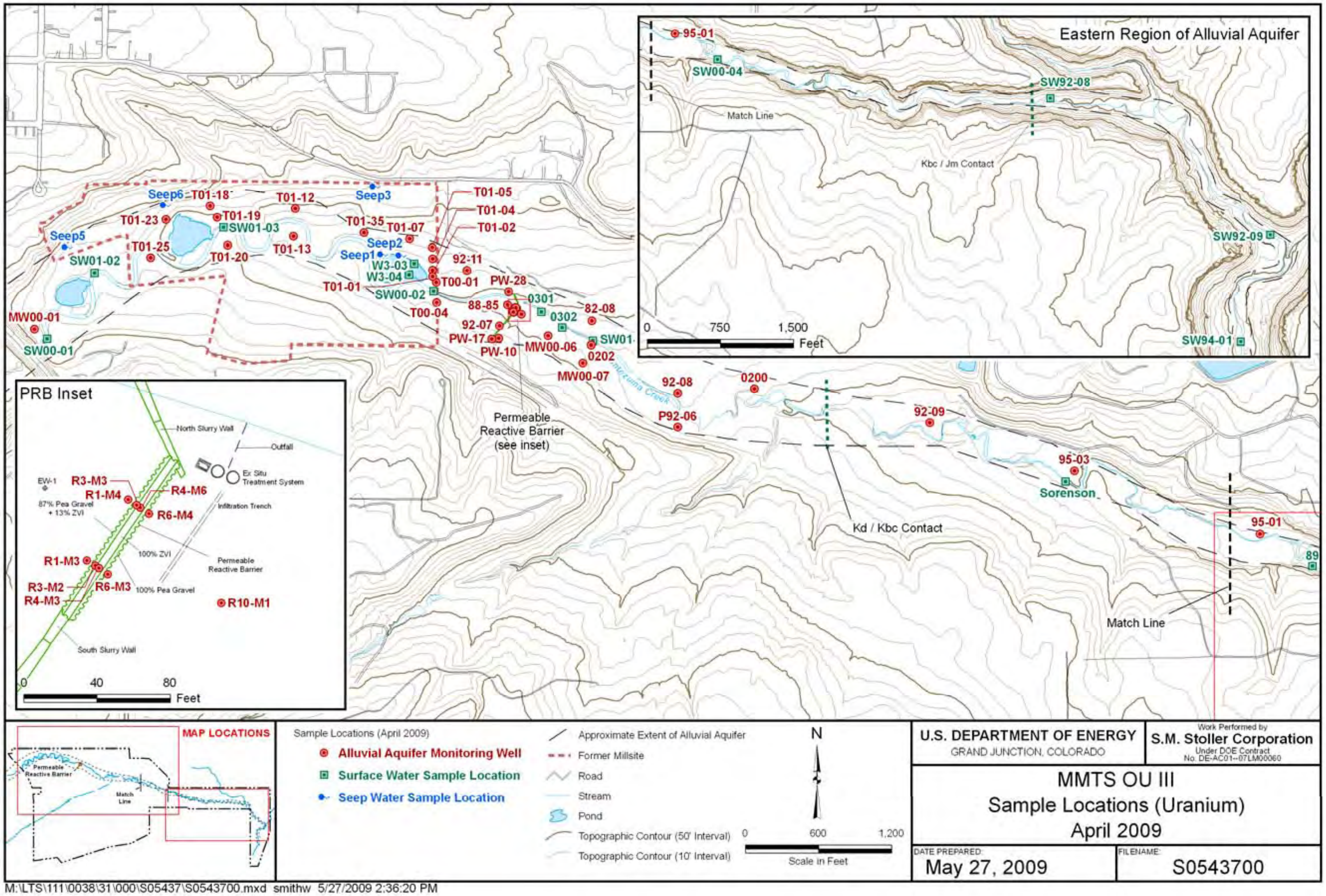

Figure 2. OU III Water Quality Monitoring Locations, April 2009

During restoration of the mill site, the aquifer was reconstructed to occupy a narrow (30 to 40 ft wide) channel of granular fill placed on the bedrock. Groundwater saturation in this corridor is only several feet thick. This corridor, through which Montezuma Creek flows, occupies the central and lowest portion of the valley, thus accounting for the gaining stream condition. Flow of alluvial groundwater at the eastern boundary of the mill site is about 15 to 20 gallons per minute (gpm). Analysis of the OU III water budget is documented in the RIA/FFS as supporting information to the conceptual and numerical groundwater models.

