Appendix A

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

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Executive Summary

(Unless otherwise noted, all references are to Volume I of the 1998 RI)

Introduction (Section 1.0 Introduction, pg 1–1) (Section 1.1 Purpose of the Remedial Investigation, pg 1–1)

This report presents results of the remedial investigation (RI) conducted for Operable Unit (OU) III of the Monticello Mill Tailings Site (MMTS). The purpose of the RI was to collect sufficient information and data to characterize the nature and extent of environmental contamination in OU III, to identify the sources of this contamination, to assess how the patterns of contamination will change over time after the on-site sources (tailings piles) have been removed, and to quantify the levels of risk to human health and the environment from the contaminants associated with OU III.

Site Description (Section 1.2 OU III Site Description, pg 1–7)

MMTS is located in southeast Utah, in and near the city of Monticello (Figure ES–1). OU III encompasses groundwater and surface water at and downgradient of the Monticello Millsite, as well as contaminated soil and sediment deposited downstream of the Millsite along Montezuma Creek (Figure ES–2). The Millsite is a 110-acre tract of land owned by the U.S. Department of Energy (DOE). Mill tailings and associated contaminated material remain on the Millsite as a result of historical vanadium and uranium milling operations. An estimated 200,000 cubic yards of contaminated material has been identified in the former mill area, and approximately 2.1 million cubic yards of tailings and contaminated soil have been identified in the tailings-impoundment area of the Millsite. The tailings are contained in four piles within the floodplain of Montezuma Creek and are in hydraulic contact with a shallow alluvial aquifer underlying the site. The tailings are the primary source of contamination in groundwater, surface water, soil, and sediment within OU III.

The OU III soil and sediment area (Figure ES–2), which is located entirely on private land, begins approximately 0.5 mile east of the eastern Millsite boundary and extends downstream along Montezuma Creek approximately 14,000 feet (ft). The downstream portion of the soil and sediment area ends approximately 3,000 feet below the confluence of Montezuma and Vega Creeks where the physical features change and large boulders make access difficult. To better match the human-health risk scenario and diverse ecological habitat, the OU III soil and sediment area was organized into three segments based on the physical characteristics of the creek and expected future use. Upper Montezuma Creek is closest to the Millsite. In the western portion of Upper Montezuma Creek the creek is entrenched; the eastern portion is characterized by beaver ponds, some of which have been breached. Middle Montezuma Creek is characterized by steep canyon walls and wetlands. Lower Montezuma Creek, which is the farthest from the Millsite, has a broader valley bottom with floodplain width ranging from 150 to 450 ft. Upper, Middle, and Lower Montezuma Creek areas are currently used for cattle grazing and recreation; no residences are located within the OU III soil and sediment area. Surface water and the alluvial aquifer are not used as drinking water sources.

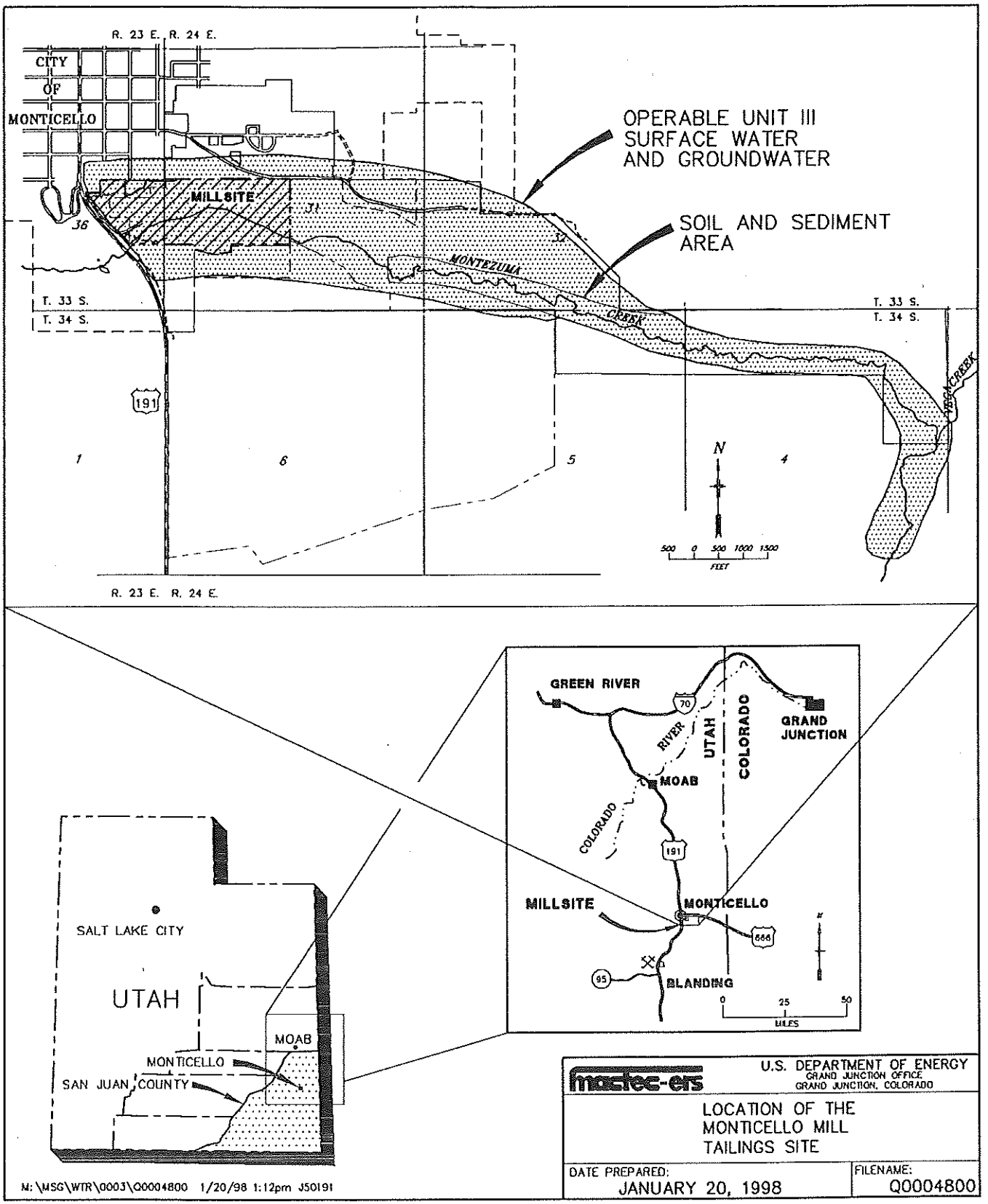

Figure ES–1. Location of the Monticello Mill Tailings Site

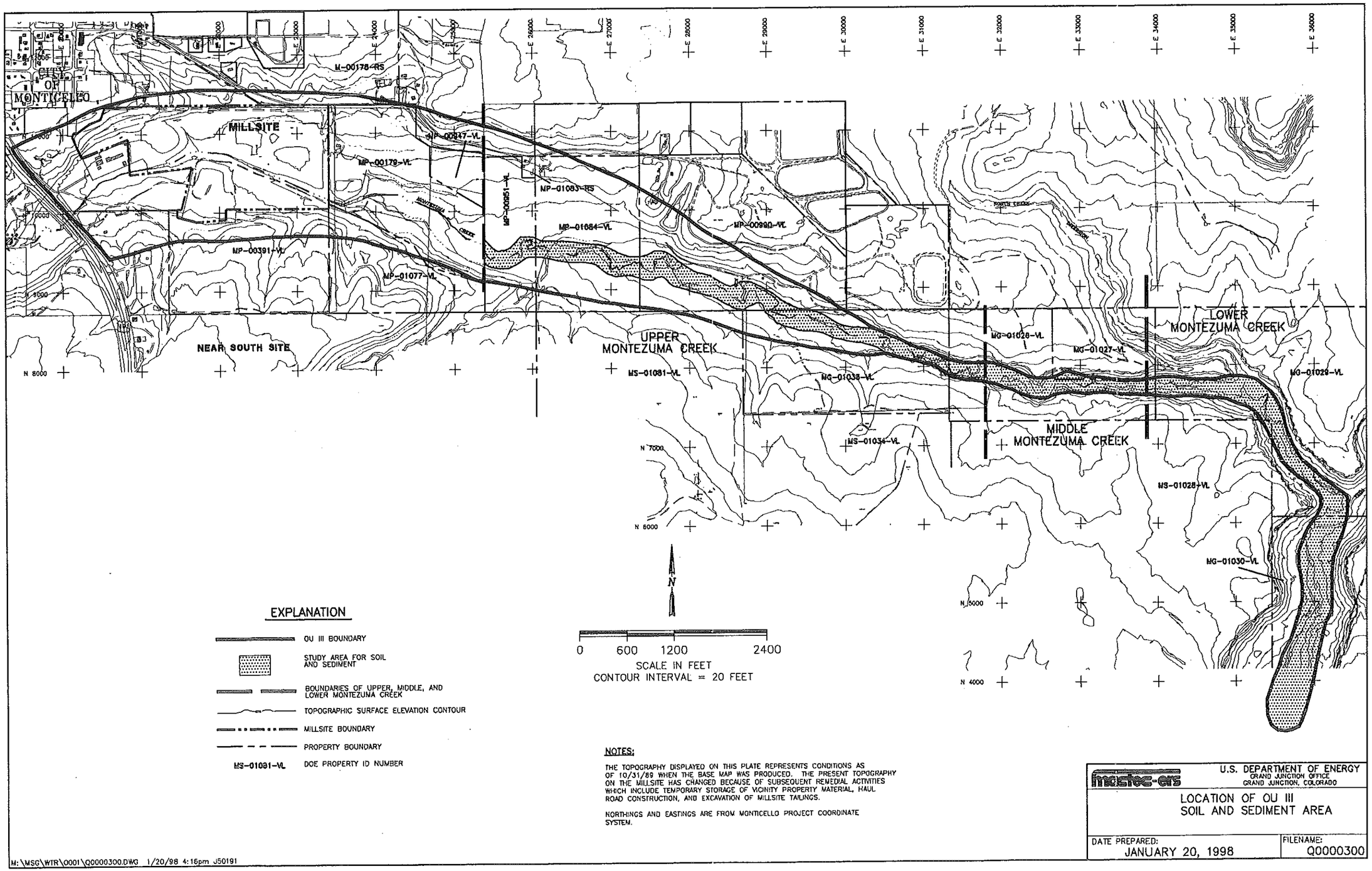

Figure ES–2. OU III Soil and Sediment Area

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Administrative History (Section 1.3 Administrative History, pg 1–8)

MMTS is a former uranium and vanadium ore-processing mill in the city of Monticello, Utah, that operated from the early 1940s until 1960. The Millsite was placed on the National Priorities List (NPL) in 1989 because of potentially elevated risks associated with contaminated materials related to past milling activities. The Millsite and adjacent peripheral properties are currently being remediated in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The DOE, U.S. Environmental Protection Agency (EPA), and State of Utah (State) have entered into a Federal Facilities Agreement (FFA) that specifies DOE as the lead agency and gives oversight authority to EPA and the State.

