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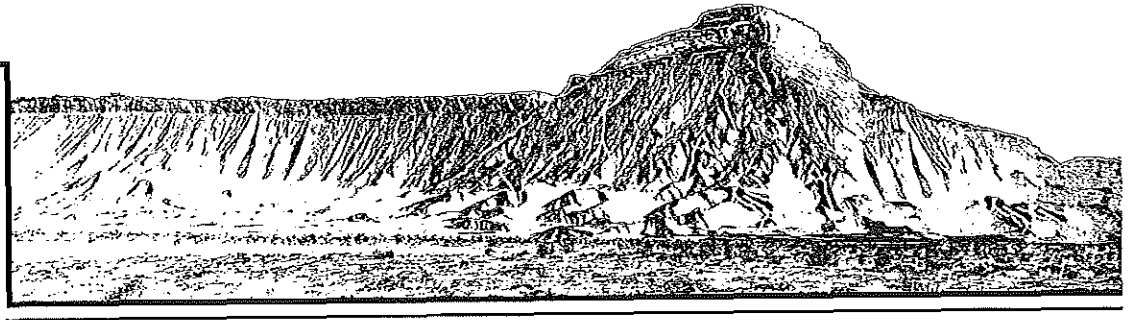
Monticello Mill Tailings Site
Operable Unit III

Final
Remedial Investigation Addendum/ Focused Feasibility Study

January 2004

U.S. Department of Energy



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Focused Feasibility Study

January 2004

Prepared by
U.S. Department of Energy
Grand Junction, Colorado

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Signature Page

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Remedial Investigation Addendum/
Focused Feasibility Study

January 2004

Submitted By: Arthur W Kleinrath

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U.S. Department of Energy, Grand Junction, Colorado

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Appendices

Note: *The Appendices from the Draft Final version dated September 2003 have not changed and are incorporated as part of this Final version dated January 2004.*

Appendix A Annotated Executive Summary from the 1998 Draft Final Remedial Investigation for Operable Unit III of the Monticello Mill Tailings Site

Appendix B Ground Water Management Policy for the Monticello Mill Tailings Site and Adjacent Areas

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Appendix D Surface Water and Ground Water Time-Concentration Plots, Stream Discharge Measurements, Ground Water Level Data, and Ground Water Well Hydrographs

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9. Uranium Results for 2002
10. Vanadium Results for 2002

Acronyms

ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
cfs	cubic feet per second
cm	centimeters
cm/s	centimeters per second
COC	contaminant of concern
CSM	conceptual site model
CT	central tendency
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
EDE	effect dose equivalent
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ESL	Environmental Sciences Laboratory
ETAG	Ecological Technical Assistance Group
FFA	Federal Facilities Agreement
Fm.	formation
FS	Feasibility Study
ft	feet/foot
GHB	general head boundary
g/kg	grams
gpm	gallons per minute
GRA	General Response Actions
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IDW	investigation-derived waste
ILCR	incremental lifetime cancer risk
IRA	Interim Remedial Action
K_d	distribution coefficient
kg	kilogram
LOAEL	lowest observed adverse effects level
LTS&M	long-term surveillance and maintenance
µg/L	micrograms per liter
µR/h	microroentgens per hour
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL/g	milliliters per gram
mm	millimeters
MMTS	Monticello Mill Tailings Site

Acronyms (continued)

mrem/pCi	millirem per picocurie
mrem/yr	millirem per year
N	northing
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NOAEL	no observed adverse effects level
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
OU	Operable Unit
pCi/g	picocuries per gram
pCi/L	picocuries per liter
Pb-210	lead-210
PeRT	permeable reactive treatment
PRB	permeable reactive barrier
PRG	preliminary remediation goal
PV	present value
Ra-226	radium-226
Ra-228	radium-228
RAO	Remedial Action Objective
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RME	reasonable maximum exposure
RMSE	root mean squared error
Rn-222	radon-222
ROD	record of decision
SDWA	Safe Drinking Water Act
State	State of Utah
Th-230	thorium-230
U.A.C.	*Utah Administrative Code*
U.C.A.	Utah Code Annotated
UDEQ	Utah Department of Environmental Quality
UMTRCA	Uranium Mill Tailings Radiation Control Act
UPDES	Utah Pollutant Discharge Elimination System
USACE	U.S. Army Corps of Engineers
U.S.C.	*United States Code*
USGS	United States Geological Survey
UST	underground storage tank
WWTP	Waste Water Treatment Plant
yd^3	cubic yards
yr	year(s)
ZVI	zero-valent iron

Executive Summary

Purpose and Scope of Report

This Remedial Investigation (RI) Addendum/Focused Feasibility Study (FFS) updates the 1998 final RI report and presents the results of an FFS conducted for Operable Unit (OU) III, contaminated surface water and ground water, of the Monticello Mill Tailings Site (MMTS). This report follows soil and sediment remedial actions for OUs I and II of MMTS and completion of an Interim Remedial Action (IRA) for OU III, which significantly altered baseline conditions at the site. The main objectives of this report are to

- Document the updated human health risk assessment (HHRA) using current concentration data, site conditions, and toxicity information.
- Document the updated OU III ecological risk assessment (ERA) for receptors and pathways that were identified as a possible concern in the 1998 RI, using current concentration data, site conditions, and toxicity information.
- Document the ground water model that was developed on the basis of current site conditions to support the HHRA and FFS.
- Complete a feasibility study focused on OU III surface water and ground water.

This document was prepared by the U.S. Department of Energy (DOE) Grand Junction, Colorado, Office to fulfill its obligations under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Executive Order 12580. The information presented in this report will be the primary basis for proposing a remedy in the Proposed Plan and for a Record of Decision (ROD), which will document the selected remedy for OU III surface water and ground water.

Project Overview

MMTS is the location of a former ore-buying station and vanadium and uranium mill that operated from about 1948 to 1960. Mill tailings were impounded in four piles on the 110-acre site through 1999, resulting in contamination of soil, surface water, and the shallow water-table aquifer (alluvial aquifer). The MMTS was included on the National Priorities List in 1989 and is being remediated by DOE in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act, and the National Oil and Hazardous Substances Pollution Contingency Plan. Approximately 2.5 million cubic yards of contaminated soil and debris from the Millsite (OU I), peripheral properties (OU II), and vicinity properties were excavated and placed in an on-site repository for permanent storage in 1998 and 1999. Cleanup standards applied to the Millsite specified that soil in the top 15 centimeters of the land surface should be remediated until Ra-226 concentrations are less than or equal to 5 picocuries per gram (pCi/g) above background; at depths greater than 15 centimeters, soil should be remediated until Ra-226 concentrations are less than or equal to 15 pCi/g above background. On some peripheral properties, supplemental standards were applied, and cleanup was to alternate site-specific standards.

The 1990 ROD for OUs I and II stipulated that a ROD for OU III would be produced when sufficient data were gathered to make a remedial action decision through a focused RI/FS. Data

collection for the OU III RI began in November 1992 and continued through 1996. The OU III RI (final) and FS (draft) reports were prepared concurrently in 1998, prior to OU I and OU II remediation. Because the baseline conditions for developing and evaluating remedial alternatives were likely to change significantly as a result of site remediation, the draft FS was not finalized at that time. Similarly, conclusions of the baseline risk assessments could be affected by the changed site conditions. To address these issues, an Interim Remedial Action (IRA) was implemented with the intent of (1) updating the 1998 RI and completing an FS after the ground water system had stabilized following OU I and OU II remedial actions, (2) completing a treatability study for permeable reactive barrier (PRB) technology, (3) collecting additional monitoring and characterization data, (4) treating water collected during Millsite dewatering activities, and (5) implementing an institutional control to restrict use of contaminated ground water. The IRA ROD for OU III (DOE 1998d) was signed by the U.S. Environmental Protection Agency (EPA) and Utah Department of Environmental Quality (UDEQ) in September 1998. Progress reports that detail the scope and results of the IRA were prepared by DOE in 1999, 2000, and 2001. An evaluation of the permeable reactive treatment wall treatability study was completed in 2002 (DOE 2002a).