In the agricultural area east of the mill site, the alluvial aquifer widens to several hundred feet (north to south). The bedrock surface beneath the valley floor is relatively flat but steepens sharply at the valley margins. Farther east at the head of the canyon, the alluvial aquifer narrows to about 100 ft and remains thin. This constriction forces some alluvial groundwater into Montezuma Creek. Also in this reach, the Dakota Sandstone aquitard has been eroded by the creek, allowing some semiconfined groundwater in the Burro Canyon aquifer to discharge to the overlying alluvium and to Montezuma Creek. These conditions, which cause dilution of uranium in the aquifer and also displace alluvial groundwater into Montezuma Creek for further dilution, 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 1.

The canyon remains narrow for nearly 1 mile farther east as the creek incises the Burro Canyon Sandstone (approximately 120 ft thick). Numerous seeps near the base of the canyon walls in this reach attest to groundwater discharge from the Burro Canyon aquifer. The canyon then widens, coincident with the exposure of slope-forming mudstones of the Morrison Formation as the upper bedrock. The approximate location of the contact between the Burro Canyon Sandstone (Kbc) and Morrison Formation (Jm) in the valley floor is indicated in Figure 1. At the downstream boundary of OU III the alluvial aquifer pinches out entirely in rugged canyon terrain. All alluvial groundwater presumably discharges to the creek by this point or is absorbed by the bedrock formation.

1.3.2 Groundwater and Surface Water Contamination

Contaminants of concern (COCs) for OU III surface water and groundwater are arsenic, manganese, molybdenum, nitrate, selenium, uranium, vanadium, and gross alpha and beta activity. OU III water quality monitoring occurs twice yearly (April and October), and results are reported yearly. Table 2 lists COC remediation goals 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) Project, or a value derived from the OU III human health risk assessment, as indicated in the table. Surface water remediation goals correspond to current water quality standards for the State of Utah. At the time the OU III ROD became effective, there was no standard for uranium in surface water. Utah has since adopted 30 picocuries per liter 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 (ARARs) for OU III, and risk factors to derive a risk-based goal are isotope-specific.

Table 2. 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 N)	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: OU III ROD.
[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. 30 pCi/L converts to approximately 44 µg/L.
[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.

Remedial actions for OU I removed the primary source of groundwater and surface water contamination (mill tailings) in 1998 and 1999. All large-scale construction activities associated with remediation and site restoration that would perturb the groundwater/surface water setting were completed by 2001. Source removal resulted in significantly reducing COC concentrations in groundwater and surface water at many locations. However, each COC persists in alluvial groundwater at one or more location in concentrations that exceed the respective remediation goal. With the exception of uranium, COC concentrations generally do not exceed the remediation goal by more than a factor of two and are limited in distribution to the area between the former mill site and the PRB. The extent of groundwater and surface water contamination at OU III is provided in detail in the annual water quality reports.

Figure 3 illustrates the extent of uranium contamination in the alluvial aquifer and in surface water for April 2009 (October 2008 results are asterisked; Figure 2 provides monitoring location identifications). Symbol coding identifies sample type (circles for groundwater and squares for surface water) and whether the uranium remediation goal was exceeded (filled symbol) or not (open symbol) at the given location. 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. Uranium is also the primary contributor to potential risk to human health for the groundwater ingestion scenario. Contamination in Montezuma Creek is absent on the mill site and downstream for about one mile, at which point and through the remainder of OU III the uranium standard is exceeded. Investigation of this occurrence is addressed in Section 2.3. A separate concern over selenium contamination in wetland environments and potential ecological risk is under investigation by DOE as required by the ROD (see ROD Appendix C, “Biomonitoring”).