A Record of Decision (ROD) was signed in 1990 by the FFA parties that specified how the MMTS and surrounding properties (OU I and OU II) would be remediated. Remediation and restoration of OUs I and II is currently being conducted according to this ROD and is scheduled to be completed, as defined by concurrence on the remedial action reports, by October 2001. The 1990 ROD also stipulated that a focused remedial investigation/feasibility study (RI/FS) would be conducted to address surface-water and groundwater contamination from the MMTS and contaminated soil and sediment deposited downstream of the MMTS in and along Montezuma Creek (OU III).

Analysis of Previous Investigations
(Section 1.4 Conclusions from Previous Investigations , pg 1–12)

As early as the 1950s, environmental investigations were conducted at and near the MMTS. These early investigations (defined as investigations from the 1950s until 1992) were used to (1) establish the physical characteristics of OU III and provide a preliminary indication of the nature and extent of contamination within OU III, (2) develop an initial conceptual site model and identify potential exposure pathways and receptors to assist in the preliminary assessment of risk, and (3) focus subsequent data-collection efforts. The results from these investigations indicated that (1) surface-water quality downstream of the Millsite had degraded, (2) radionuclide and metal contamination existed in the shallow alluvial aquifer at and downgradient of the Millsite, and (3) elevated levels of radium-226 (Ra-226), uranium, and vanadium existed in sediment downstream of the Millsite. However, because of data-quality concerns, only data collected during and after November 1992 (when data collection began for the RI) were used to quantitatively assess risk and to define the nature and extent of contamination.

Physical Characteristics of the Site

Physiography (Section 2.1 Physiography, pg 2–1)

The OU III soil and sediment area corresponds to the Montezuma Creek floodplain, from approximately 0.5 mile east of the eastern boundary of the Millsite to approximately 3,000 ft downstream from the confluence of Montezuma Creek and Vega Creek. Montezuma Creek is a small, perennial stream with headwaters in the Abajo Mountains about 5 miles west of Monticello. The surface elevation of OU III is approximately 7,000 ft above mean sea level.

Meteorology (Section 2.2 Meteorology, pg 2–1)

The climate of Monticello is semiarid with four distinct seasons. Winter is cold and windy with occasional heavy snows. Spring is cool, unsettled, and typically windy with snow occurring as late as May. Spring and early summer (April through June) are the driest months of the year; late summer and early fall (late July to early October) are the wettest.

The average annual temperature is approximately 46°F. January is the coldest month, with average high and low temperatures of approximately 35°F and 13°F, respectively. July is the warmest month, with average high and low temperatures of approximately 84°F and 53°F, respectively. Average annual precipitation for Monticello is approximately 15 inches. Approximately 10 inches of precipitation fall as rain; the average annual snowfall is about 60 inches.

Prevailing winds are most commonly from the south-southwest and northwest. Night winds commonly occur from the west-southwest because of the eastward drainage of cool air from the Abajo Mountains. Some of the nighttime flow is channelized and follows Montezuma Creek Canyon. The average daily wind speed in Monticello is 5 miles per hour (DOE 1996b).

Geologic Setting (Section 2.3 Geology, pg 2–2)

San Juan County and Monticello are underlain by a thick sequence of Paleozoic and Mesozoic sedimentary rocks that slope mainly to the east. Below these rocks is a Precambrian crystalline basement that consists of metasedimentary and metaigneous rocks. Tertiary sedimentary rocks are not present in the area. The Abajo Mountains, about 5 miles west of Monticello, are a cluster of laccoliths that were intruded into the sedimentary rocks during Oligocene time (23 to 38 million years before present). Unconsolidated deposits of Quaternary-age pediment gravel, loess, and alluvium cover much of the bedrock surface between the Abajo Mountains and Montezuma Creek.

The Montezuma Creek valley above the confluence with Vega Creek was cut mainly during Quaternary time. West of U.S. Highway 191, the Montezuma Creek valley is cut into Mancos Shale of Late Cretaceous age. East of the highway, the valley cuts gradually into older rocks of the Dakota Sandstone of Late Cretaceous age and the Burro Canyon Formation of Early Cretaceous age. Approximately 0.5 mile upstream from the confluence of Vega Creek, Montezuma Creek begins cutting into the soft mudstones and shales of the Brushy Basin Member of the Morrison Formation of Late Jurassic age. Approximately 1 mile below the confluence of Vega Creek, Montezuma Creek begins cutting through more resistant sandstones of the Salt Wash Member of the Morrison Formation, as shown in geologic mapping by Huff and Lesure (1965).

No evidence of surface or subsurface faults has been found in the immediate vicinity of the Millsite. The closest significant geologic structure to the OU III area is the Verdure graben. The east-west trending graben is 0.5 mile wide and forms much of the valley of Verdure Creek about 4 to 5 miles to the south of the Millsite. The structure extends east from the Abajo Mountains for a distance of 25 miles. The maximum displacement of the bounding faults is 180 ft. Faulting and graben formation are believed to have occurred no later than Oligocene time. Subsurface

fractures occur in the Mancos Shale, Dakota Sandstone, and Burro Canyon Formations. Most fractures are subvertical and are either discontinuous or filled by secondary mineralization.

Soils (Section 2.3.6 Unconsolidated Surficial Deposits, pg 2–9)

Soils within OU III are typical of floodplains and alluvial bottoms. The surface horizon includes an organic-rich loam or sandy loam and the subsurface horizon consists of several organic-rich soils that vary in texture. Subsurface textures include sand, loamy sand, sandy loam, loam, sandy clay loam, and clay loam. Parent materials include recent layers of alluvium, loess, and surrounding Mancos Shale and Dakota Sandstone bedrock.

Vegetation (Section 2.4 Soils and Vegetation, pg 2–10)

Within the OU III soil and sediment area, eight different plant communities have developed over time as a result of differences in geology, soils, slope aspect, water table, and land-use practices. The dominant plant species within each community and the characteristics of the creek valley in which the communities are found are listed in Table ES–1.

Hydrology

Surface Water (Section 2.5.1 Surface Water, pg 2–14)

Two main watersheds drain the east side of the Abajo Mountains: North Creek and South Creek. These two streams, along with an unnamed tributary to South Creek that is generally dry, join west of U.S. Highway 191 to form Montezuma Creek. Other smaller creeks also drain the east slope of the Abajo Mountains but circumvent the tailings area and join Montezuma Creek downstream of the Millsite. In 1985, Monticello Reservoir (Loyd's Lake) was constructed on South Creek, approximately one mile upstream from the Millsite. The base flow of Montezuma Creek at and below the Millsite is maintained by groundwater discharge from the shallow alluvial aquifer and by leakage through the earthen dam at Monticello Reservoir. Flow in Montezuma Creek is generally perennial; however, portions of the creek are seasonally dry some years. Average flow rates are approximately 1 cubic feet per second (ft^3/s) in the OU III area.

Montezuma Creek and the alluvial aquifer underlying the creek valley are hydraulically connected. Gaining and losing reaches occur along Montezuma Creek. Measured flow data and field observations indicate that Montezuma Creek is losing immediately upstream from the Millsite, gaining on the west half of the Millsite, static to slightly gaining across the east portion of the Millsite, either gaining or losing in the western reach of Upper Montezuma Creek, and slightly gaining through the remainder of OU III. The gains and losses are attributed primarily to exchange between Montezuma Creek and the alluvial aquifer. In lower Upper Montezuma Creek and Middle Montezuma Creek, discharge of Burro Canyon groundwater contributes to stream flow.

Table ES–1. Plant Communities in OU III Soil and Sediment Area

Plant Community	Area of Creek Valley	Dominant Species
South-Facing Juniper/Oak	upland area	gambel oak (*Quercus gambelii*) Rocky Mountain juniper (*Juniperus scopulorum*) Utah juniper (*Juniperus osteosperma*) pinon pine (*Pinus edulis*) squaw-apple (*Peraphyllum ramosissimum*)
North-Facing Juniper/Oak	upland area	gambel oak (*Quercus gambelii*) Rocky Mountain juniper (*Juniperus scopulorum*) squaw-apple (*Peraphyllum ramosissimum*) currant (*Ribes* ssp.) serviceberry (*Amelanchier utahensis*)
Sagebrush/Wheatgrass	upland area	big sagebrush (*Artemesia tridentata*) fringed sagebrush (*Artemesia frigida*) western wheatgrass (*Pascopyrum smithii*) crested wheatgrass (*Agropyron cristatum*)
Rabbitbrush/Cheatgrass	upland area	rabbitbrush (*Chrysothamnus nauseosus*) snakeweed (*Gutierrezia sarothrae*) cheatgrasss (*Bromus tectorum*) crested wheatgrass (*Agropyron cristatum*)
Willow/Grass	riparian area	sandbar willow (*Salix exigua*) whiplash willow (*Salix lasiandra*) redtop (*Agrostis stolonifera*) bullrush (*Scirpus* spp.) horsetail (*Hippochaete laevigata* and *Equisetum arvense*)
Grass	riparian area	cheatgrass (*Bromus tectorum*) bindweed (*Convulvulus arvensis*) plantain (*Plantago lanceolatai*) dock (*Rumex crispus*)
Willow/Rush	wetland area	sedges (*Carex* spp.) rushes (*Juncus* spp.) horsetail (*Hippochaete laevigata* and *Equisetum arvense*)
Rushes	wetland area	rushes (*Juncus* spp.) sedges (*Carex* spp.) redtop (*Agrostis stolonifera*)

Note: Common and scientific names are consistent with Welsh et al. (1987).