In August 1999, DOE and the city of Monticello entered into a Cooperative Agreement wherein the city would be responsible for completing restoration of the former Millsite with support from DOE. DOE prepared a Covenant Deferral Request (DOE 2000a) for transfer of ownership of the Millsite and several adjacent properties to the city prior to completion of all remedial action in accordance with CERCLA. The request was approved by the Governor of Utah and the EPA Regional Administrator. In June 2000, ownership was transferred to the city of Monticello under the Federal Lands-to-Parks Program administered by the National Park Service. Restoration of the Millsite was completed on August 31, 2001, although issues remain with regard to the stability and permanency of the efforts to restore the Millsite area and convert it into a park.

Physical Setting

The MMTS is located in southeastern Utah, in and near the city of Monticello, San Juan County. Features of the site, including the OU III study area and extent of uranium contamination in ground water, are illustrated in Figure ES–1. The area encompassing OU III is sparsely populated and is used primarily for ranching, confined-animal facility, and dry-land farming. The northwestern portion of the study area lies within the city limits of Monticello (population about 1,900 in 2000). The regional setting comprises the broad, nearly flat surface of the Great Sage Plain, which is about 7,000 feet (ft) in elevation. Climatic conditions of four distinct seasons typical of semiarid, mid-latitude steppes characterize the Monticello area. Average annual precipitation is approximately 15 inches and occurs mainly during late summer and early fall monsoon storms. Potential agricultural evapotranspiration and pan evaporation approaches 40 inches per year.

Montezuma Creek is the main surface water feature in OU III, flowing west to east through the center of the study area. It is a small perennial stream with headwaters in the Abajo Mountains, which rise to nearly 11,000 ft approximately 5 miles west of Monticello. Typical base flow in the creek ranges up to about 0.5 cubic feet per second (225 gallons per minute). A municipal reservoir and water treatment plant interrupt natural flow in the creek. Montezuma Creek and its tributaries have incised a canyon network into the local bedrock formations in the east portion of

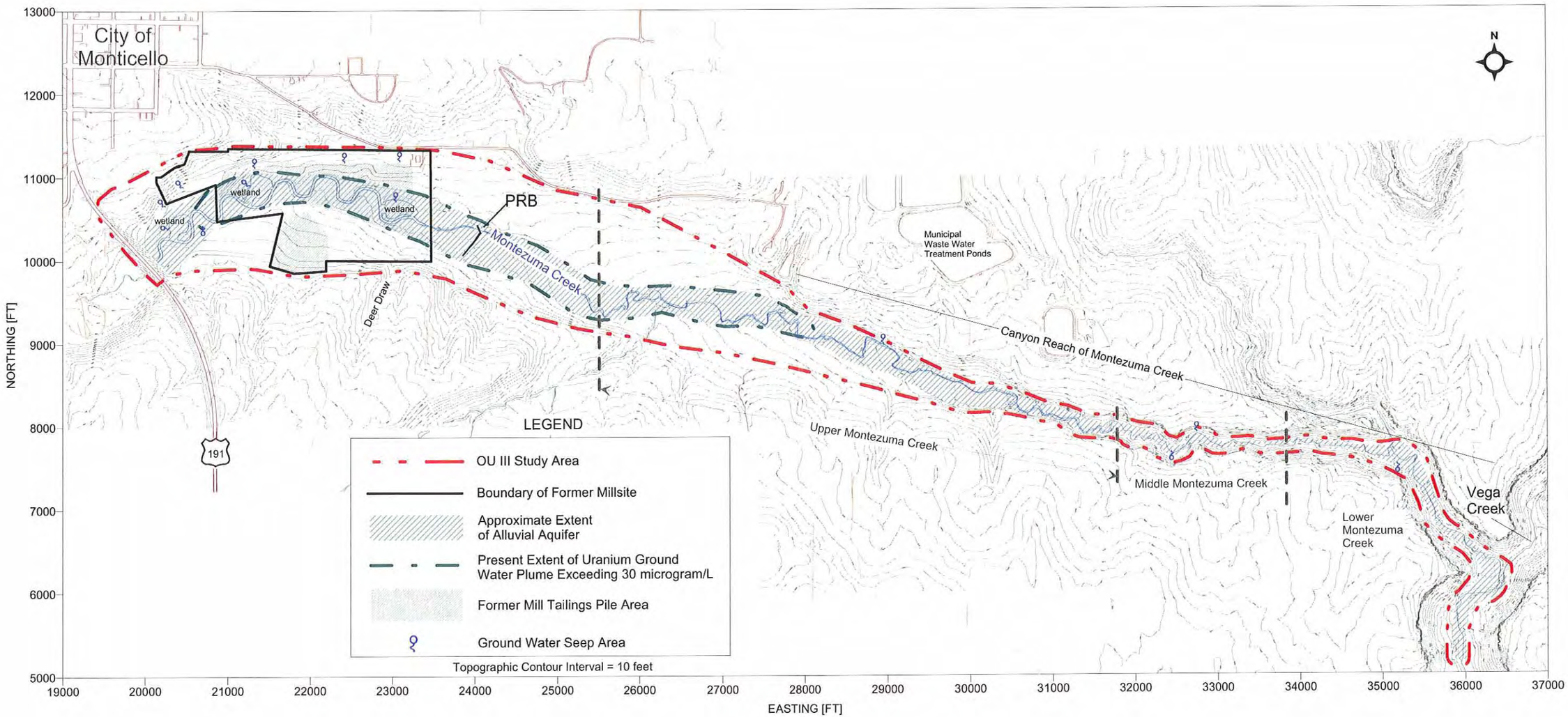

Figure ES-1. Location of the MMTS

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the study area. Contaminated surface water and ground water comprising OU III lie within the valley and canyon formed by Montezuma Creek.

The hydrostratigraphic units associated with OU III are the alluvial aquifer, the underlying Dakota Sandstone aquitard and the Burro Canyon sandstone aquifer. Saturated, permeable sand and gravel forming a channel-fill deposit beneath the valley of Montezuma Creek constitutes the alluvial aquifer at the site. The alluvial channel is about 450 ft wide (north to south) at the eastern boundary of the Millsite and narrows to less than 200 ft about 1 mile east, where the valley becomes a steep-walled canyon. The bedrock erosional surface at the base of the alluvial aquifer is relatively flat across the width of the aquifer. Depth to bedrock is generally less than 15 ft below ground surface in the valley floor, and the typical saturated thickness of the aquifer is about 5 ft.

On the Millsite, the alluvial aquifer discharges to Montezuma Creek and to three adjoining wetlands that were constructed during site restoration. Montezuma Creek loses water to the alluvial aquifer between the eastern boundary of the Millsite and approximately 1 mile downstream. Farther east, a strong gaining stream condition results due to pinching out of the alluvial aquifer because of bedrock control and from ground water discharge from the Burro Canyon Formation (Fm.) to the alluvial aquifer and ultimately to the creek. Ground water seepage from sources above the valley along the northern margin of the Millsite is an additional, important source of recharge to the alluvial aquifer.

Ground Water and Surface Water Use

Although the primary sources of contamination (mill tailings) were removed in 1998 and 1999, alluvial ground water continues to be contaminated in excess of risk and applicable or relevant and appropriate requirement (ARAR)-based water quality standards. In the absence of Millsite-related contamination, UDEQ classifies OU III alluvial aquifer ground water as Class II, Drinking Water Quality Ground Water. The alluvial aquifer is currently not used for drinking water, irrigation, or livestock watering. The potential to develop the alluvial aquifer as a domestic source, even without the existing ground water use restriction (see below), is low because the saturated zone is very thin and generally unproductive in the area where housing construction is feasible above the Montezuma Creek floodplain. Furthermore, the location of potential future home sites could be reasonably provided with municipal water. The city of Monticello has historically distributed Burro Canyon Fm. ground water only for nondomestic purposes (municipal and residential irrigation). Because of recent drought, Burro Canyon ground water is now available to augment the culinary water supply. Montezuma Creek is used for irrigation and livestock watering.