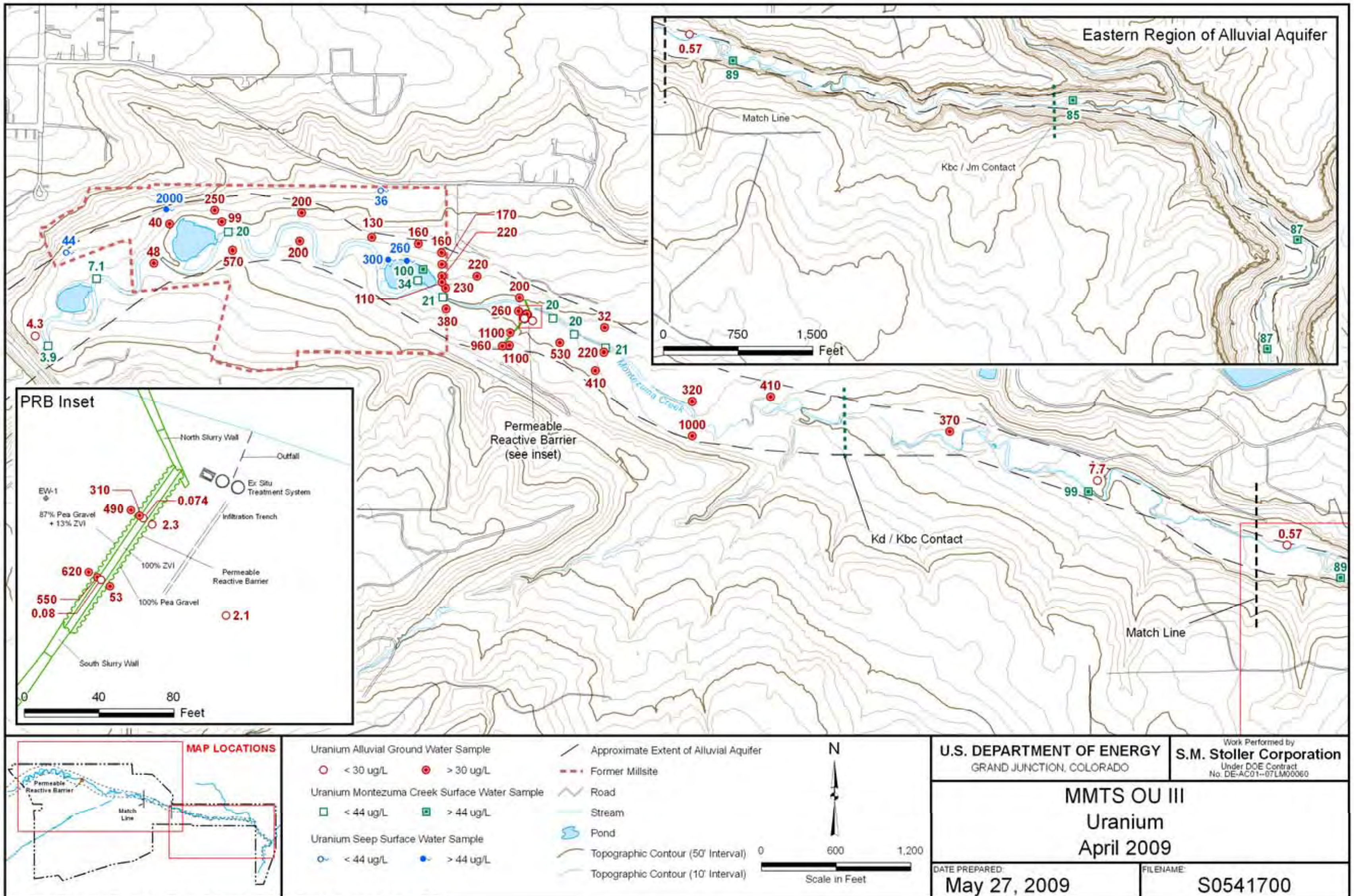

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Figure 3. Uranium Concentration in Groundwater, Surface Water, and Seeps, April 2009

1.3.3 Groundwater Use and Institutional Controls

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

The City of Monticello has historically distributed water from the Burro Canyon aquifer for nondomestic purposes (municipal and residential irrigation), but during recent drought, which peaked in 2002, the City began to augment the culinary supply with Burro Canyon groundwater.

At that time, pumping records obtained from the City indicate that the 10 municipal extraction wells, located within a 1-mile radius of town center, sustained a combined pumping rate of approximately 350 gpm over periods of several months. The primary source of domestic-use water for Monticello area residents continues to be surface runoff from the watershed of North Creek in the Abajo Mountains. Diversion systems in the mountains route the water to the municipal water treatment plant located on North Creek about 1.5 miles northwest (upstream) of the mill site. MMTS conditions or activities have no current or historical impact on the municipal water system.

The institutional controls that restrict OU III groundwater use are implemented through a groundwater management policy and a deed annotation. The *Ground Water Management Policy for the Monticello Mill Tailings Site and Adjacent Areas*, prepared and administered by the Utah State Engineer's Office, became effective in May 1999 (see *Long-Term Surveillance and Maintenance Plan for the Monticello NPL Sites* ([LTSM Plan] rev. 0, June 2007). The policy authorizes the State to reject applications to appropriate water for domestic use from the alluvial aquifer within the Monticello Groundwater Restricted Area until contaminant concentrations reach acceptable levels as determined by DOE, EPA, and UDEQ. Applications to drill wells into the deeper Burro Canyon aquifer are approved if the well construction will not allow communication between the alluvial and bedrock formations. The restricted area encompasses the entire contaminant plume and extends some distance beyond its downgradient terminus. Groundwater use on the former mill site and several peripheral properties is also prohibited under the conditions of the land transfer from DOE to the City of Monticello that occurred in 1999 (in *Final Covenant Deferral Request for Transfer of Federal Property in Monticello, Utah*, January 2000). As prescribed in the LTSM Plan, DOE contacts the State Engineer's Office annually and inspects the restricted area to confirm compliance with these controls.