Montezuma Creek is not used as a source of potable water; however, in the Upper, Middle and Lower sections it is used as a water source for livestock. Before 1994, approximately 25 to 30 acre-ft/yr of creek water was diverted at the east boundary of the Millsite for crop irrigation on the Somerville property south of the creek. This diversion has since been discontinued pending Millsite remediation. Shares of creek water are owned by other local residents; however, the amount of water used for irrigation is unknown.

Groundwater (Section 2.5.2 Groundwater, pg 2–16)

The hydrologic units associated with OU III are an upper alluvial aquifer consisting mostly of Quaternary alluvium and colluvium (bedrock detritus), an aquitard comprising Mancos Shale and Dakota Sandstone, and the underlying Burro Canyon bedrock aquifer. Below the Burro Canyon aquifer is the Brushy Basin Member of the Morrison Formation, which is relatively impermeable to groundwater flow. In all cases, the direction of groundwater flow is to the east, parallel to the axis of Montezuma Creek.

Saturated thickness of the alluvial aquifer ranges from approximately 2 to 25 ft but is generally less than 15 ft. The alluvial aquifer is recharged by infiltration of precipitation, surface-water loss from Montezuma Creek, and lateral groundwater flow from upgradient of the Millsite. Cultural sources are suspected to recharge the aquifer in the northwest portion of the Millsite. Depths to groundwater generally range from 8 to 15 ft but reach 20 to 50 ft on the tailings piles. In the northwest area of the Millsite, groundwater is within several feet of ground surface. Very shallow groundwater (less than 2 ft below grade) is also present in eastern Upper Montezuma Creek. The alluvial aquifer is currently not used for drinking water, irrigation, or livestock watering.

The Mancos Shale and Dakota Sandstone act as an aquitard between the alluvial aquifer and the underlying Burro Canyon aquifer in the Millsite area. Groundwater flow within this aquitard is minimal and predominately vertically downward.

The Dakota Sandstone has been eroded away and the alluvial aquifer is in direct contact with the Burro Canyon Formation approximately 4,000 ft east of the Millsite. Burro Canyon water discharges to the alluvial aquifer and Montezuma Creek within the valley where Dakota Sandstone is absent. Discharge also occurs from cliff outcrops along the margin of Montezuma Canyon below the Vega Creek confluence. The primary recharge zone for the Burro Canyon Aquifer is in outcrop areas on the east side of the Abajo Mountains.

The thickness of the Burro Canyon Formation is 114 ft approximately 600 feet east of the Millsite. The depth from ground surface to the potentiometric surface at this location is about 33 ft. The potentiometric surface of the Burro Canyon aquifer is above ground surface (flowing artesian conditions) in the easternmost portion of Upper Montezuma Creek, where the farthest downgradient monitoring wells are located.

The city of Monticello occasionally withdraws Burro Canyon groundwater from city-owned wells for nonpotable use only. Burro Canyon water has also been used by private households. Most of the wells are old and have not been used for several years; however, some wells have been used during the last 10 years for domestic irrigation and to water livestock.

Wildlife (Section 2.6 Wildlife, pg 2–18)

The OU III area supports abundant terrestrial wildlife, particularly along the Montezuma Creek corridor. Dominant species include mule deer, red and gray fox, coyote, mountain lion, bobcat, racoon, skunk, least chipmunk, rock squirrel, muskrat, weasel, beaver, and several species of rabbits, voles, and mice. No fish currently inhabit Montezuma Creek within the OU III soil and sediment area, although fish inhabit Loyd's Lake and Verdure Creek. Studies conducted in 1995

and 1996 indicate that substantial physical barriers (5 to 10-ft drops through boulders) within the rugged canyon area of Montezuma Creek most likely prevent migration of fish into the OU III area. Another factor that may negatively impact the viability of fish in Montezuma Creek is the water diversions for agriculture and other uses that decrease flow to very low levels.

Several federally listed threatened and endangered species and State-sensitive species are known to inhabit San Juan County; however, only two of the listed species, the State-sensitive spotted bat and northern goshawk, have been observed in the OU III soil and sediment area. The spotted bat most likely roosts in the cliff walls along Montezuma Creek within the OU III area and feeds on insects during evening hours. The northern goshawk most likely visits the OU III soil and sediment area during the winter months to feed. Its preferred habitat is in tall stands of old-growth conifer forest, which are not prevalent in the OU III area. These birds likely winter in areas of Montezuma Canyon downstream of OU III and breed during the summer months in the Abajo Mountains.

Wetlands (Section 2.7 Wetlands, pg 2–23)

A total of 16.7 acres of wetlands are within the soil and sediment area. In general, the wetlands are directly adjacent to both banks of Montezuma Creek and extend from 2 to 30 ft from the creek bed.

Demography (Section 2.8 Demography, pg 2–25) (Section 2.8.1 Population) (Section 2.8.2 Housing) (Section 2.8.3 Employment and Ecomonic Structure)

An estimated 2,200 people lived in Monticello in 1996, and 13,400 people lived in sparsely populated San Juan County in 1994. Approximately 50 percent of the county population is Native American. A severe shortage of housing exists for San Juan County, particularly for low-income families. Historically, the economies of San Juan County and the city of Monticello have depended on natural resources, a dependence that has led to a "boom and bust" economic pattern. This dependence has decreased in recent years; the trade (wholesale and retail) and service industries now employ the largest percentage (37 percent) of the county's workforce. San Juan County is one of the most impoverished counties in the United States with a per capita income in 1993 of $9,606; approximately 70 percent of the county's Native Americans live below the poverty level. In the second quarter of 1995, San Juan County's unemployment rate was 7.7 percent, compared to a state unemployment rate of 3.6 percent during the same quarter.

Regional Transportation Network (Section 2.8.4 Regional Transportation Network, pg 2–26)

U.S. Highways 191 and 666 are the major routes providing access to Monticello and the OU III area. Traffic volumes along these routes are relatively low because of the sparse populations. Highway 191 is a major tourist route between Moab (Arches and Canyonlands National Parks) to the north of Monticello and Lake Powell to the south.

Land Use and Ownership (Section 2.9 Land Use and Ownership, pg 2–26)

Land in the OU III soil and sediment area along Montezuma Creek is used mainly for farming, grazing, and recreation. Recreational activities include hunting, hiking, and horseback riding. The land is privately owned and no residences are present in this portion of OU III. Other areas of OU III include the Millsite and peripheral properties that overlie contaminated groundwater.

Two residences are located on the peripheral properties. The public has minimal access to OU III because the land in and near OU III is privately owned or controlled by the U. S. Government.

Scenic, Historic, and Cultural Resources (Section 2.10 Scenic, Historic, and Cultural Resources, pg 2–27)
Scenic resources within the area include rural and pastoral views of the plains and the Abajo Mountains and views of the canyon walls within the Montezuma Creek Valley. Archaeological evidence indicates that the San Juan County region may have been inhabited as early as 9500 B.C.; historic and cultural resource surveys conducted within OU III found one historic site on the floodplain of Montezuma Creek and numerous prehistoric sites along the canyon walls.

Noise (Section 2.11 Noise, pg 2–28)

Noise levels in the OU III area are typical of construction sites (from cleanup of the Millsite) within the western portion and typical of rural settings in the remainder of OU III.

Site Characterization Activities (Section 3.0 Site Characterization Activities, pg 3–1)

Site characterization activities were implemented in multiple phases; the objectives of each phase included collecting reliable and accurate data on (1) the concentration of Millsite-related chemicals in environmental media (groundwater, surface water, soil, sediment, and biota) or on (2) the hydrologic characteristics of the site. Each phase consisted of a review of existing data to better focus the data collection efforts and preparation of planning documents. The planning documents were extensively reviewed; procedures were established for sample collection and analysis; and quality assurance measures were specified including the collection of quality control samples. Additionally, all aspects of data collection and analysis were documented including data review and validation.

Results of the field investigations were used (1) to evaluate the presence or absence and relative concentrations of contaminants in each media at various locations within OU III and within the reference areas, (2) to evaluate potential migration pathways of contaminants within the environment, (3) to provide input for groundwater flow and contaminant transport modeling, and (4) to provide a basis for evaluation of risks to human health and the environment.

(Section 6.1.3 Chemicals of Potential Concern, pg 6–2 and Section 6.2.2 Problem Formulation, pg 6–13)
Initially, sampling and analysis included a wide range of chemicals, including metals and radionuclides, volatile and semivolatile organic compounds, pesticides, polychlorinated biphenyls, and herbicides. These were identified as chemicals of potential concern (COPCs) based on process knowledge, State and federal standards, and other criteria. On the basis of additional of considerations such as comparison of observed levels of metals and radionuclides to naturally occurring levels (background) and screening level assessment of potential risks to human health or the environment, the original group of COPCs was reduced to the list of contaminants of concern (COCs) for the human health risk assessment (HHRA; Table ES–2), and for the ecological risk assessment (ERA; Table ES–3). (The process used to select COCs is summarized in Section 6.0). Concentrations of these COCs have been investigated in detail in a variety of media and are summarized below.

Table ES–2. Summary of Human Health Contaminants of Concern

Contaminant	Alluvial Aquifer Groundwater	Montezuma Creek Surface Water	Montezuma Creek Canyon Soils In the Top 6 Inches
Chemical Toxicants			
Arsenic	X	X	X
Manganese	X		
Selenium	X		
Sodium	X[a]	X[a]	
Sulfate	X[a]	X[a]	
Elemental Uranium	X	X	X
Vanadium	X		
Radioactive Isotopes			
Pb-210 (γ, β)	X	X	X
Ra-226 (α, γ)	X	X	X
Rn-222 (α)	X		
Th-230 (α, γ)			X
U-234 (α)	X	X	X
U-235 (neutrons)	X	X	X
U-238 (α)	X	X	X
Gross Alpha	X[b]	X[b]	
Gross Beta	X[b]		
External Gamma			X

[a]Included as default COCs and will be addressed qualitatively. No toxicity or regulatory information is available from standard EPA sources (e.g., Health Effects Summary Tables) to support the risk assessment.
[b]Gross alpha and beta are indicators of contamination and will not be quantitatively evaluated. They are significant from a regulatory perspective.