Nature and Extent of Contamination

Ground Water Contamination

Contaminants of concern (COCs) for OU III (surface water and ground water) are arsenic, manganese, molybdenum, nitrate, selenium, uranium (and uranium isotopes), vanadium, gross alpha, and gross beta. Ground water in the Burro Canyon aquifer has not been affected by Millsite-related contamination. Contaminants in the alluvial aquifer have migrated off the Millsite in levels that exceed their respective preliminary remediation goals (PRGs) indicated in

Table ES–1. Uranium contamination is the most extensive with respect to concentration above its PRG and distance from the source. The present extent of uranium contamination is shown in Figure ES–1. The eastern (downgradient) extent of the uranium plume has remained stable throughout the site characterization (1992 to present). Since completion of OU I and OU II removal actions and installation of the PRB, decreasing concentration trends for several COCs, including uranium, are evident in the monitoring data. Monitoring data for year 2002 indicate that:

- Wide spread ground water contamination above PRGs on the Millsite is limited to manganese and uranium. PRGs for the remaining COCs except nitrate are exceeded only at the eastern end of the Millsite. Nitrate concentrations are below the PRG at all locations on the Millsite.
- Arsenic concentrations exceeded the PRG only at several wells between the east boundary of the Millsite and the PRB. Maximum concentrations were about twice the PRG.
- Manganese concentrations did not exceed the PRG in ground water off the Millsite.
- Molybdenum concentrations exceeded the PRG only at one location in ground water off the Millsite. The maximum concentration was about 1.1 times the PRG.
- Nitrate concentrations exceeded the PRG at only one location, which is upgradient of the PRB, during 2002. The concentration was about 1.5 times the PRG.
- Selenium concentrations exceeded the PRG at numerous wells between the east boundary of the Millsite and immediately downgradient of the PRB. Maximum concentrations were within a factor of two of the PRG. Recently increasing selenium concentrations in ground water are attributed to mobilization of naturally occurring selenium due to ground water interaction with bedrock formations (Cretaceous Mancos Shale and pyritized, carbonaceous intervals of Dakota Sandstone Fm). Drought conditions during the last few years may have contributed to the mobilization of selenium by creating oxidizing conditions under which selenium leaching is enhanced.
- Uranium concentrations exceeded the PRG by at least a factor of 20 east of the Millsite and upgradient of the PRB; contamination greater than the PRG extended 1 mile to the east.
- Vanadium concentrations exceeded the PRG only at several wells between the east boundary of the Millsite and the PRB. Maximum concentrations were about twice the PRG.

Table ES–1. Ground Water PRGs

COC	PRG	PRG Reference
Arsenic	10 µg/L	SDWA
Manganese	880 µg/L	Risk based; developed by UDEQ
Molybdenum	100 µg/L	UMTRCA
Nitrate (as N)	10 mg/L	SDWA
Selenium	50 µg/L	SDWA
Uranium	30 µg/L	SDWA
Vanadium	330 µg/L	Risk based; EPA Region 3 RBC
U-234/238	30 pCi/L	UMTRCA
Gross Alpha	15 pCi/L	SDWA

Notes: µg/L = micrograms per liter, mg/L = milligrams per liter, pCi/L = picocuries per liter, SDWA = Safe Drinking Water Act, UMTRCA = Uranium Mill Tailings Radiation Control Act, RBC = risk-based concentration.

Surface Water Contamination

Concentrations of OU III COCs in surface water during 2002 indicate that:

- Arsenic, manganese, molybdenum, and vanadium concentrations in seeps or Montezuma Creek surface water do not exceed Utah surface water standards (Table ES−2) or, in their absence, ground water PRGs that are based on human health (Table ES−1).
- Gross alpha results adjusted for uranium do not exceed the Utah surface water standard.
- Uranium concentrations exceed Safe Drinking Water Act (SDWA) standards in Montezuma Creek on and downstream of the Millsite.
- Nitrate and selenium are the only COCs having concentrations that exceed Utah surface water standards. Nitrate concentrations exceeded the Utah standard at only one seep, which originates off-site and flows onto the Millsite, by as much as 10 times the standard.
- Selenium levels exceeded the standard for protection of aquatic wildlife by a factor of two in Montezuma Creek and by as much as a factor of 25 times at the seeps in the eastern area of the Millsite (Figure ES−1). The recent increasing selenium levels in Montezuma Creek and seeps on the east side of the Millsite are attributed to the same processes responsible for increasing concentrations in alluvial ground water.

Table ES−2. Surface Water PRGs

COC	PRG	PRG Reference
Arsenic	10 µg/L	SDWA[a]
Nitrate as N	4 mg/L	Utah Domestic, Recreation, and Aesthetics Standard
Selenium	5 µg/L	Utah Aquatic Wildlife Standard
Gross Alpha	15 pCi/L	Utah Domestic and Agricultural Standard

[a]The strictest Utah surface water standard for arsenic (50 µg/L) is based on domestic use. It is anticipated that Utah will revise this standard to be consistent with the SDWA by December 1, 2003.

Except for selenium, COC concentrations in Montezuma Creek have either decreased from or remained stable at 1998 levels and are below identified benchmarks. The increase in selenium concentrations in Montezuma Creek required that risk to the southwestern willow flycatcher, spotted bat, and benthic macroinvertebrates be reevaluated as part of the RI Addendum.

Institutional Controls

Ground Water Use Restrictions

Two ground water use restrictions are in place for portions of the alluvial ground water system: a ground water management policy and a quitclaim deed. Preparation of a ground water management policy for the contaminated alluvial ground water system by the Utah State Engineer's office began in 1998. The *Ground Water Management Policy for the Monticello Mill Tailings Site and Adjacent Areas* (a copy is provided in Appendix B) became effective May 21, 1999. The policy states that new applications to appropriate water for domestic use from the shallow alluvial aquifer within the boundaries of the Monticello Ground Water Restricted Area (Figure ES−2) will not be approved until it is determined that the risk to human health is eliminated or reduced to acceptable levels; existing water rights are not affected. Also, change applications proposing to divert and use water from the shallow aquifer for domestic purposes will not be approved. The policy further states that applications to drill wells into the deeper