1.3.4 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 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.

A municipal reservoir (Loyds Lake), located about one-half mile upstream of the mill site captures mountain runoff in South Creek, a tributary of Montezuma Creek. 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.

2.0 Compliance Strategy Scope of Work

2.1 Evaluate Pump-and-Treat Remediation

The PRB was designed to immobilize uranium and other site contaminants as groundwater flows passively through the reactive media. It was installed in June 1999 on private property about 750 ft east of the former mill site (see Figure 1 for location). Since installation of the PRB in 1999, mineralization in the PRB has significantly reduced its capacity to transmit groundwater. This was accompanied by excessive groundwater mounding in the alluvial aquifer immediately upgradient of the PRB. Following these developments, an ex situ groundwater pump-and-treat system was installed in June 2005 as an alternative to the in situ PRB in studying treatment of inorganic contaminants using ZVI. In accordance with the ESD, DOE will operate the ex situ system as an enhancement to natural attenuation processes. Active groundwater treatment will focus on the portion of the alluvial aquifer between the former mill site and the PRB.

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

2.1.1 Scope of Work

DOE will operate and maintain the current pump-and-treat enhancement to provide maximum groundwater treatment within the established discharge parameters. As of May 2009, the numeric criteria negotiated with Utah Division of Water Quality allows a maximum discharge rate of 10 gpm to Montezuma Creek, effluent not to exceed 45.4 mg/L total iron, and pH to remain between 6.5 and 9 standard units.

The treatment system is currently monitored on a monthly basis as directed under Program Directive MNT-2009-03 and sampling and analysis plan accompanying that directive. One sample is collected of the influent groundwater, one sample is collected at the drain port of each treatment cell, one sample is collected from the combined effluent at the point of discharge to Montezuma Creek, and one sample is collected from the creek about 100 ft downstream of the outfall. Samples are submitted to an LM contract laboratory for analysis of uranium and total iron. Sample pH is measured in the field at time of sample collection. The LM contractor's Environmental Support Services group manages all results in the project database. Treatment system flow rates, pressure gradients, and water levels are reviewed weekly to provide early indications of deteriorating flow conditions and identify maintenance needs.

Media exchange or reducing the flow rate has been triggered in the past by rising levels of iron in the effluent, uranium treatment efficiency decreasing by about 50 percent, and excessive head loss across the cells. DOE, in concurrence with UDEQ and EPA, will develop standard operating procedures (in progress) to better define treatment system monitoring and operations requirements and to identify the conditions for determining the need to exchange the reactive media or modify flow rates. The process of acquiring additional performance information upon which to base the operations and response criteria will require at least several months. Until that time DOE will operate the system according to current practices. Current and future disposal of the spent treatment medium will proceed in accordance with the radiological control, transport, and disposal requirements provided in the LTSM Plan for managing radiologically contaminated material encountered at the MMTS.

2.1.2 Data Use Objectives

The objective of evaluating the ex situ treatment system is to determine if active treatment combined with natural attenuation processes can meet the current water quality goals (Table 2) in a reasonable time for that portion of the aquifer between the former mill site and PRB. This determination will be based on continued analysis of uranium concentration trends according to current practices of using regional averages and well-by-well trending to forecast the restoration period. Trending analysis must consider the concentration "tailing effect" described in Section 2.2.3. This effect suggests that early trends are not reliable indicators of restoration time because the early trends can decrease with time progressing to relatively stable and elevated concentrations.

Performance of the pump-and-treat system will be reported in the FFA quarterly reports. These reports will present uranium mass removal, volume of groundwater treated, influent and effluent water chemistry, and compliance with discharge allowances. Performance will also be summarized in the annual groundwater reports.

DOE, with EPA and UDEQ concurrence, will determine the benefit of expanding the pump-and-treat system to increase capture and treatment of contaminated groundwater from within the aquifer region upgradient of the PRB and will evaluate whether such action creates additional potential for release and exposure of contaminated groundwater. The decision to expand the treatment system and the scope and design of the expansion will be based in part on the results of the field investigation described in Section 2.2.2 and in part on the fate of the PRB (see Section 2.2.1). Potential target areas in which to expand groundwater capture will be those with maximum uranium concentration and saturated thickness of the aquifer.

2.2 Evaluate Natural Attenuation Factors

The annual groundwater for 2006 report (*Monticello Mill Tailings Site Operable Unit III Annual Ground Water Report October 2005 through April 2006*, September 2006) first identified that water quality improvement was not progressing as predicted by the OU III groundwater model and did not meet ROD-established performance criteria. This recognition was discussed at subsequent FFA meetings and later confirmed by nonparametric trend detection tests as documented in *Monticello Mill Tailings Site Operable Unit III Analysis of Uranium Trends in Ground Water*, August 2007. Several possible causes were cited for the discrepancy between expected and observed progress, including possible flow stagnation created by flow restriction at the PRB, inaccurate representation of the initial uranium plume in the model in the region of the aquifer upgradient of the PRB, inaccurate representation of uranium mobility in the groundwater model, contamination from seeps, and climate factors.