Table ES–3. Ecological Risk Assessment—Contaminants of Concern

Chemical Toxicants			
arsenic	cobalt	copper	molybdenum
nitrate	lead	selenium	elemental uranium
vanadium	zinc		
Radioactive Isotopes			
lead-210 (γ, β)	radium-226 (α, γ)	thorium-230 (α, γ)	uranium-234 (α)
uranium-235 (neutrons)	uranium-238 (α)		

Surface-water and groundwater samples were collected during the annual monitoring task of the RI, which began in November 1992 and continued through July 1996. This task consisted primarilyof collecting samples on a semiannual basis for chemical analyses. Table ES–4 lists the total number of surface-water and groundwater samples collected as part of the annual monitoring program. Surface-water sampling locations are shown in Figures ES–3 and ES–4. Groundwater sampling locations are shown in Figures ES–5 and ES–6.

(Section 3.1.1 Surface Water Monitoring, pg 3–2) (Section 3.1.2 Groundwater Monitoring, pg 3–14)

Table ES–4. Summary of Surface-Water and Groundwater Samples Collected for the Annual Monitoring Program, 1992–1996

Sampling Area	Number of Surface-Water Samples Collected	Number of Groundwater Samples Collected
Upgradient-West of Highway 191	27	58
Millsite	39	98
Upper Montezuma Creek	40	100
Middle Montezuma Creek	0	0
Lower Montezuma Creek	23	0
Downstream and Off Site or Crossgradient	10	7

Soil and sediment characterization during the RI began in 1994 and continued through September 1996. Characterization included measuring gamma exposure rates (a real-time, surrogate field measurement for Ra-226), measuring in-situ Ra-226, and collecting soil and sediment samples for metals and radioisotope analysis. Table ES–5 lists the total number of soil and sediment samples collected during the RI.

(Section 3.2 Soil and Sediment Characterization, pg 3–35)

Table ES–5. Summary of Measurements Made During Soil and Sediment Characterization: Summary 1995–1996

Sampling Area	Number of Field Measurements for Ra-226 (Ground surface and subsurface samples)	Number of Soil and Sediment Samples Collected for Chemical Analyses
Reference Area	14	19
Upper Montezuma Creek	900	110
Middle Montezuma Creek	160	49
Lower Montezuma Creek	590	112
Downstream and Off Site	14	18

Biota samples were collected for metals and radionuclide analyses during the summer and fall of 1995 and during the spring and summer of 1996. Samples were collected of grass, forbs, shrubs, and terrestrial invertebrates across 14 transects that were established along Montezuma Creek, 6 transects across the Verdure Creek reference area, and 1 transect across the Vega Creek reference area. Benthic macroinvertebrate samples were collected from the creeks in the vicinity

(Section 3.3 Ecological Characterization, pg 3–49)

of the transects. Cliff swallows were collected for chemical and histopathological analyses at one Montezuma Creek transect and at the Vega Creek transect.

During the ecological characterization, investigations were conducted to document the presence or absence of State-sensitive or Federal threatened and endangered receptors within OU III. These investigations focused on the peregrine falcon (endangered), southwestern willow flycatcher (endangered), northern goshawk (State sensitive), and spotted bat (State sensitive). Surveys of the southwestern willow flycatcher and spotted bat were conducted according to U.S. Fish and Wildlife service protocol. The presence or absence of the peregrine falcon and northern goshawk was noted during wildlife characterization "walks" through the OU III soil and sediment area in 1995, 1996, and 1997. The peregrine falcon and southwestern willow flycatcher were not identified during these investigations, whereas the northern goshawk and spotted bat were positively identified. Investigations concerning the presence or absence of fish in Montezuma Creek were also conducted. No fish were found in the OU III portion of Montezuma Creek.

(Section 3.3.1 Ecological Surveys, pg 3–50)

EPA and UDEQ conducted a screening level study of mule deer and beef cattle to determine if contaminants were bioaccumulating in the animal tissues. Muscle, liver, kidney, and bone samples were collected. Analyses showed no significant difference between test and reference tissues (Henningsen 1997).

(Section 3.4 Data Collection to Support Assessment of Human Health Risk, pg 3–65)

(Section 3.6 Groundwater Modeling Support Activities, pg 3–86)

Hydrologic characterization was undertaken to refine the hydrologic conceptual site model and to obtain information needed to support the groundwater flow and transport modeling. These activities included drilling 9 soil borings through the alluvium, installing 21 alluvial monitoring wells and 21 bedrock monitoring wells, coring bedrock at bedrock well locations, detailed mapping of the site geology, mapping seeps and springs, monitoring surface water discharge, monitoring groundwater levels, performing 51 slug tests, and performing packer tests and vertical hydraulic conductivity tests.

Nature and Extent of Contamination

Information on the nature and extent of contamination is based on direct measurements of the concentrations of Millsite-related metals and radionuclides in the abiotic media (groundwater, surface water, soil, and sediment). The discussion on the nature and extent of contamination is organized by medium.

Groundwater Contamination (Section 4.1.1 Alluvial Aquifer, pg 4–1)

Groundwater samples collected from wells completed in the alluvial aquifer contained elevated concentrations (relative to background) of various metals, uranium decay-series radionuclides, sulfate, and nitrate. The highest concentrations were detected in samples collected from well 93–201–2 (Figure ES–5) located in the northwest portion of the Millsite. Wells downgradient