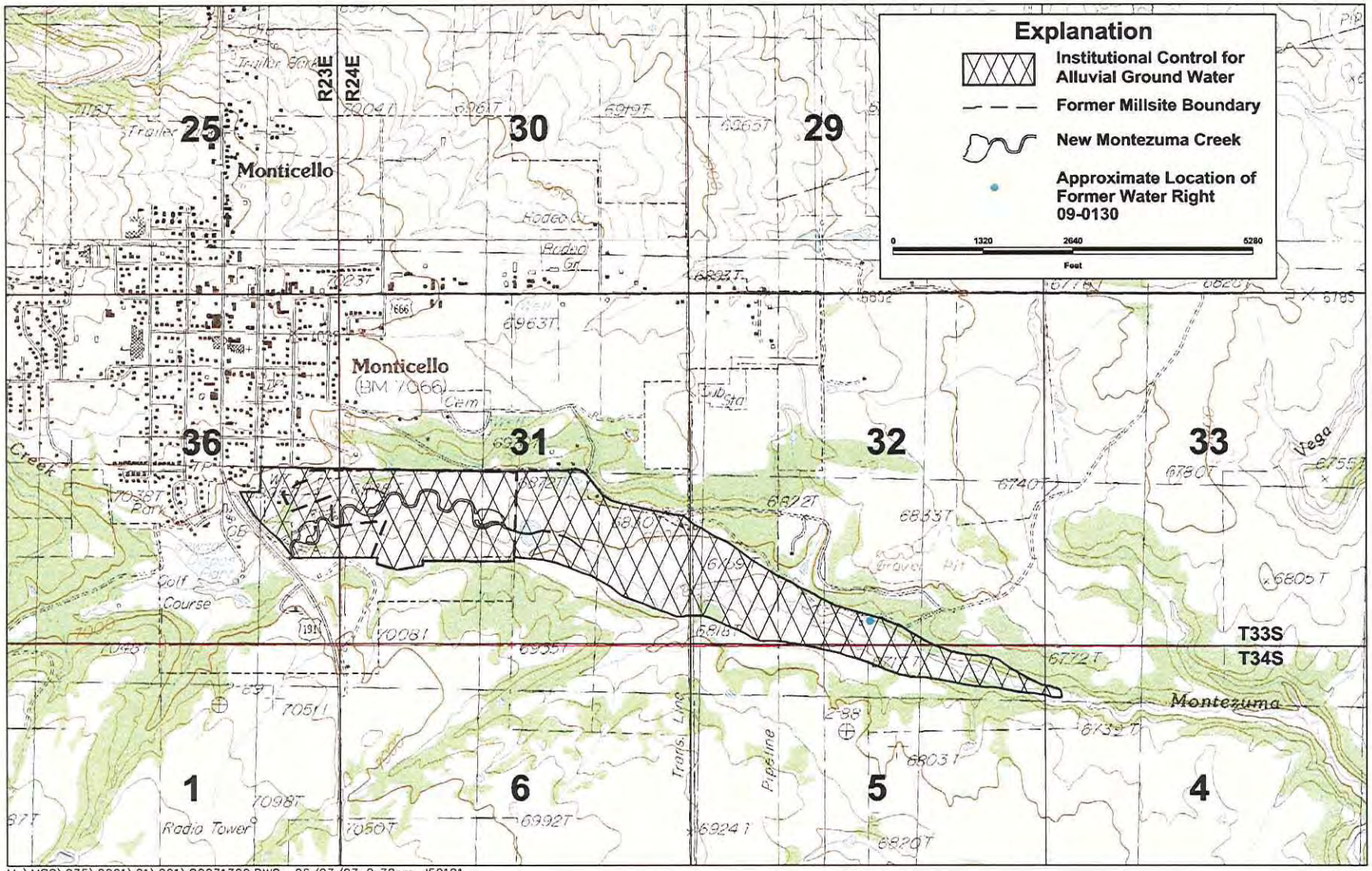

Figure ES-2. Monticello Ground Water Restricted Area

Burro Canyon Fm. would be approved if it could be demonstrated that the well construction would not allow the shallow alluvial water to flow to the deeper formation. DOE purchased the sole water right for domestic use (Water Right 09–0130) within the Monticello Ground Water Restricted Area in 2001. The quitclaim deed that transfers the Millsite to the city of Monticello for use as a public park prohibits use of any ground water within the boundary of the Millsite for the purpose of human consumption. This restriction protects human health by preventing exposure to ground water on the Millsite.

DOE conducts annual inspections within the Monticello Ground Water Restricted Area for evidence of well installations or ground water use. To date, no new private wells have been installed, and there is no evidence of domestic use of alluvial ground water in the OU III area. One attempt to file a claim on ground water from an existing well completed in the Burro Canyon aquifer was since rejected by the State Engineer's office because the applicant could provide no documentation of well construction or integrity in isolating alluvial and bedrock aquifer ground waters.

Restrictive Easements

Restrictive easements were implemented on properties within OU III where supplemental standards for soil and sediment remediation were applied. The restrictive easement prohibits the building of a habitable structure and the removal of soils from within the easement area. By June 2001, the U.S. Army Corps of Engineers had negotiated settlement with all affected property owners regarding compensation for the restrictive easements. The restricted area closely approximates the OU III study area boundary within Upper, Middle, and Lower Montezuma Creek, as shown in Figure ES–1.

PRB Treatability Study

Construction of the PRB as an IRA treatability study was completed at the location shown in Figure ES–1 on June 30, 1999. The PRB consists of a zone of reactive media (zero-valent iron [ZVI]) that is 105 ft in length perpendicular to the direction of ground water flow and 6 ft thick parallel to ground water flow. The ZVI intercepts the entire saturated thickness of the aquifer and is keyed into underlying, low-permeability bedrock. Bentonite-amended soil slurry walls, also keyed into the bedrock, extend to the north and south to funnel ground water to the PRB. A small amount of ground water flows around the outer ends of the slurry walls. Extensive activities have been undertaken to evaluate the treatment and hydraulic performance of the PRB. These included

- Comprehensive water quality and water level monitoring.
- Hydraulic testing.
- Natural and artificial tracer tracking.
- Mass balance analysis of reaction products.
- Geochemical modeling.
- Ground water flow modeling.

Progress reports that detail the scope and results of PRB performance monitoring and testing were prepared by DOE in 2000 and 2001 (DOE 2000b, 2001a). Monitoring results for year 2002 are presented in this RI Addendum. Performance of the Monticello PRB has also been reported in scientific publications. Table ES–3 presents a comparison of the contaminant concentrations from October 2002 with the PRGs that have been developed for OU III. All analyte

concentrations are less than their respective PRGs in the ground water exiting the PRB. The operational lifespan of the PRB is expected to be at least 15 years since installation.

Table ES-3. Contaminant Concentrations Compared to Preliminary Remediation Goals for OU III

Analyte	Upgradient Concentration[a] (µg/L)	Concentration Within the PRB (µg/L)	Downgradient Concentration (µg/L)	Preliminary Remediation Goal (µg/L)
Arsenic	10.7	<0.1	1.7	10
Manganese	171	338	767	880
Molybdenum	104	<1.7	<1.7	100
NO_3+NO_2 as N	2080	27	32.5	10,000
Selenium	103	<0.13	<0.1	50
Uranium	535	<0.1	1.5	30
Vanadium	392	<0.3	0.5	330

[a]These contaminant concentrations are from the October 2002 sampling event. The upgradient concentrations are the mean values from the Row 1 wells (R1–M3 and R1–M4); the concentrations within the wall are the mean values from the Row 4 wells (R4–M3 and R4–M6), and the downgradient concentrations are the mean values from Row 6 wells (R6–M2 to R6–M5 and T6–D). See page 2-11 for a map with well locations.

Millsite Dewatering and Treatment

The primary objective of Millsite dewatering and treatment was to facilitate excavation and removal of mill tailings and contaminated soil that extended below the water table. Water recovered from dewatering efforts was used for dust control or was treated at the wastewater treatment plant (WWTP) to Utah Pollutant Discharge Elimination System standards before discharge to Montezuma Creek. The plant operated from March 1998 to May 1999. Approximately 54 million gallons of water were treated and released to Montezuma Creek during WWTP operation, thus removing contamination from the surface and ground water systems. An additional 4.08 million gallons were used for dust suppression after the WWTP was decommissioned in May 1999. The uranium removed during remediation was approximately 3 to 6 percent of the total pre-remediation inventory.

IRA Data Collection

IRA data collection activities were designed to characterize site conditions following remedial action and restoration for OU I and OU II. IRA data collection activities included

- Ground water and surface water monitoring for water quality analysis, ground water levels, and surface water flow. Monitoring was conducted semiannually in 1998 and quarterly in 1999, 2000, 2001, and 2002, and included comprehensive monitoring of the PRB.
- Installation of monitor wells. Numerous wells were installed on the Millsite to characterize the extent of ground water contamination, extent of the alluvial aquifer, and ground water flow direction in response to major alterations due to remedial action and restoration. Numerous wells were added to the monitoring network in the vicinity of the PRB to more closely monitor performance of that system.
- Characterize the distribution of COCs in subpile vadose zone soil to evaluate the potential of this material as a residual source of ground water contamination.

- Characterize the mobility of COCs in subpile vadose zone soil by column leach testing to evaluate the potential of this material as a residual source of ground water contamination.
- Characterize mobility of COCs in the saturated zone by column leach testing and sorption batch testing to evaluate COC sorption and flushing characteristics.

Progress reports that detail the scope and results of the IRA were prepared by DOE in 1999, 2000, and 2001. Analytical results for ground water and surface water monitoring are updated in this RI Addendum/FFS.

Ground Water Model

A steady-state ground water flow model was developed for the alluvial aquifer within OU III of the MMTS to synthesize the current understanding of the factors controlling the occurrence and movement of ground water within OU III. The baseline conditions represented in the model are those characterizing the ground water system and uranium ground water plume following remedial actions and site reconstruction completed for OUs I and II. A solute transport model was coupled to the flow model to predict future concentrations of uranium in the alluvial aquifer for a simulated period of 50 years beginning October 2002. Uranium was selected for transport modeling because it is the principal contributor to potential risk to human health and because uranium is much more widely distributed at greater concentrations relative to PRGs than the other COCs. The geochemical behavior of uranium is also well understood, and uranium fate and transport characteristics were evaluated in OU III site investigations. The concentrations of COCs other than uranium (e.g., arsenic, molybdenum, vanadium) are expected to gradually decrease without significant transport beyond their present extent because they are less mobile than uranium. Recent increased levels of selenium in ground water and surface water, as distinct from the remaining COCs, is addressed as a component of the ERA in Section 4.0.