2.2.1 Flow Stagnation at the PRB

DOE recognizes that flow stagnation at the PRB may contribute to poor remedy performance. The PRB was represented in the groundwater model as a zone of constant hydraulic conductivity exceeding that of the surrounding aquifer and with no removal of contaminants. With reduced flow through the PRB, natural attenuation processes such as hydrodynamic dispersion and contaminant discharge at hydrologic boundaries may be much less effective than is possible under the model assumptions. The present compromised performance of the PRB allows for its decommissioning under the ROD. DOE tentatively plans to decommission the PRB in 2013. The decommissioning approach and associated risks will be documented in a remedial design/remedial action work plan that is subject to EPA and UDEQ review and concurrence. There is otherwise no additional work scope, data objective, or reporting requirement specific to evaluating the impact of flow stagnation at the PRB that is not addressed under Section 2.1. In accordance with the ESD, DOE will leave the PRB in place to continue to serve as a barrier to assist in the capture and treatment of groundwater; or, if electing to decommission the PRB, will provide a replacement facility that will continue to capture groundwater at that location.

2.2.2 Uranium Plume Definition

Uranium concentrations have recently increased at some monitoring locations in the area south of Montezuma Creek between the PRB and former mill site. This result contrasts with the model prediction and may indicate that a localized "hot spot" of groundwater contamination may be greater in extent than previously characterized. If so, the model would have under-predicted the restoration period for this region of the aquifer. The location of the hot spot as currently recognized is near the south end of the south slurry wall of the PRB, where uranium concentrations presently approach or exceed 1,000 micrograms per liter (µg/L) (see Figure 3).

2.2.2.1 Scope of Work

<u>Review Existing Data</u>

DOE will review existing reports that characterize the extent of uranium contamination in groundwater in the area of interest. Reports that include such information are P*ermeable Reactive Treatment (PeRT) Wall Characterization Report*, September 1998; and *Monticello PERT Wall Project Field Characterization Summary*, March 1999. These reports document field studies (soil borings and groundwater sample collection and analysis) that were implemented to characterize subsurface conditions in selecting the location and design of the PRB. Other pertinent information for review is provided in *Monticello Mill Tailings Site Operable Unit III Interim Remedial Action Progress Report, July 2000–July 2001*, August 2001. Section 4.2.13 of that report, "South Millsite Source Investigation," includes information on possible sources of groundwater contamination in the southeast portion of the mill site through storage of mill process liquids.

Field Study

DOE will conduct a field study to define uranium contamination in groundwater and subsurface geology in the area upgradient of the PRB. DOE will install temporary borings into the alluvial aquifer to collect a water sample for analysis of uranium and major ions. Groundwater samples from local monitoring wells will also be collected and analyzed. Boreholes will be advanced to bedrock, and water levels will be measured and recorded to determine the extent and saturated thickness of the aquifer. Details to direct the study will be provided in a program directive and an accompanying sampling and analysis plan prepared by DOE. Program directives and accompanying sampling and analysis plans serve to document and define the scope of field work that is not provided in *Monticello Mill Tailings Site Operable Unit III Post-ROD Monitoring Plan*, August 2004, or the OU III ROD. Program directives and accompanying sampling and analysis plans are reviewable by and are implemented in accordance with Section XIX Quality Assurance, item B, of the Federal Facilities Agreement for the Monticello (Utah) Site. Fieldwork was completed in 2009. Samples of aquifer substrate will not be collected for analysis of uranium content during this study because such a task was completed under the IRA to evaluate uranium inventory in the substrate and COC desorption behavior from the substrate (see Section 2.2.3).

2.2.2.2 Data Use Objectives

Information obtained from the field study and review of previous reports will be used to better define the extent of the uranium plume in this region of the aquifer. A better definition of the uranium plume in this area will lead to an improved understanding of the limitations of the OU III groundwater model, will aid in interpreting current concentration trends in the area, and will assist in determining if expanding groundwater capture for the pump-and-treat system in this area is feasible. Results of this investigation will be presented to EPA and UDEQ in FFA meetings, documented in stand-alone letter reports, and summarized in annual groundwater reports.

2.2.3 Uranium Mobility in Groundwater

The OU III groundwater model was developed on the assumption of equilibrium partitioning of uranium between groundwater and the aquifer substrate grains. This property of rapid and reversible sorption was represented by a constant distribution coefficient (K_d) that was determined through standard laboratory batch test methods. This representation ignored uranium sorption into phases of varying mobility and dual-domain mass transfer effects and so likely resulted in an overoptimistic prediction of the restoration period, because the less mobile phases can act as long-term secondary sources of uranium release to groundwater.