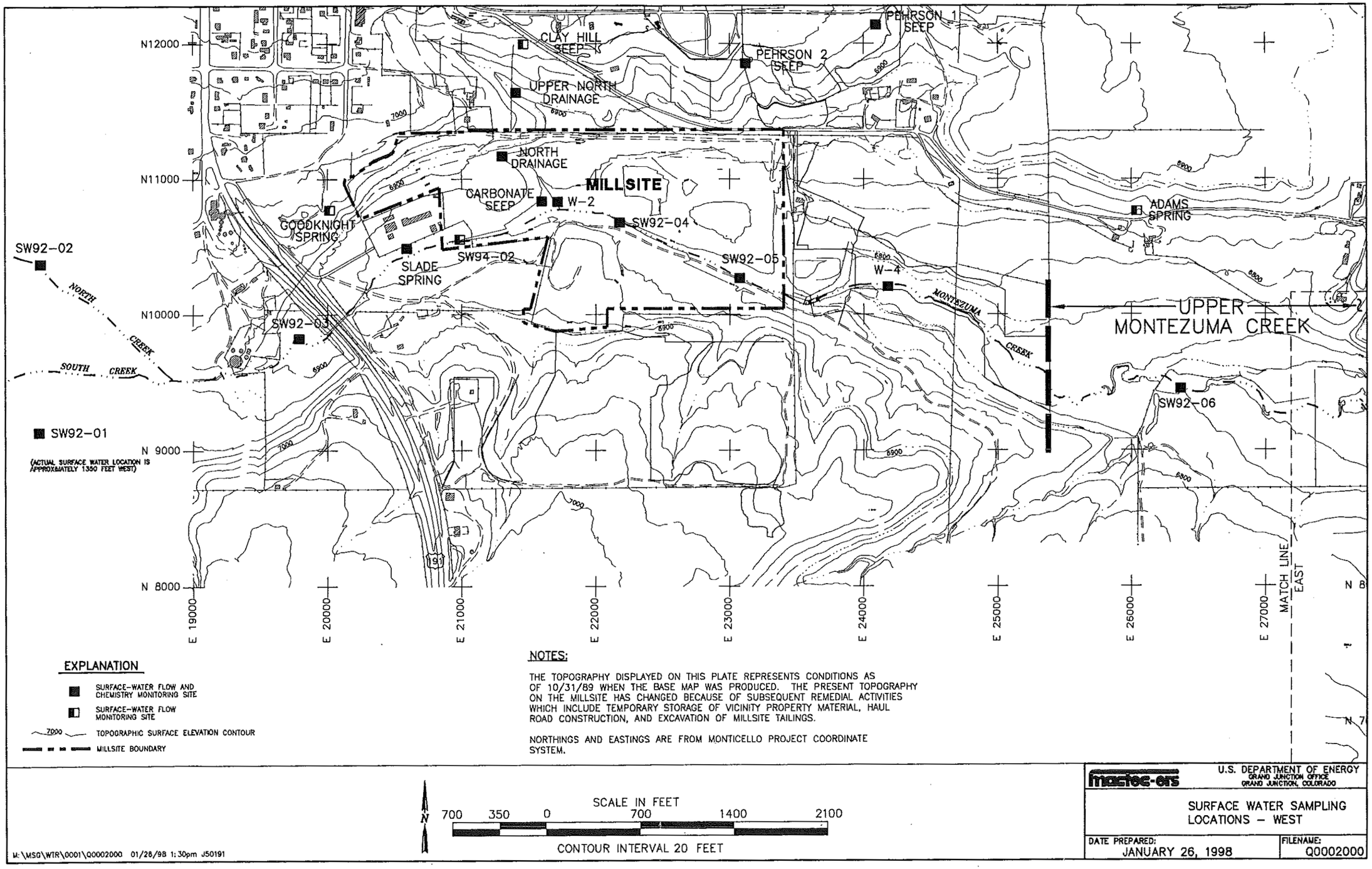

Figure ES–3. Locations of Surface-Water Sampling Sites—West

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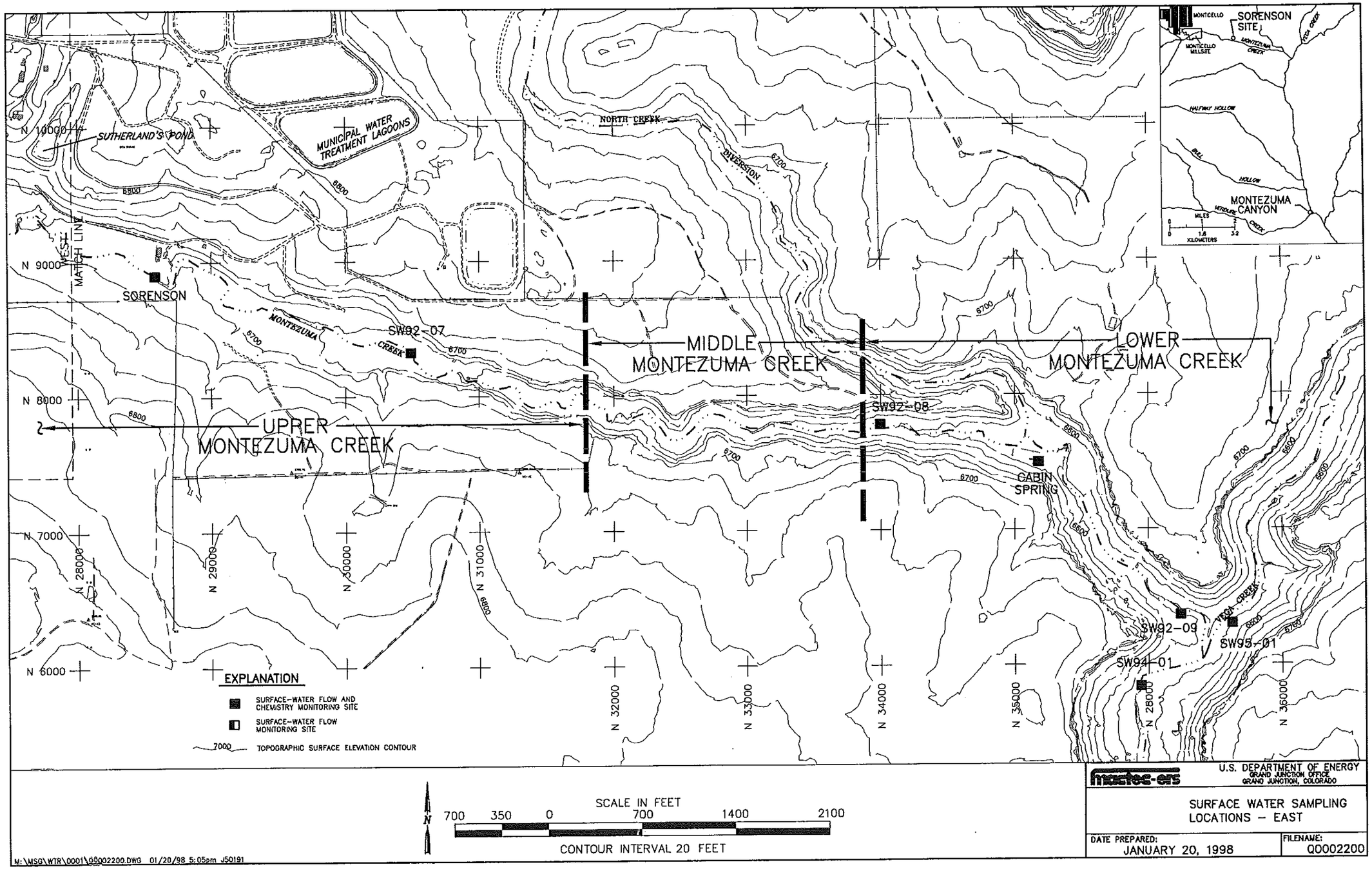

Figure ES–4. Locations of Surface-Water Sampling Sites—East

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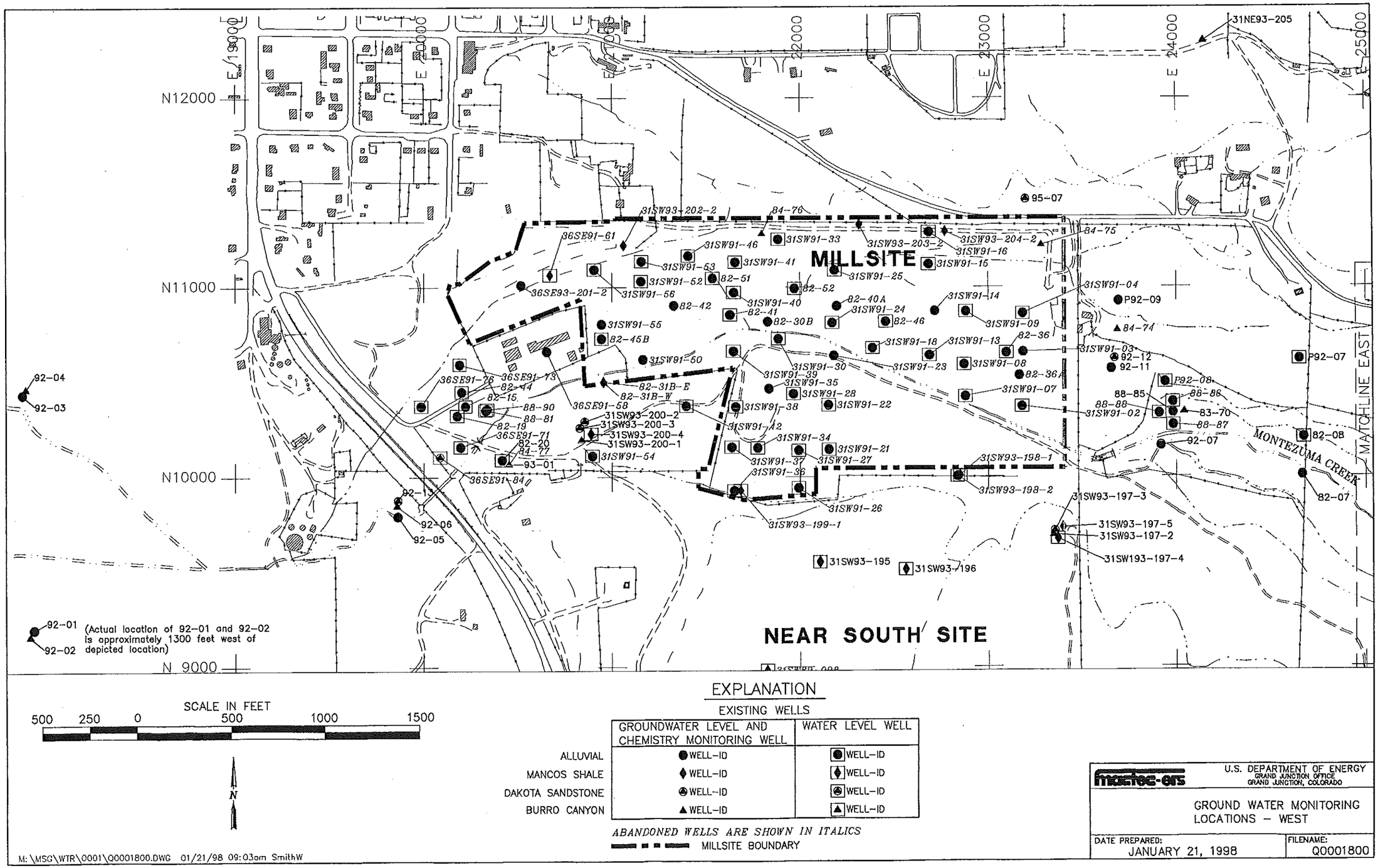

Figure ES-5. Locations of Monitoring Wells—West

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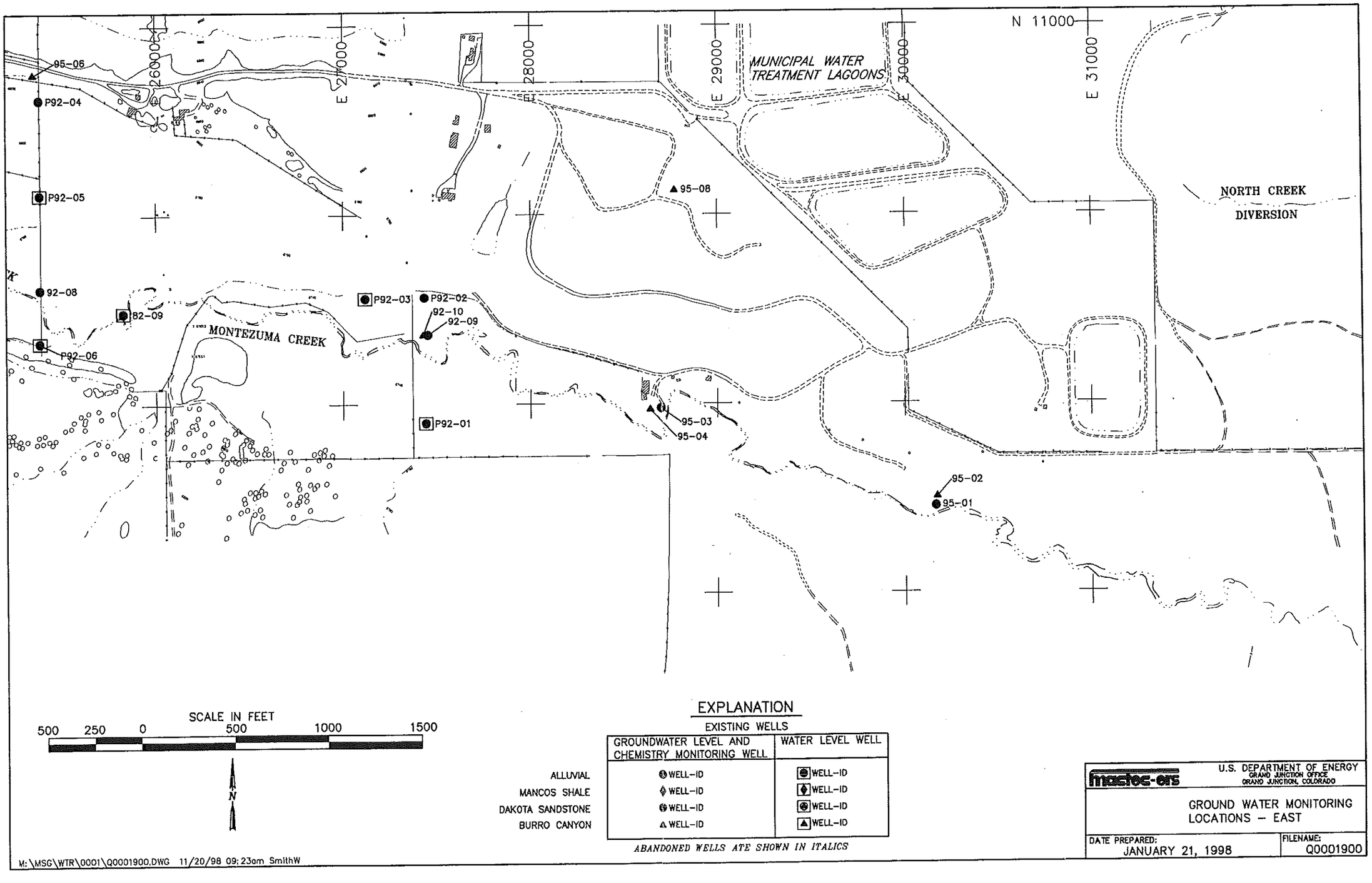