The ground water flow model was constructed using the computer program MODFLOW, in which the alluvial aquifer comprised an isotropic and homogeneous single layer. The lateral margins (north and south) and the base of the model were no-flow boundaries to represent low-permeability bedrock that bounds the alluvial aquifer. Model inflow boundaries were assigned to represent the underflow component from the west and the recharge received along the north and south margins of the aquifer on the Millsite. Montezuma Creek was represented as a ground water outflow boundary to simulate the predominant gaining-stream condition observed at the site. Recharge received from the Burro Canyon aquifer was represented as a specified flux boundary in the appropriate reach of Montezuma Creek.

The flow model was calibrated to ground water levels measured at 66 monitor wells in October 2001 and to measured flows of ground water discharge. The flow calibration targets were determined from periodic measurement of steady-state ground water discharge from the alluvial aquifer to dewatering excavations on the Millsite during remedial actions, from pumping test analysis and geochemical mass balance analysis of ground water flow through the PRB, and from measurements of the flow in Montezuma Creek.

Transport of uranium in the alluvial aquifer was simulated using the computer program MT3D96. Initial concentrations of uranium in ground water were specified in the model as measured in October 2002. The PRB was assumed to have no effect in immobilizing uranium in the model. Remnant subpile soil was represented in the model as a source of uranium

contamination to ground water on the basis of column leach experiments and infiltration lysimetry research at Monticello. The geochemical behavior of uranium during transport was represented in MT3D96 by specifying a solid-liquid partitioning coefficient (K_d) that assumed linear, equilibrium-controlled (rapid and reversible) sorption. Representative values of K_d for OU III were determined in laboratory batch tests.

The ground water model predicts that uranium concentrations will decrease to less than 30 micrograms per liter (µg/L) throughout the study area in 42 years, beginning October 2002. The uranium plume downgradient of the Millsite is attenuated by dilution resulting from discharge of Burro Canyon Fm. ground water to the alluvial aquifer and by discharge of the alluvial aquifer to Montezuma Creek. These processes occur in the narrow reach of Montezuma Creek where the upper bedrock is the Burro Canyon Fm. These hydrologic boundaries prevent the uranium plume concentrations greater than 30 µg/L from advancing beyond its present extent. It is also predicted that the uranium plume will move beyond the PRB in about 13 years (about 2015). Rapid restoration of ground water quality on the Millsite is achieved by measured inflows from lateral sources. These inflows are ultimately captured by the wetlands and creek on the Millsite and are then conveyed from the study area principally as surface flow.

Human Health Risk Assessment

The human health risk assessment was updated using current concentration and toxicity data. Several activities completed since 1998 have affected surface water and ground water concentrations; these include the Millsite excavation, remediation of soil and sediment along Montezuma Creek, Millsite dewatering and treatment, and the installation and treatment of ground water with the PRB. The COCs were adjusted to reflect the impacts to the surface water and ground water systems and because additional monitoring data are available. Lead-210, radium-226, radon-222, and thorium-230 were eliminated as COCs in surface water and/or ground water, and molybdenum and nitrate were added as COCs in ground water. Most of the toxicity values did not change except those for the isotopes of uranium, which were lowered resulting in a higher risk.

The same exposure scenarios were used in the original assessment and the update:

- Current landowners and other nearby residents as agricultural workers and occasional recreational users.
- Other current residents of Monticello as occasional recreational users.
- Future residents of Upper Montezuma Creek from use of water in the alluvial aquifer and as recreational users in an extended backyard scenario.
- Future landowners as agricultural workers and recreational users.
- Other future residents of Monticello as occasional recreational users.

Two types of exposure assumptions are used to provide risk managers with a range of potential exposures: reasonable maximum exposure (RME) and central tendency (CT). RME is defined as an exposure well above the average but still within the range of possible values. CT uses exposure assumptions that result in an average or best-estimate exposure to an individual (approximately 50th percentile of possible exposures). Although generally considered to be average estimates, CT still tends to provide somewhat conservative exposure estimates.

In this update, exposure point concentrations for the soils and sediments were not altered from the original risk assessment. Therefore, any benefit gained from the remediation along Montezuma Creek is not reflected in the results. The updated results are summarized in Table ES–4, which is organized by expected impacts. Added cancer risks are presented for nonradionuclides (arsenic) and radionuclides (uranium-234, uranium-235 + daughters, and uranium-238 + daughters), noncarcinogenic hazard index (HI) (negative impacts other than cancer, such as loss of kidney function, liver disease, etc.) from arsenic, manganese, molybdenum, nitrate, selenium, uranium, vanadium, and a dose assessment from gamma radiation. The beef consumption pathway was eliminated from the updated evaluation because risks associated with this pathway are two to three orders of magnitude lower than the ground water ingestion pathway, and analytical results of tissue samples collected by EPA confirmed the limited uptake of the COCs to cattle muscle tissue that was predicted in the original risk assessment.

The future use residential scenario was evaluated using two sets of exposure point concentrations. One estimation, near-term exposure, was based on worst-case, current (October 2002) concentrations in well 92-11; the other used the 20-year modeled uranium concentration coupled with the current concentrations for the other COCs in well 92-09 as surrogates for the future concentrations (i.e., only uranium is expected to increase in this area). The 20-year estimates are expected to more accurately portray future conditions.

Risks are proportional to the exposure point concentrations; lower contaminant concentrations result in reduced risks. All types of risk have been reduced from the original assessment because of lower contaminant concentrations. Carcinogenic risks from nonradionuclides were lower because of the lower arsenic concentration in ground water; consumption of ground water accounts for over 99 percent of this type of risk. Elimination of the radionuclide COCs (mostly lead-210, which has a high toxicity) and lower contaminant concentrations reduced cancer risks from radionuclides. This was somewhat offset by increased toxicity values for the uranium isotopes. Ground water is still the predominant pathway for these contaminants; however, exposure to gamma radiation in the upper canyon accounts for approximately 25 to 35 percent of the total risks for the RME residential scenario. Noncarcinogenic risks were also reduced because of decreasing contaminant concentrations; only a small increase in risks occurred from adding molybdenum and nitrate as COCs. The predominant contributors to noncarcinogenic risk (HI) are uranium, vanadium, and arsenic.

Overall, the unlikely exposure scenario of the use of alluvial ground water as the primary drinking water source dominates the estimated risks for the future use residential scenarios for both the near-term and 20-year estimates. Risks associated with this pathway exceed established benchmarks. For the more likely recreational/agriculture scenario, risks are generally below any established benchmarks. The highest risks are for added cancer risks from radionuclides, which range from $1.3 \times 10^{-5}$to 1.3×10^{-4} for CT and RME exposure factors, respectively. The risk driver for this scenario is gamma exposure rate, which is likely lower than presented in the human health risk assessment because of the remediation of soil and sediment along Montezuma Creek.

Table ES-4. Summary of Results from the Human Health Risk Assessment

	Current Use Recreational/Agricultural		**Future Use Recreational/Agricultural**		**Future Use Residential (near term)**		**Future Use Residential (20 Year)**	
Risk Type	Central Tendency	Reasonable Maximum Exposure	Central Tendency	Reasonable Maximum Exposure	Central Tendency	Reasonable Maximum Exposure	Central Tendency	Reasonable Maximum Exposure
Chemical (added cancer risk, unitless probability)	8.8E-09	3.6E-07	8.8E-09	3.6E-07	5.7E-05	3.5E-04	5.5E-06	3.4E-05
Radionuclides (added cancer risk, unitless probability)	1.3E-05	1.3E-04	1.3E-05	1.3E-04	7.9E-05	4.7E-04	6.4E-05	4.0E-04
Noncarcinogenic risk (hazard index, unitless)	0.00	0.01	0.00	0.01	4.8	8.7	1.8	3.3
Dose assessment (effective dose equivalent, millirem per year)	1.8	5.5	1.8	5.5	27.9	45.7	22.3	37.1

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Ecological Risk Assessment

Concentrations of all COCs except selenium have either decreased in surface water and ground water or have remained the same. Cobalt, copper, lead, and zinc were eliminated as COCs because concentrations in surface water and ground water either decreased to nondetectable levels or were below aquatic benchmarks. Selenium concentrations began to increase in 2000 when unweathered bedrock on the Millsite was exposed by excavation; the resulting weathering released selenium to ground water and surface water. Elevated concentrations of selenium from off-site sources also enter the Millsite as seeps along the north margin. The increasing trend in selenium concentrations appears to have stabilized and recent monitoring indicates it may be decreasing in some areas. Selenium concentrations in surface water are greatest near Wetland 3 created during Millsite restoration.