An example of uranium sequestration into phases of varying mobility was demonstrated in a sequential extraction study using MMTS soil collected from beneath the former mill tailings impoundments (refer to Sandia National Laboratory report cited in Section 2.2.3.1). In that study, the fraction of rapidly leachable uranium was typically less than 20 percent of the total uranium inventory. The bulk of the uranium was not readily leached but was available as a continuing source to groundwater, although at slower rates of release.

Another example of uranium desorption from a substrate that departs from the constant K_d approach is seen in the results of column tests conducted under the IRA (see *Monticello Mill Tailings Site Operable Unit III Interim Remedial Action Progress Report, July 2000–July 2001*, August 2001). These tests were designed to represent physical models of the OU III groundwater environment to evaluate contaminant flushing under actual flow and geochemical conditions. In multiple tests using substrate samples collected from various locations in the uranium plume, rapid desorption of uranium occurred from initial concentrations approaching 1,000 µg/L through five to seven pore volumes. The effluent uranium concentration then persisted at about 200 µg/L through an additional 20 or more pore volumes. This "tailing effect," whether the result of a variable K_d or dual porosity factors, may account for the relatively stable uranium concentrations of between about 200 and 300 µg/L currently observed at many OU III monitoring locations. The tailing effect, which was not represented in the OU III model, will likely prolong aquifer restoration far beyond the predicted 42-year restoration period.

2.2.3.1 Scope of Work

Literature Review

DOE will review existing site information and literature sources to evaluate uranium sorption/desorption behavior in the subsurface environment. Existing site-specific data include:

- *Sequential Extractions for UMTRA Soils at Monticello, Utah*, Sandia National Laboratory report to MMTS management, July 1998.
- *Monticello Mill Tailings Site Operable Unit III Interim Remedial Action Progress Report, July 2000–July 2001*, August 2001 (presents OU III column desorption study).

Literature sources include but are not limited to:

- Nikolla, P., et al. "Kinetic Desorption and Sorption of U(VI) during Reactive Transport in a Contaminated Hanford Sediment," *Environmental Science and Technology*, 2005, 39: 3157−3165.
- Benson, C.M. and P.V. Brady. "Beyond the K_d Approach," *Ground Water* 38 (3) May−June 2000.

Additionally, DOE will review technical studies conducted at the DOE site at Hanford, Washington, regarding the transport and remediation of inorganic contaminants in groundwater; one such study is located at http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17031.pdf. DOE will also review information at http://www.epa.gov/nrmrl/pubs/600r08114/600r08114.pdf focusing on the availability of treatment media that may be advantageous to ZVI, the availability of chemical agents suitable for enhanced flushing of uranium from aquifer substrate, and laboratory or case studies that address limitations or improved methods to attain remediation objectives for inorganic contaminants similar to those found at OU III.

Review Existing MMTS Data

DOE will use an analytical approach to revise the initial estimate of the aquifer restoration period using the column tests as physical analogs of the groundwater environment. This estimate will use existing site hydrogeologic data to determine the rate at which one pore volume of groundwater is displaced in the alluvial aquifer between the PRB and mill site. The column test results will then be extrapolated to estimate the time required to attain the uranium remediation goal, or the 200 µg/L threshold, for example.

2.2.3.2 Data Use Objectives

DOE will review literature sources (case studies and laboratory investigation) and MMTS data to evaluate the validity of the OU III transport model assumption of uniform, rapid, and reversible equilibrium-controlled sorption in representing uranium transport behavior at OU III, and that application of this assumption likely resulted in overestimating the rate of water quality restoration. Literature and site data review will also provide information to determine if current remediation goals can be attained in a reasonable time or if desorption limitations could prolong the process indefinitely. Although completed at an earlier stage of the OU III investigation, the information in the reports cited in Section 2.2.3.1 remains relevant for the defined data use objectives.

2.2.4 Contaminated Seepage

A perennial seep on the north margin of the mill site (Seep 6, see Figure 2) emanates high concentrations (up to 2,000 µg/L) of dissolved uranium. The seep is located hydraulically above the alluvial aquifer. Leaking water lines (municipal sewage and irrigation) on private property above the seep are the suspected sources of water to Seep 6. Mill tailings used as bedding material for the water lines are the suspected source of the contamination. The water utility corridor was designated a supplemental standards cleanup area during remediation of this property. These conditions may prolong attainment of uranium water quality protection standards at Seep 6 indefinitely.