Figure ES-6. Locations of Monitoring Wells—East

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from this well have relatively low levels of contamination, which indicates that the region around well 93–201–2 is not hydraulically connected to the area underlying the majority of the Millsite, or that the contaminant migration from well 93–201–2 is limited. The next highest concentrations were detected in samples collected in the eastern two-thirds of the Millsite, indicating that the Acid, Carbonate, Vanadium, and East Tailings piles are the sources of contamination.

(Section 4.1.1 Alluvial Aquifer, pg 4–1)

Arsenic, manganese, molybdenum, selenium, vanadium, uranium, and Pb-210 have migrated through the alluvial aquifer off the Millsite and have contaminated the groundwater at downgradient locations on private property east of the Millsite. Selenium, Pb-210, nitrate, and Ra-226/228 were detected in concentrations above regulatory standards on the Millsite only. Molybdenum and U-234/238 were detected in concentrations above regulatory standards both on the Millsite and downgradient of the Millsite.

(Section 4.1.1 Alluvial Aquifer, pg 4–28)

Contaminant concentrations generally decrease with increasing distance from the Millsite. Just east of the Millsite, concentration contours change direction from being predominantly east-west (parallel to groundwater flow on the Millsite) to being northwest to southeast. The concentration contours in the area east of the Millsite are consistent with the groundwater flow direction in this area, which generally follows the alignment of the historic natural channel of Montezuma Creek.

(Section 4.1.1 Alluvial Aquifer, pg 4–28)

Most of the time-concentration plots do not show significant changes in concentration over time, which suggests that the plumes have generally reached steady-state conditions with respect to contaminant sources on the Millsite. Some plots show the effect of dilution during high-flow times of the year and fluctuate consistently and inversely with water level.

(Section 4.1.1 Alluvial Aquifer, pg 4–28)

Burro Canyon groundwater is not contaminated. The Mancos Shale and Dakota Sandstone appear to be adequate aquitards in areas where a downward gradient is present in the alluvial aquifer. East of the Millsite, where the alluvial aquifer directly overlies the Burro Canyon aquifer, there is upward flow from the Burro Canyon aquifer to the alluvial aquifer which prevents contaminant movement into the Burro Canyon aquifer. In these eastern areas where the Burro Canyon aquifer is under artesian conditions (near well pairs 95–03 and 95–04 and pairs 95–01 and 95–02; Figures ES–5 and ES–6), the alluvial aquifer groundwater quality is strongly affected by influx from the Burro Canyon aquifer.

(Section 4.1.2 Bedrock Groundwater, pg 4–28)

Surface-Water Contamination (Section 4.2 Surface Water, pg 4–41)

Samples collected from tailings-pile seeps on the Millsite have the highest concentrations of metals and radionuclides; concentrations of most analytes range from one- to two-orders of magnitude greater than concentrations measured in samples from Montezuma Creek. Because Montezuma Creek surface-water data indicate that the more highly concentrated contaminants in the seeps are rapidly diluted as they flow into the creek, Montezuma Creek is the focus of the nature and extent of contamination in surface water.

The concentrations of cobalt, lead, Th-230, Pb-210, Ra-226, and zinc were at or below background concentrations at all Montezuma Creek sampling locations. Elevated concentrations (with respect to background) of arsenic, copper, selenium, nitrate, and sulfate in Montezuma Creek are generally limited to the Millsite or just downstream of the Millsite boundary.

Molybdenum, radon-222, and vanadium were detected at elevated concentrations over a larger extent downstream but generally reach background concentrations in Lower Montezuma Creek. Uranium and manganese were detected throughout and downstream of OU III. However, elevated manganese concentrations may be attributed to discharge of Burro Canyon groundwater that is naturally high in manganese.

All sample locations throughout the surface-water monitoring network on Montezuma Creek have elevated uranium concentrations. Uranium concentrations increase downstream of the Millsite in Upper Montezuma Creek where contaminated alluvial groundwater discharges to the creek (between W–4 and Sorenson). Uranium concentrations peak at the Sorenson site in Upper Montezuma Creek with an average concentration of 150 pCi/L and decrease to an average concentration of 85 pCi/L at location SW94–01 in the eastern portion of Lower Montezuma Creek. Peak concentrations at the Sorenson location are probably due to alluvial groundwater discharge and may in part be due to local sources of soil and sediment contamination near or upgradient of the sampling site. The concentrations of all contaminants either remain relatively stable or decrease in Lower Montezuma Creek, which indicates that there is no significant leaching from any soil and sediment source within this portion of the canyon.

Soil and Sediment Contamination

(Section 4.3 Soil and Sediment, pg 4–53)

The primary source of soil and sediment contamination in the OU III soil and sediment area is the Millsite. Montezuma Creek, which flows through and adjacent to tailings piles on the Millsite, has been the primary transport mechanism for soils and sediments. Because contaminants have been transported to OU III via surface water, contaminant concentrations in soils and sediments vary widely depending on the past and current depositional properties of Montezuma Creek.

(Section 4.3.1 Upper Montezuma Creek, pg 4–55)

Ra-226 has a gamma-emitting decay product that allows the extent of Ra-226 contamination to be estimated with portable field instruments. For this reason, Ra-226 was used as an indicator analyte to map the extent of contamination in all sections of the OU III soil and sediment area. Extensive collection of Ra-226 data resulted in a detailed delineation of the extent of Ra-226 contamination. Generally, Ra-226 contamination is present in a relatively narrow band of soil and sediment on both sides of Montezuma Creek; the lateral extent of contamination is controlled by the floodplain topography.

The correlation coefficient between Ra-226 and the other OU III contaminants were estimated for soil and sediments. Arsenic, cobalt, copper, lead, Pb-210, Th-230, uranium (total), U-234, U-235, U-238, and vanadium generally have high positive correlation coefficients with Ra-226 that result in a distribution of those contaminants in Upper Montezuma Canyon similar to the distribution of Ra-226. In sediments, uranium has a weaker correlation with Ra-226, which can be attributed to its leaching from saturated sediments. Molybdenum, selenium, and zinc have poor correlation with Ra-226 in Upper Montezuma Creek. Because Upper Montezuma Creek concentrations of these contaminants are similar to concentrations in the reference area, these chemicals are interpreted to have a minimal component of Millsite-related contamination, and distribution is therefore random with respect to Ra-226 concentrations. Nitrate and sulfate have little or no correlation with Ra-226, and will therefore have a distribution in Upper Montezuma Creek that is independent of the distribution of Ra-226. Nitrate and sulfate concentrations

throughout the OU III soil and sediment area cannot be solely attributed to Millsite contamination; cattle grazing in the area and discharge from the municipal water treatment lagoons could contribute nitrogenous wastes as an additional source of nitrate, and potential sulfate sources include coal and carbonaceous shales in the Dakota Sandstone and gypsum in the Mancos Shale.

Evidence based on soil sample analyses and field measurements indicates that more than 73 percent of the volume of Ra-226 contamination in Upper Montezuma Creek is in the 0- to 6-inch depth interval, and more than 90 percent is less than 12 inches deep; less than 3 percent is greater than 24 inches deep. Ra-226 contamination at depths greater than 24 inches in Upper Montezuma Creek is mainly in areas where thick sediments are present. These areas include the soils adjacent to the section of Montezuma Creek between the channelized portion of the creek and the narrows, where the floodplain opens up and becomes topographically flat and wide. Thicker sediments are also present in the irrigation and beaver ponds where the deepest Ra-226 contamination is found.

In summer 1998, during a non-time-critical removal action in Upper Montezuma Creek, contamination was detected at depths that generally extended to 42 inches. At four of the 22 deposits excavated to date, contamination extended to a depth of 6 ft.

(Section 4.3.2 Middle Montezuma Creek, pg 4–64)

Evidence based on soil sample analyses and field measurements indicates that over 80 percent of the volume of Ra-226 contamination in Middle Montezuma Creek is in the 0- to 6-inch depth interval, and more than 90 percent is less than 12 inches deep; less than 5 percent is greater than 24 inches deep. Ra-226 contamination greater than 24 inches deep is present on the inside of meanders of Montezuma Creek in the western portion of Middle Montezuma Creek. In these areas, thicker sediments have resulted from overbank deposits during flood events on Montezuma Creek. Less than 5 percent of the Ra-226 contamination (by volume) in Middle Montezuma Creek is greater than 24 inches.

(Section 4.3.3 Lower Montezuma Creek, pg 4–70)

Evidence based on soil sample analyses and field measurements indicates that over 60 percent of the volume of Ra-226 contamination in Lower Montezuma Creek is in the 0- to 6-inch depth interval, and more than 87 percent is less than 12 inches deep; less than 3 percent is greater than 24 inches deep. Ra-226 contamination at depths greater than 24 inches is present near the confluence of the North Creek Diversion and Montezuma Creek, where the floodplain opens up and becomes topographically flat and wide. In this area, thicker sediments have resulted from overbank deposits during flood events on Montezuma Creek. Many of the highest Ra-226 concentrations in Lower Montezuma Creek are found in this area, as well as the largest lateral extent of Ra-226 contamination.