After considering the increase in selenium concentrations, the ETAG suggested focusing this update on potential risks to the spotted bat and southwestern willow flycatcher. These receptors are of particular concern because of their status as state and federal endangered species, respectively. They are also the only receptors for which selenium was identified as a risk-driving COC in the 1998 ERA. The risk-driving exposure pathway associated with selenium was invertebrate ingestion. Benthic macroinvertebrates were included because results of the earlier ERA were inconclusive and those organisms are in direct contact with surface water.

Because of the interaction between ground water and surface water, and sample results indicating that soil and sediment on the Millsite are currently not contaminated, the effects of all activities since 1998 can be accounted for in the ERA update by using current surface water concentrations. No additional analyses of grasses or invertebrates have been performed since completion of the 1998 ERA. In general, decreases in COC concentrations in surface water and ground water should also result in concentration decreases for those same constituents in grasses and invertebrates. However, for contaminants that bioaccumulate, such as selenium concentrations in biotic media may still be a concern.

This update focuses on potential risks to the spotted bat, southwestern willow flycatcher, and benthic macroinvertebrates as a result of increases in selenium concentrations in surface water. For the spotted bat and southwestern willow flycatcher, risk was reevaluated by updating the surface water ingestion pathway with new exposure point concentrations and reevaluating risks associated with terrestrial invertebrate ingestion. For benthic macroinvertebrates, risks were reevaluated by comparing selenium concentrations in Montezuma Creek with concentrations from Verdure Creek approximately 8 miles south of the Millsite where benthic macroinvertebrate studies had been completed.

During preparation of this update it became apparent that the receptors chosen for evaluation in the 1998 ERA are not appropriate to evaluate the ecological effects of increased selenium concentrations in surface water. The ETAG identified insectivorous avian receptors that prey on aquatic invertebrates as potential receptors of concern. This update does not address risk to these new ecological receptors for several reasons.

- The largest increases of selenium in surface water have been near the wetlands created on the Millsite. These wetlands have not developed to the state where they are high quality habitat. At the present stage, Wetland 3 is relatively small and does not contain any open

water or a shrub midstory component. As such, it does not serve as high quality habitat for avian species such as shorebirds or waterfowl.

- The wetlands were created on the restored Millsite using clean backfill material; therefore, the amount of time that has passed for selenium to accumulate in these soils and sediments is relatively short.
- It is anticipated that selenium concentrations may decrease in surface water once the effects of the restoration activities have stabilized and the current drought situation eases.
- There are no new analytical data for sediment and aquatic invertebrates.

For these reasons, this update discusses uncertainties and continued monitoring that is necessary to evaluate risks to ecological receptors from exposure to selenium. Necessary data will be collected as part of the long-term monitoring for the site; an outline of the long-term monitoring plan will be included in the ROD.

Risks Associated With Surface Water Ingestion by the Spotted Bat and Southwestern Willow Flycatcher

Risks calculated for selenium via surface water ingestion by the spotted bat and flycatcher for the 1998 ERA were very low; maximum hazard quotients (HQs) approached 0.002. Exposure point concentrations used for the those calculations were approximately 2.0 µg/L. Data from 2001 and 2002 indicated that concentrations in Upper Montezuma Creek average 8.6 µg/L; the Utah Aquatic Wildlife Criteria is 5 µg/L. Selenium concentrations are greatest in seeps on the Millsite, where the maximum concentration measured in 2002 was 129 µg/L. Even though the seeps are very limited in extent, they represent worst-case concentrations. If these worst-case values were used with the same exposure parameters and assumptions as those in the 1998 ERA, the resulting risk for the spotted bat and flycatcher would be two orders of magnitude higher than those in 1998—about 0.1 for maximum HQs. These risks are still well below the threshold value of 1.0, which is used to signal a potential for concern. Therefore, increases in selenium in surface water should not be a concern for surface water ingestion by the spotted bat and southwestern willow flycatcher.

Risks Associated With Invertebrate Ingestion by the Spotted Bat and Southwestern Willow Flycatcher

According to the 1998 ERA the highest potential risks posed to the flycatcher and spotted bat were due to concentrations of selenium in benthic and terrestrial invertebrates that make up the major portions of their diets. Ninety-nine percent and 95 percent of dietary intakes for the spotted bat and flycatcher, respectively, were assumed to be invertebrates.

Selenium concentrations in samples of invertebrates from the site ranged from 0.33 to 2.9 milligrams per kilogram (mg/kg) and averaged slightly higher than 1 mg/kg. Reference area concentrations were as high as 1.5 mg/kg and averaged slightly less than 1 mg/kg, based on data presented in the 1998 RI (DOE 1998a).

Table ES–5 presents a summary of HQs calculated for the flycatcher and bat via invertebrate ingestion for Upper Montezuma Creek, Upper and Middle Montezuma Creek, and the reference area for the site (Verdure Creek). Numerical benchmarks used to calculate HQs were selected

with an attempt to identify benchmarks representing both the "no observed adverse effects level" (NOAEL) and "lowest observed adverse effects level"(LOAEL).

Table ES-5. Selenium HQs for Invertebrate Ingestion at Monticello OU III—1998 ERA Results

Receptor/Location	$HQ-CT_{NOAEL}$	$HQ-RME_{NOAEL}$	$HQ-CT_{LOAEL}$	$HQ-RME_{LOAEL}$
Spotted Bat—U	1.28	1.36	0.73	0.78
Spotted Bat—UM	1.12	1.19	0.64	0.68
Reference Area Range	0.30–1.5	0.32–1.62	0.17–0.87	0.19–0.93
Flycatcher—U	1.63	2.92	0.82	1.5
Flycatcher—UM	1.43	2.55	0.71	1.3
Reference Area Range	0.39–1.94	0.70–3.48	0.19–0.97	0.35–1.74

U=Upper Montezuma Creek
UM=Upper and Middle Montezuma Creek

At the time of the 1998 ERA, site-related HQs calculated for intakes of selenium through ingestion of invertebrates were within the range calculated for the Verdure Creek reference area, despite the higher concentrations of selenium in Montezuma Creek surface water. This suggests that terrestrial invertebrate concentrations may not be directly related to surface water concentrations and that selenium levels in terrestrial invertebrates from OU III do not differ significantly from background. No new monitoring data have been obtained for OU III invertebrates since completion of the 1998 ERA, so it is not possible to recalculate those HQs based on current site conditions. However, because selenium tends to bioaccumulate, the effect that increased concentrations in surface water might have on invertebrate concentrations is not known.

A U.S. Department of the Interior evaluation (DOI 1998) summarized the potential effects of different levels of selenium in various media based on a review of the ecotoxicological literature. Results of their evaluation pertinent for comparison to OU III are summarized in Table ES-6.

Table ES-6. Summary of the Ecotoxicity of Selenium (from DOI 1998)

Medium	Concentration	Effect
Water	1–3 µg/L	LOAELs in fish and wildlife through bioaccumulation
Terrestrial invertebrates	0.1–2.5 mg/kg	Background invertebrate concentrations (typically <1.5 mg/kg)
Aquatic invertebrates	0.4–4.5 mg/kg	Background invertebrate concentrations (typically <2.0 mg/kg)
Aquatic invertebrates	2.5–15 mg/kg	Experimental LOAEL for subacute (growth) effects in invertebrates
Avian dietary intakes (e.g., invertebrates)	3–8 mg/kg	Threshold for reproductive impairment
Bird, whole body	<2 mg/kg	Typical background
Dietary intakes, rats	3 mg/kg (dry wt.)	LOAEL, reproductive selenosis
Dietary intakes, dogs	7 mg/kg	Sublethal effects, LOAEL

Source: DOI 1998

Concentrations of selenium measured in cliff swallow carcasses for OU III (less than 1.8 mg/kg; see Volume VII, Appendix H, page H-67 of the1998 RI) were within the range identified as background for avian whole-body concentrations. Despite the slightly elevated risks calculated for ingestion of invertebrates by the spotted bat and southwestern willow flycatcher at OU III, selenium concentrations measured in OU III invertebrates are within the range of background. On the basis of a threshold range of 3 to 8 mg/kg for reproductive impairment in birds and a

threshold of 3 mg/kg for mammals (rats), average OU III invertebrate concentrations (less than 1 mg/kg) would need to increase by a factor of at least 3 (and perhaps as large as 8) over those observed through previous sampling and analysis to fall within this range. An increase of this magnitude appears unlikely given that hot-spot remediation has removed the most concentrated sources of contamination in soils and sediments. Also, the majority of food sources for the terrestrial invertebrates would not have contact with the selenium contaminated surface water (Montezuma Creek) or soils (since they were remediated). It is not possible to determine if such an increase could occur in the future.