2.2.4.1 Scope of Work

Evaluating uranium contamination at Seep 6 will include a review of historical information on the local hydrology, remedial actions on the adjacent property, and uranium contamination in nearby monitoring wells and surface water. Water samples will be collected at Seeps 6, 5, and 3 for analysis of uranium and radon-222. High radon-222 in the seep water may confirm mill tailings as the source of contamination, because radium-226 is the parent nuclide of radon-222, and radium-226 was not an extraction product at the Monticello mill. DOE will prepare a program directive to guide the field and analytical aspects of this work. The work may occur concurrently with the groundwater hot-spot investigation described in Section 2.2.2.

2.2.4.2 Data Use Objectives

Seep 6 will be studied to evaluate if meeting the water quality protection standards for uranium at that location is feasible. The presence of buried mill tailings as a continuing source of contamination would suggest that attaining the uranium standard is not feasible. Seep 6 is suspected to have a minor impact, if any, on alluvial groundwater or surface water quality. Review of nearby groundwater and surface water results will be used to confirm or reject this position.

2.2.5 Climate Effects

DOE recognizes that climatic conditions could affect the progress of water quality restoration. High water conditions may be expected to result in lower contaminant concentrations in groundwater because of dilution effects, and conversely, low water years such as experienced between approximately 1999 through 2004 may be expected to result in higher contaminant concentrations. The relationship between water level in the aquifer and uranium concentration is not clear, however. For example, after a period of low water conditions, the water table may encounter previously saturated sediments within the contaminant plume to cause additional contaminant desorption and a concentration rebound effect.

2.2.5.1 Scope of Work

Groundwater monitoring data will be analyzed to determine if uranium concentration is sensitive to water level in the aquifer. Areas of interest are the northern portion of the mill site where uranium concentrations have remained relatively static at approximately 200 µg/L during wet and dry periods, and east of the mill site to the PRB, where uranium concentrations are relatively high and where water table fluctuations are greater. Monitoring data will be evaluated to determine a qualitative relationship between saturated thickness or water table fluctuation and uranium concentration at selected monitoring wells in these areas.

2.2.5.2 Data Use Objectives

The analysis of water level and uranium concentration at selected monitoring wells will be used to determine if aquifer restoration may be sensitive to climate factors. This determination will improve the understanding of natural attenuation processes and reduce uncertainty in estimating the restoration period.

2.3 Evaluate Surface Water Restoration

The recently enacted state standard for uranium in surface water (30 picocuries per liter; equivalent to approximately 44 µg/L) post-dates the ROD but was adopted as an RAO in the ESD. This new standard is not exceeded in Montezuma Creek on the mill site or within about 1 mile downstream of the mill site. At the Sorensen location, however (see Figure 2 and Figure 3), uranium concentrations are about double the standard and remain so through the remainder of OU III. Potential sources of uranium loading to the creek at these downstream locations are the discharge of groundwater from the contaminant plume and from residual mill tailings within creek-bank deposits. The uranium contaminant plume terminates a short distance upstream of the Sorensen location in a reach of groundwater discharge, and the floodplain of Montezuma Creek referred to as Upper, Middle, and Lower Montezuma Creek in Figure 1 was remediated to supplemental cleanup standards, leaving known creek-side deposits of residual mill tailings in place.

2.3.1 Scope of Work

Monitoring will be temporarily reinstated at former Montezuma Creek locations SW92-07 and SW92-09 (monitoring discontinued October 1999) and at SW94-01 (monitoring at these locations was discontinued after April 2002). These locations (see Figure 2) are downstream of the Sorensen location and typically have uranium concentrations consistent with those at the Sorensen location.

Information on radiological contamination in soil and sediment that remains in the canyon will be reviewed to identify possible source areas of contamination to Montezuma Creek. Documentation of radiological contamination and partial removal actions in the floodplain of Montezuma Creek is included in *MMTS OU III Remedial Investigation Volume 1*, September 1998; *MMTS OU III Application for Supplemental Standards for Upper, Middle, and Lower Montezuma Creek Volume I*, May 1999 (revised October 1999), and in MMTS remedial action completion reports for the affected properties. Middle Montezuma Creek was not remediated because its pristine value exceeds the environmental risk posed by site-derived contamination.

DOE conducted limited investigation in October 1997 to determine the source of uranium entering Montezuma Creek at or near the Sorenson site. That work was conducted under Program Directive MSGRAP-97-01 to sample six supplementary surface water sites (SW97-01 to SW97-05E) near suspected areas of residual mill tailings contamination adjacent to the creek. Results of that study will be reevaluated, and DOE will conduct a similar effort in October 2009 or 2010 to define the source of uranium loading to Montezuma Creek in the affected reach.