In summer 1998, during a non-time-critical removal action in Lower Montezuma Creek soils, contamination was detected at depths greater than 24 inches at one of four deposits; contamination at that location extended to 36 inches.

(Section 4.3.4 Downstream Offsite, pg 4–78)

Sediment sampling above the confluence of Montezuma and Verdure Creeks confirmed that only insignificant amounts of Ra-226 and other contaminants have been transported beyond the Lower Montezuma Creek boundary. Concentrations of other contaminants in surface-sediment samples from the reference area were compared with contaminant concentrations of downgradient sediment samples. Downgradient contaminant concentrations (except sulfate) were near

background levels. Only sulfate had downgradient sample concentrations significantly higher than concentrations in the reference area; however, these elevated concentrations can be attributed to sources other than the Millsite.

Contaminant Fate and Transport

(Section 5.1.1 Chemical Properties and Crustal Abundance, pg 5–1)

The chemical properties of contaminants and physicochemical processes affecting the contaminants were evaluated to help estimate their fate during transport in surface water and groundwater. The chemical properties evaluated were oxidation state, aqueous species, crustal abundance, and radioactive decay.

The oxidation state of a chemical governs its tendency to form dissolved (aqueous) complexes, adsorbed complexes, or precipitated minerals. Strong aqueous complexes tend to remain in solution and, therefore, be mobile. An example of this is the divalent uranyl carbonate complex. Crustal abundances will determine if natural sources of contaminants are available in a given area. The presence of ore-bearing geologic units, in particular, can result in naturally elevated (above "average") levels of some chemicals in the environment.

Radioactive decay can have a significant effect on the fate of certain radionuclides. The short half-life of Pb-210 (22.26 years) indicates that in some systems it will decay to insignificant concentrations in about 220 years.

(Section 5.1.2 Physicochemical Processes, pg 5–3)

The physicochemical processes evaluated were aqueous complexation, adsorption, mineral precipitation and dissolution, colloid formation, and biological processes. Adsorption appeared to significantly decrease the mobility of several OU III contaminants. Sorption is believed to account for the following observed order in which concentrations of contaminants in groundwater decreased as a function of distance from the Millsite tailings piles (from most to least mobile): U > Mo ≥ Se > As > V = Ra.

(Section 5.2.1 Transport Processes, pg 5–7)

The fate and transport of contaminants in the alluvial aquifer was predicted by modeling groundwater flow and solute transport. Hydrogeologic data obtained throughout the RI was used to develop a conceptual model of groundwater flow within and between the primary hydrostratigraphic units of the MMTS, which are the alluvial aquifer in the Montezuma Creek valley, the underlying Mancos Shale/Dakota Sandstone aquitard, and the underlying Burro Canyon sandstone aquifer. Interaction between Montezuma Creek and groundwater was also a component of the conceptual model.

(Section 5.2.2 Groundwater Flow Model, pg 5–10)

A numerical model was then developed using the computer code MODFLOW to simulate three-dimensional steady-state groundwater flow within the alluvial aquifer. The model consists of a single unconfined layer (alluvial aquifer) bounded laterally and at depth by no-flow boundaries (impermeable bedrock). Montezuma Creek is represented as a hydrologic boundary that permits groundwater flux between the alluvial aquifer and the creek. The model was calibrated to measured hydraulic heads in the alluvial aquifer averaged over a 3-year period of observation. Measured flux between Montezuma Creek and the alluvial aquifer was used as a secondary calibration target. Model calibration was assisted using the parameter estimation

computer code MODFLOWP (Hill 1992), which was also used to perform a parameter sensitivity analysis.

(Section 5.2.3 Solute Transport Modeling, pg 5–13)

The computer program MT3D was used in conjunction with the calibrated groundwater flow model to simulate transport of arsenic, lead-210, manganese, radium-226, and uranium in the alluvial aquifer. The transport models were first calibrated to present-day analyte distributions in groundwater based on assumed contaminant sources on the Millsite and steady-state groundwater flow. The transport models did not address the potential contamination to surface water and groundwater from secondary source material downgradient of the Millsite. Contaminant plume development was simulated for a 48-year period corresponding to the time since the earliest known emplacement of tailings on the Millsite (January 1948) through January 1996. Aquifer dispersivity and the distribution (solid:liquid) coefficient (K_d) for each analyte were treated as calibration parameters. Site-specific experimentally determined K_d values for several analytes were also used as indicators of contaminant mobility and to assist calibrating this parameter. Radioactive decay and ingrowth was not simulated in the transport models.

The calibrated transport models were then used to simulate natural attenuation of the alluvial aquifer for a 100-year period following Millsite remediation. Two scenarios were developed to bracket anticipated remediation alternatives for Millsite tailings and soil. One model scenario assumed removal of all material in which Ra-226 concentrations exceed 15 pCi/g; this scenario results in some soil being left in place above the water table. The 15 pCi/g cleanup level was used only for purposes of estimating thickness of remaining vadose zone. November 1994 water levels were used for estimation purposes; these were about average or slightly less than average for the RI measurement period. The zone between the excavation level and the water table (residual vadose zone or RVZ) was represented as a source of groundwater contamination even though Ra-226 cleanup levels were met. The RVZ source makes worst-case assumptions using results of pore-water samples collected in native soils underlying the tailings piles, and other sample data to model RVZ contaminant concentrations. Precipitation rates and K_d values were used to model fluxes from RVZ to groundwater. The second scenario assumed that all areal sources were at background concentrations, which effectively eliminated all groundwater contaminant sources above the aquifer. Both scenarios assumed removal of all mill tailings. The two scenarios were developed to bracket the maximum and minimum contributions to groundwater contamination from the vadose zone on the Millsite. Currently, Millsite remediation involves cleanup to a level between these two extremes. The transport models did not address the potential contamination to surface water and groundwater from secondary source material downgradient of the Millsite or address the consequences of selecting different cleanup levels (e.g., 5 or 15 pCi/g Ra-226).

(Section 5.2.5 Limitations of Transport Model Predictions, pg 5–26)

The calibration and prediction simulations assumed that the existing groundwater flow processes represented in the flow model remained constant during the respective simulated time periods. Flow conditions may change in response to activities such as groundwater and surface water diversion or pumping, stream realignment, modification of topography, and emplacement of backfill. Such activities would potentially affect the hydraulic conductivity and groundwater flow velocities, areal recharge rates, and stream/aquifer interaction, for example. Remediation may also alter the distribution of contaminants in the aquifer relative to present-day conditions.

(Section 5.2.4 Results, pg 5–23)

Transport model results are summarized in Table ES–6. On the basis of these results, the concentrations of each modeled analyte will exceed its regulatory standard or background concentration through 100 years in Millsite groundwater regardless of the modeled remediation alternative. Downgradient of the Millsite, uranium concentrations will exceed the regulatory standard (30 pCi/L) and manganese will exceed background concentrations for greater than 100 years for the modeled RVZ scenario. Under the no-RVZ scenario, the concentrations of each analyte except manganese will decrease to background levels or below regulatory standards within 100 years downgradient of the Millsite.

A comparison of the results of the two scenarios indicates that the vadose zone beneath the tailings piles represents a potentially significant source of contamination from uranium, manganese, and to a lesser extent, Pb-210.

For both scenarios, groundwater concentrations of some contaminants, such as uranium, are predicted to continuously decrease from present-day values following Millsite remediation. Other contaminants, such as arsenic, are predicted to move downgradient at concentrations that do not exceed regulatory standards. Although not modeled, excavation dewatering during Millsite remediation may remove significant volumes of contaminated groundwater and potentially decrease the predicted restoration periods.

Baseline Risk Assessments (Volume VI, Appendix L of 1998 RI)

Human Health Risk Assessment (Appendix L, Section 2.1 Overview of Sampling, pg 2–1, Section 1–3 Scope of the Baseline Human Health Risk Assessment, pg 1–5)

A baseline HHRA was prepared for OU III that evaluated risks to human health from all sources of OU III contamination. Standard EPA guidance documents (e.g., EPA 1989a) were used to develop the HHRA.

(Appendix L, Section 2.4 Approach for Identifying Contaminants of Concern, pg 2–49, Section 2.5 Summary of Contaminants of Concern, pg 2–52)

After identifying COPCs, one of the initial activities in a risk assessment is winnowing these to a set of contaminants of concern (COCs). Selection of COCs requires a systematic process for identifying site-related chemicals that may pose unacceptable risks at a site and evaluating available sampling data for their potential use in a risk assessment. COCs were determined using a process from EPA Region 8 that involved considering historical evidence of production and release from the Millsite and comparing sampling results to regulatory benchmarks, acceptable intakes of essential human nutrients, and background concentrations (EPA 1994c). Table ES–2 lists the identified COCs by media.

(Appendix L, Section 3.1.2 Potentially Exposed Populations, pg 3–5)

Although some residences are located within OU III (which includes all the land above groundwater in the area above the Millsite and within the Montezuma Creek valley below the Millsite), none use groundwater or surface water as a drinking water source, and no one currently lives on or directly adjacent to the OU III contaminated soil and sediment area (that is the Montezuma Creek stream channel, immediately adjacent wetland, and bank deposits).

Table ES–6. Transport Model Results Summary

Millsite Locations		RVZ Scenario		No-RVZ Scenario	
Analyte	Benchmark Concentration/ Activity	Time[c] [yr]	Location[d]	Time[c] [yr]	Location[d]
U-234,238	30 pCi/L[a]	>100	Majority of millsite.	60 >100	All millsite monitor wells. Between wells 91-50 and 91-35.
Arsenic	50 µg/L[a]	90 >100	All millsite wells. Small area at base of Acid Pile near well 91-35; see text.	90 >100	All millsite wells. Small area at base of Acid Pile near well 91-35.
Ra-226	5 pCi/L[a]	>100	Well 91-50; majority of millsite except nr. well 91-50 w/in 75 years.	>100	Well 91-50; majority of millsite except near well 91-50 w/in 75 years..
Pb-210	≤2 pCi/L[b]	>100	Wells 91-50, 91-35, 91-23 and area north of wells 82-40A and 91-14.	~100	Well 91-50; majority of millsite area except between wells 91-50 and 91-35 w/in 100 yr.
Manganese	30 µg/L[b]	>100	Majority of millsite.	>100	Majority of millsite.
Downgradient Locations					
U-234,238	30 pCi/L[a]	>100	Millsite east to well 92-09.	40 80	All downgradient monitor wells. Small area between wells 92-08 and 92-09.
Arsenic	50 µg/L[a]	0	Entire downgradient area.	0	Entire downgradient area.
Ra-226	5 pCi/L[a]	0	Entire downgradient area.	0	Entire downgradient area.
Pb-210	≤2 pCi/L[b]	85	Entire downgradient area.	55 - 60	Entire downgradient area.
Manganese	30 µg/L[b]	>100	Millsite east to and including well 92-09.	>100	Millsite east to and including well 92-09.