Even if the increases in selenium concentrations in surface water have resulted in an increase of selenium in OU III invertebrates, exposures to elevated selenium levels by the spotted bat and flycatcher would need to occur and be of sufficient magnitude to merit any cause for concern. Because invertebrates account for 99 percent and 95 percent of the dietary intakes of the spotted bat and flycatcher, respectively, the assumptions made (discussed below) regarding intakes of site-related (and presumably contaminated) invertebrates are critical in calculating potential risks; uncertainties in the assumptions must be considered in interpreting resulting calculated risks.

For instance, risk to the spotted bat was estimated in the 1998 ERA using data from samples of flying invertebrates that were collected in areas along Montezuma Creek that had soil and sediment contamination. The exposure point concentration used in the calculation of the HI was 1.1 mg/kg. Flying invertebrates were not sampled outside the corridor of contamination, the most contaminated portions of which were remediated. The assumption that spotted bats will spend 100 percent of their time feeding in the contaminated area when it is known that they will travel up to 10 kilometers from their roosts to forage is conservative, especially considering the proximity of other surface water bodies in the area (e.g., the municipal treatment ponds [Figure ES–1] and Loyd's Lake 1 mile west of Highway 191). Also, the samples contained a mix of invertebrate species and not moths, which are the spotted bats' predominant food source; the effect of different species being sampled on exposure point concentration used in 1998 is unknown.

For the spotted bat and the southwestern willow flycatcher, it is probable that the exposure assumptions used in the 1998 ERA are conservative and, therefore, may not be realistic for site conditions for the following reasons. Effects of elevated selenium concentrations, if any, would probably be localized based on OU III selenium distributions in surface water. This localized effect would probably not have any significant impact on the spotted bats, which roost along cliff faces and forage up to 10 kilometers from their roosts. It is possible that a significant part of the bats' diet would then consist of invertebrates from outside the selenium-affected area.

Not all the suitable flycatcher nesting habitat at OU III has elevated levels of selenium. Birds selecting nesting locations outside the selenium-contaminated area would not have elevated risks for ingestion of selenium in invertebrates. Also, although flycatchers maintain well-defined territories, which are typically no larger than the size of the area with elevated levels of selenium, flycatchers are known to leave their territories even during the nesting stage to gather food for their nestlings (USFWS 2002). Birds that are not nesting are also known to travel to areas outside their territories (USFWS 2002). Therefore, the assumption that 100 percent of dietary invertebrates is from the contaminated area likely contributes to an overestimation of site-related selenium intake for the southwestern willow flycatcher.

Risk to Benthic Macroinvertebrates

Because selenium concentrations exceed the Utah Aquatic Wildlife Quality Criteria, concentrations could be of some concern for aquatic organisms, specifically benthic macroinvertebrates. No new data are available for invertebrates specific to OU III.

However, the U.S. Department of Interior (DOI) states that the lowest threshold for chronic toxicity for selenite or selenate occurs at approximately 25 to 100 µg/L and no clear community-level effects were apparent at concentrations of 25 µg/L. Using the DOI data as criteria, risks to the benthic community in Montezuma Creek are probably low because the highest concentration of selenium measured in Montezuma Creek during 2001 and 2002 was 12.1 µg/L. Risks to the benthic community may be of a concern at Wetland 3 and seeps on the Millsite; however, currently there is no open water at Wetland 3 or at the seeps other than seep 3.

Summary and Recommendations for Continued Monitoring

The analysis presented in this update supports the conclusions reached in the 1998 ERA that there is not a current significant risk to the environment from OU III COCs other than selenium and that presently no alternatives need to be developed in the FFS to mitigate ecological risk. For COCs other than selenium, the decreases in COC concentrations in surface water, ground water, soil, and sediment should result in concentration decreases for those same constituents in biotic media. Therefore, it is assumed that risks to the ecological receptors identified in 1998 associated with all ecological COCs except selenium have been reduced by remedial action and that the conclusions reached in the 1998 ERA remain valid (i.e., no significant ecological risks), except for the concerns with selenium. It is probable that the increase in selenium concentrations is partly a result of the remediation of these COCs.

Selenium concentrations in surface water in Montezuma Creek are unlikely to be a significant risk to benthic macroinvertebrates in the short term or the long term.

Given that the best habitat for the spotted bat and southwestern willow flycatcher is in an area where concentrations of selenium in the creek average between 5.1 and 7.0 µg/L and hot-spot remediation of contaminated soil and sediment has occurred, it is likely that the overly conservative exposure parameters balance any possible increase in selenium exposure from terrestrial invertebrate ingestion. It is unlikely that the population as a whole for these receptors is currently at significant risk from selenium.

However, current concentrations of selenium in Millsite surface water and sediment in the Millsite wetlands are not representative of long-term concentrations in those media. While it is anticipated that concentrations in surface water and ground water may decrease as the bedrock surface weathers and less selenium is available for leaching, the tendency for selenium to accumulate in the environment will have the opposite effect on concentrations measured. Also, in their present state (i.e., newly established and in a drought regime), the wetlands on the Millsite are not a long-term representation of their value as habitat or their potential for risks to ecological receptors.

Because of these uncertainties, future risks to ecological receptors from exposure to selenium cannot be addressed at this time. If Wetland 3 develops as designed, there is a potential risk to

ecological receptors, in particular waterfowl, because of the presence of selenium. A post-remedial monitoring plan will be developed to address potential uncertainties with regard to the ecological health of wetlands on the Millsite due to selenium. Specific sampling goals and design will be included in the OU III Proposed Plan and ROD.

The list of ecological receptors will be reviewed to determine their adequacy to reflect potential current and future concerns at the site. Surface water monitoring is expected to continue at seeps and wetlands on the Millsite and at several locations in Montezuma Creek from Highway 191 east to the sediment pond in the narrow part of the canyon. Ground water monitoring is expected to continue in the vicinity of Wetland 3 and downgradient of the Millsite to the PRB location. Other components of monitoring that will be considered are sediment and aquatic invertebrate sampling. Results of the data collection effort dictated by the post-remedial monitoring plan will be evaluated before the next CERCLA 5-year review scheduled for 2007.

Focused Feasibility Study

The FFS identifies and evaluates remedial alternatives for contaminated ground water associated with the post-source-removal period at OU III. Separate remedial alternatives for OU III contaminated surface water are not developed because remediation of ground water at OU III will also restore surface water quality. Remedial actions for the other contaminated media at MMTS (soil and sediment) were completed in August 1999.

The following remedial action objectives (RAOs) were developed for OU III ground water and surface water:

- Prevent ingestion of alluvial ground water that contains carcinogenic COCs posing an incremental lifetime cancer risk greater than 10^{-4} or that have concentrations exceeding federal or State ground water standards.
- Prevent ingestion of alluvial ground water that contains noncarcinogenic COCs posing an HI or HQ greater than 1.0 or that have concentrations exceeding federal or State ground water standards.
- Achieve compliance with State surface water standards for COCs in Montezuma Creek.

Ground water RAOs will be achieved when COC concentrations in ground water meet PRGs. Ground water PRGs were developed for OU III COCs on the basis of calculated potential risk to human health and water quality standards established by ARARs. Ecological receptors are not exposed to ground water, and therefore ecological risk was not considered during development of ground water PRGs (Table ES–1). The area of attainment for OU III ground water is defined as any portion of the alluvial aquifer within the boundary of the Millsite and downgradient of the Millsite where concentrations of COCs exceed PRGs. Consensus among EPA, UDEQ, and DOE requires that the remediation time frame for any remedial alternative retained for detailed analysis in this FFS should be not longer than 50 years. The associated time frames for the OU III alternatives range from approximately 38 to 42 years, as determined from ground water modeling and observed concentration trends.