Also as part of the Montezuma Creek evaluation, calculations will be performed to determine if groundwater discharge near the terminus of the uranium plume can account for the observed uranium loading to the creek. The uranium plume extends nearly to the Sorenson location at concentrations that may be great enough to support the observed increase in Montezuma Creek without a contribution from residual mill tailings in the stream bank deposits. The reach above the Sorenson location is a known gaining stream condition.

2.3.2 Data Use Objectives

Field study and data review will determine the likely source of uranium contamination observed in Montezuma Creek at and downstream of the Sorensen site. Source identification will aid in determining if meeting the recently established surface water protection standard is feasible. A continuing source, represented by residual mill tailings in creek-bank sediments, could prolong surface water restoration indefinitely as compared to a decreasing source represented by the discharge of contaminated groundwater from the uranium plume.

2.4 Groundwater Modeling

DOE, in consultation with EPA and UDEQ, will determine the need for and scope of additional groundwater modeling as new information becomes available and as existing information is reviewed under the scope of work identified in this water quality compliance plan. DOE, in consultation with EPA, and UDEQ, employed numerical groundwater flow and solute transport modeling under the RIA/FFS to support selection of the MNA remedy. The objective of that modeling was to predict if the water quality restoration goal for uranium could be achieved by natural processes in a reasonable period. The primary hydrogeologic factors represented in the model that would contribute to water quality restoration were hydrodynamic dispersion and contaminant discharge to Montezuma Creek.

The modeling objective was not to demonstrate permanent sequestration of uranium in the aquifer matrix as justification for the MNA remedy, but instead was to determine if a reasonable cleanup period was possible under the assumptions of reversible uranium partitioning between dissolved and sorbed phases and a constant K_d. These geochemical assumptions may be the primary cause of the departure between model-predicted trends and observed uranium trends, as described in Section 1.2.1.

If at a later date DOE, EPA, and UDEQ determine the need for modeling to evaluate the contingency remedy restoration period, analytical methods based on extrapolating the column test results described in Section 2.2.3 will be considered in addition to numerical methods. The column tests, which were designed to replicate natural flushing in the alluvial aquifer, suggest that release of uranium from the aquifer substrate will have a long-term impact on water quality.

2.5 Documentation and Reporting

Results of the work elements outlined in this water quality compliance strategy will be documented in stand-alone letter reports and in the annual water quality reports, and they will be addressed in meetings and quarterly reports convened under the Monticello projects FFA. As the work elements are completed, DOE will solicit input from EPA and UDEQ on the preferred reporting format.

DOE will prepare program directives and the associated sampling and analysis plans to guide the field studies proposed under this compliance strategy. All directives and associated sampling and analysis plans will be subject to EPA and UDEQ review and concurrence.

3.0 Contingency Remedy Evaluation

DOE will implement this compliance strategy to evaluate the feasibility, risk reduction, and cost of the contingency remedy (MNA with institutional controls and pump-and-treat enhancement) in meeting current RAOs for OU III. In accordance with the ESD, DOE, EPA and UDEQ will implement the contingency remedy until currently established RAOs are met in the area upgradient of the existing PRB and slurry walls. If it is determined that meeting RAOs is infeasible, DOE, EPA, and UDEQ agree that petitioning for ARAR waivers based on technical impracticability will be appropriate.

DOE expects that evaluating the contingency remedy, based on the scope of work that will be implemented under this compliance strategy, and will continue through the current 5-year review period. The latest assessment of remedy protectiveness, completed in 2007 under the CERCLA 5-year review, concluded that the original groundwater remedy (MNA with institutional controls) remained fully protective of human health despite the slow progress of water quality restoration. This is because there is no current exposure path for the primary contributor to potential risk, which is human consumption of uranium-contaminated groundwater. Furthermore, the aquifer is not used for any purpose and is likely to remain unused because it is low-yielding, is susceptible to agricultural impacts, and other sources of domestic-use water are readily available. Potential risk to human health is also minimized by the institutional controls that prevent access to the contaminated groundwater.

Montezuma Creek and the alluvial aquifer are hydraulically connected, and some incidental use of contaminated groundwater occurs by way of limited crop irrigation from Montezuma Creek and livestock access to the creek. DOE, EPA, and UDEQ have determined that these exposure pathways pose insignificant risk. Additionally, the creek has insufficient water for boating and swimming and does not support fish.

The latest 5-year review also concluded that the protectiveness of the selected remedy to ecological receptors could not be fully determined because the effects of recent increases in selenium in biotic and abiotic media were unknown. The ROD for OU III therefore directed a biomonitoring program to monitor and evaluate the impact of the selenium occurrence in OU III. Biomonitoring activities are in progress and are anticipated to allow a comprehensive ecological risk determination by the next 5-year review in 2012. Implementation of the contingency remedy did not alter the scope of the biomonitoring task.