The remedial alternatives that are evaluated in detail for OU III are

- Alternative 1: No Further Remedial Action With Institutional Controls.
- Alternative 2: Monitored Natural Attenuation With Institutional Controls.
- Alternative 3: Permeable Reactive Barrier With Monitored Natural Attenuation and Institutional Controls.
- Alternative 4: Enhanced Permeable Reactive Barrier With Monitored Natural Attenuation and Institutional Controls.

Two other alternatives were developed that involved ground water extraction at (1) a uranium plume hot-spot location and (2) from the area of the plume where uranium concentrations exceed 200 μg/L, followed by solar evaporative treatment at an existing on-site facility. These alternatives were not evaluated in detail because of the relatively higher complexity of implementation and the relative costs were disproportionate to the expected benefit. Components of the final alternatives are described below. Expected future risk reduction, relative to current potential risk due to the radiological effects of uranium, is compared in Table ES–7. Results of the detailed analysis are summarized in Table ES–8.

Table ES–7. Summary of Estimated Risk from Radioactive COCs

Alternative	RME		
	Risk at Year 0	**Risk at Year 20**	**Risk at Year 40**
1	4.7×10^{-4}	4.0×10^{-4}	1.4×10^{-4}
2	4.7×10^{-4}	4.0×10^{-4}	1.4×10^{-4}
3	4.7×10^{-4}	3.5×10^{-4}	1.4×10^{-4}
4 with option 1[a]	4.7×10^{-4}	3.5×10^{-4}	1.4×10^{-4}
4 with option 2[a]	4.7×10^{-4}	3.4×10^{-4}	1.4×10^{-4}
Alternative	**CT**		
	Risk at Year 0	**Risk at Year 20**	**Risk at Year 40**
1	7.9×10^{-5}	6.4×10^{-5}	1.4×10^{-5}
2	7.9×10^{-5}	6.4×10^{-5}	1.4×10^{-5}
3	7.9×10^{-5}	5.5×10^{-5}	1.5×10^{-5}
4 with option 1[a]	7.9×10^{-5}	5.6×10^{-5}	1.4×10^{-5}
4 with option 2[a]	7.9×10^{-5}	5.3×10^{-5}	1.4×10^{-5}

[a]Options 1 and 2 are defined in Section 5.5.4.

Alternative 1: No Further Action With Institutional Controls

This alternative is protective of human health and the environment because the existing ground water use restrictions would remain in effect until COC concentrations in ground water decrease to levels below PRGs. CERCLA waivers would be required to achieve compliance with ARARs because COC concentrations presently exceed established water quality standards, and this alternative has no allowance for a remediation time frame. Water-quality monitoring would continue at a reduced scope, and the PRB would be excavated and disposed of in a repository consistent with appropriate state statutes soon after the ROD for OU III became effective.

Table ES-8. Comparative Analysis of Alternatives[a]

Screening Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Overall protection of human health and the environment	Meet RAOs in 42 yr. Institutional control prevents ground water use.	Meet RAOs in 42 yr. Institutional controls prevent ground water use.	Meet RAOs in 40 yr. Institutional controls prevent ground water use.	Meet RAOs in 38 (Option 2) to 39 yr (Option 1). Institutional controls prevent ground water use.
Compliance with ARARS[b]	May require waivers.	Compliance with ARARs.	Compliance with ARARs.	Compliance with ARARs.
Long-term effectiveness and permanence	Natural attenuation has permanent effect.	Same as Alternative 1 assuming PRB reactive media is removed prior to releasing contaminants to ground water.	Same as Alternative 1 assuming PRB reactive media is removed prior to releasing contaminants to ground water.	Same as Alternative 1 assuming PRB reactive media is removed prior to releasing contaminants to ground water.
Reduction of toxicity, mobility, and volume through treatment	No additional PRB treatment to immobilize COCs.	COCs immobilized in PRB and disposed of at appropriate facility.	COCs immobilized in PRB and disposed of at appropriate facility. Potentially greater effect than Alternative 2.	COCs immobilized in PRB and disposed of at appropriate facility. Potentially greater effect than Alternative 3.
Short-term effectiveness	Effective in protecting workers, community, and environment during implementation.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.
Implementability	Administrative requirements potentially difficult to implement (non-compliance waiver).	Technical and administrative requirements not difficult to implement.	Technical and administrative requirements not difficult to implement. Longevity of effective PRB operation unknown.	Technical requirements slightly more difficult to implement. Administrative requirements potentially most difficult to implement (landowner concerns).
Net present value	$526,000	$1,474,000	$1,460,000	$1,513,000 (Option 1) $1,536,000 (Option 2)

[a]Excludes evaluation of state and community acceptance which will be included in the ROD following public review of the Proposed Plan.
[b]Alternatives 2, 3, and 4 must meet the state ground water quality standards within the accepted remediation time frame (< 50 years).

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Alternative 2: Monitored Natural Attenuation With Institutional Controls

This alternative relies on natural attenuation processes to reduce contaminant concentrations within the aquifer. Natural attenuation mechanisms for the site have been characterized through hydrogeologic investigation and laboratory tests. Ground water modeling and observed trends indicate that concentrations of COCs will decrease to levels below PRGs within the established remediation time frame (less than 50 yr). During that time, the existing institutional controls would restrict use of contaminated ground water. Comprehensive ground water and surface water monitoring would be used to verify the progress of alluvial aquifer restoration on and downgradient of the Millsite.

Monitoring of the PRB would also continue to ensure that operational failure did not adversely affect ground water quality. The PRB would be excavated and disposed of at a repository consistent with appropriate state statutes upon failure or when continued treatment provides only marginal benefit.

Alternative 3: Permeable Reactive Barrier With Monitored Natural Attenuation and Institutional Controls

This alternative uses the PRB and natural attenuation to reduce contaminant concentrations within the aquifer. During the time contaminant concentrations exceed PRGs (less than 50 yr [Table ES–8]), the institutional controls would restrict use of contaminated ground water. Comprehensive ground water and surface water monitoring would be used to assess the progress of alluvial aquifer restoration on and downgradient of the Millsite, and performance monitoring of the PRB would continue to demonstrate its effectiveness in immobilizing ground water COCs to acceptable levels. The PRB would be excavated and disposed of in a repository consistent with appropriate state statutes upon failure or when further treatment provides only marginal benefit. A 15-year operational period for the PRB is assumed for this alternative.

Alternative 4: Enhanced Permeable Reactive Barrier With Monitored Natural Attenuation and Institutional Controls

This alternative uses the PRB and natural attenuation processes as described in Alternatives 2 and 3, with a supplementary system to treat contaminated ground water flow that bypasses the PRB. During the time contaminant concentrations exceed PRGs (less than 50 yr [Table ES–8]), the institutional controls would restrict use of contaminated ground water. Comprehensive ground water and surface water monitoring would be used to assess the progress of alluvial aquifer restoration on and downgradient of the Millsite, and performance monitoring of the PRB would continue to demonstrate its effectiveness in immobilizing ground water COCs to acceptable levels. The PRB would be excavated and disposed of in a repository consistent with appropriate state statutes upon failure or when further treatment provides only marginal benefit. A 15-year operational period for the PRB is assumed for this alternative.

Summary of Detailed Analysis

Table ES–7 compares the calculated risk for each alternative from radioactive COCs based on RME and CT exposure assumptions and the assumption that the ground water exposure pathway is complete. Calculated risk from radioactive COCs at year 0 in the table is based on the

exposure assumptions and contaminant concentrations used in the update to the baseline risk assessment. The calculated risks for years 20 and 40 use the same exposure assumptions of the baseline risk assessment. Uranium concentrations used in the risk calculations are from the OU III ground water model.

As shown in Tables ES–7 and ES–8, remediation time frames and risk reduction do not vary appreciably between remedial alternatives. Uniform application of the existing institutional controls ensures that the alternatives are equally protective of human health. Compared to Alternatives 3 and 4, Alternative 2 is capable of achieving RAOs without additional technical or administrative actions and without reliance on the PRB. Otherwise, Alternatives 2, 3, and 4 are similar in satisfying the criteria evaluated in the detailed analysis (state and community acceptance excluded) with no distinct advantages.