[a]Regulatory Standard.
[b]*Approximate background concentration. No regulatory standard available.*
[c]Maximum time required for analyte to decrease to specified concentration.
[d]Location where specified concentration is attained at the given time, e.g., the majority of the millsite area will require >100 years to attain <30 pCi/L uranium under the RVZ scenario; and, all millsite wells will be <30 pCi/L uranium in 60 years except for the area between wells 91–50 and 91–35 which will require >100 years to attain <30 pCi/L uranium under the No-RVZ scenario.

The primary populations exposed to contaminants within OU III are nearby residents who use the land along Montezuma Creek for cattle grazing, hunting, or growing alfalfa. Excluding the Millsite, all the land in OU III is privately owned. In the future, some additional development is possible within Upper Montezuma Creek, but it is not expected to occur within the contaminated soil and sediment area (i.e., the Montezuma Creek floodplain). The expected future use of the Upper Montezuma Creek is as an extended backyard. The current uses of Middle and Lower Montezuma Creek (recreational/agricultural) are likely to continue in the future.

(Appendix L, Section 3.2.1 Complete Exposure Pathways, pg 3–13)

Exposure is expected to occur from incidental ingestion, inhalation of dust, and direct exposure to gamma radiation. The potential receptors are future nearby residents, agricultural workers, and recreational users. The most sensitive subpopulation is children ages 5 to 14 who are expected to have higher daily incidental ingestion of soil and sediments associated with outdoor activities (e.g., playing) and are likely to spend the longest period of time per year in the OU III soil and sediment area. Table ES–7 presents a summary of the exposure pathway analysis.

Table ES–7. Exposure Pathway Analysis Summary

Exposure Medium	Potential Routes of Exposure	Potential Receptors	Comments
Air	Inhalation	Future residents, current agricultural workers, and recreational users.	Particulate inhalation
Soil and Sediment	Ingestion, inhalation, direct radiation exposure (gamma)	Future residents, agricultural workers, and recreational users.	Incidental ingestion, inhalation of dust
Surface Water	Ingestion (incidental)	Future residents, agricultural workers, and recreational users.	Dermal exposure is insignificant when compared to ingestion.
Groundwater	Ingestion (as a drinking water source)	Future residents	Currently not a complete pathway; this is an improbable, but potentially complete future exposure pathway.
Beef/Game Tissues	Ingestion	Future residents, agricultural workers, and recreational users.	Beef/game are exposed to contaminated vegetation, surface water, and soil.

(Appendix L, Section 3.3.1 Estimation of Exposure Point Concentrations, pg 3–17, Section 3.3.2 Exposure Assumptions, pg 3–25)

The 95 percent upper confidence limit (UCL_{95}) of the mean concentration was used for all exposure point concentrations, as recommended by EPA (1989a). Exposure assumptions were developed on the basis of site–specific conditions and EPA guidance (EPA 1989a, 1989b, 1991a).

(Appendix L, Section 3.3.3 Calculation of Average Daily Intakes, pg 3–32)

Exposures were determined using both reasonable maximum exposures (RMEs) and central tendency (CT) exposure parameters. RME is defined as exposure well above the average, but still within the range of possible values; it is analogous to "high-end" exposure estimates. CT uses

exposure assumptions that result in average or best-estimate exposures, with a tendency to still be somewhat conservative. Exposures were also estimated using background concentrations of naturally occurring COCs. The major conclusions from the assessment of exposure are

- Potential future groundwater ingestion results in the largest theoretical, but unlikely, exposures.
- Generally, higher intakes are computed for Upper Montezuma Creek, mostly because time spent in the upper segment is expected to be greater than in other segments.
- Inhalation is a minor contributor to total intake.
- Muscle tissue (beef/game) intakes are much smaller than intakes from potential future ingestion of groundwater. The comparatively low intakes by ingestion of beef and deer were confirmed in a recently completed sampling study conducted by EPA and UDEQ (Henningsen 1997).

(Appendix L, Section 4.2 Carcinogenic Effects, pg 4–4)

Risks were estimated for carcinogenic (cancer-causing) and noncarcinogenic compounds. Carcinogenic risk from nonradionuclides is measured by a dimensionless probability of cancer incidence as a result of exposure. The yardstick for carcinogenic risk to radionuclides is a dimensionless probability of cancer mortality. Both risk results can be compared to the National Contingency Plan (NCP) acceptable cancer risk range of 1 E–6 to 1 E–4 (40 CFR 300). A cancer risk of 1 E–4 (0.0001) is an added chance of cancer incidence (or mortality in the case of radionuclides) of 1 in 10,000 people attributable to exposure to site-related contamination.

(Appendix L, Section 4.1 Noncancer Effects, pg 4–1)

A hazard quotient (HQ) is used to measure risks from noncarcinogens by comparing site-specific exposures to a reference dose. Individual HQs are summed to produce a Hazard Index (HI). An HI that exceeds 1.0 is a numerical indicator of the transition between acceptable (HI<1) and unacceptable (HI>1, with uncertainty and the other eight NCP criteria considered) exposure levels (EPA 1989a).

(Appendix L, Section 5.1 Risk Characterization Methods Subsectgion "Aggregate Dose Assessment Including Internal Emitters, pg 5–4)

An aggregate dose assessment was also conducted in which effective dose equivalent (EDE) was estimated by summing external gamma plus inhalation and ingestion of radionuclides that emit radiation to internal organs. EDE can be compared to existing radiation protection benchmarks, such as the benchmark established by the Nuclear Regulatory Commission (NRC 1997) that specifies a total dose from all man-made sources (excluding medical) of 25 millirem per year (mrem/yr) or the State's dose limits for individual members of the public (Utah 1994) that specify a total dose from all sources (excluding background, source by-product, medical exposure, etc.) of 100 mrem/yr.

(Appendix L, Section 5.4 Risk Characterization, pg 5–18)

Table ES–8 presents a summary of the results for the future-use residential exposure scenario (groundwater ingestion, beef ingestion, and exposure from recreation and agricultural use of the contaminated area along Montezuma Creek within OU III).

Table ES–8. Risk Characterization Summary: ***Future-Use Residential*** *Scenario*

Assessment	OU III Setting[b]		Background		Increment Above Background[c]		OU III Setting/Background[g]	
	RME	CT	RME	CT	RME	CT	RME	CT
Added Cancer Risk, Nonradionuclides[d]	4.3 E–4	7.0 E–5	3.2 E–5	5 E–6	4 E–4	6.5 E–5	13	14
Added Cancer Risk, Radionuclides[e]	4.5 E–4	9.0 E–5	6.4 E–5	9.0 E–6	3.9 E–4	8.1 E–5	7.0	10
Hazard Index[f]	10.4	5.5	0.3	0.13	10.1	5.4	35	42
EDE (mrem/yr)	15.8	8.3	4.4	2.0	11.3	6.3	3.6	4.2

[a]The future residential scenario assumes the unlikely use of contaminated groundwater as the sole drinking water source. This scenario also assumes exposure will occur from recreational/agricultural activities. In the current year and until the groundwater ingestion pathway is complete, risks for this scenario will be identical to the recreational/agricultural scenario (see Table ES–7).
[b]Ingestion of groundwater accounts for most of the total risk. For example, for added cancer risk, radionuclides for the RME and CT cases, ingestion of groundwater accounts for 81.5 percent and 91.1 percent of the total risk, respectively.
[c]Example using added cancer risk, nonradionuclides: 4.3 E–4 – 3.2 E–5 = 4 E–4.
[d]All of the risks in this category are attributable to arsenic.
[e]The risk drivers in this category are Pb-210, U-234, and U-238.
[f]For noncarcinogenic compounds, the risk drivers are uranium and vanadium.
[g]Example using added cancer risk, nonradionuclides: 4.3 E–4 ÷ 3.2 E–5 = 13. Overall, this value provides a relative comparison between risks associated with site conditions versus background conditions. As this value increases, the relative site risks compared to background also increase.

(Appendix L, Section 5.4 Risk Characterization, pg 5–18, continued)
Conclusions from Table ES–8:

- For the RME case for OU III, the added cancer risk estimates for nonradionuclides and radionuclides exceed EPA's 1 E–6 to 1 E–4 risk range. The HI for noncarcinogens exceeds both the RME and CT cases. The excess is directly related to the unlikely assumption of potential future groundwater consumption.

- For the background setting, assuming RME and CT exposure factors, cancer risk estimates are within EPA's 1 E–6 to 1 E–4 risk range; the HI is less than 1.0.

- Incremental risks (i.e., the increase above background) are of the same order of magnitude as the risks associated with OU III.

- EDEs for OU III, background, and increment above background are below the benchmark of 25 mrem/yr.

Table ES–9 presents a similar summary for the current and future-use recreational and agricultural exposure scenario (this use is the same as the previous use except that it does not include groundwater consumption).

Conclusions from Table ES–9:

- For the RME and CT case for OU III and background, the added cancer risks for radionuclides are within EPA's 1 E–6 to 1 E–4 risk range.

- HI is less than 1.0; EDE is less than 25 mrem/yr in all cases.

Ecological Risk Assessment (Section and page references are from the Ecological Risk Assessment (Volume VII, Appendix M of 1998 RI)

(Appendix M, Section 1.0 Introduction, pg 1–1, Section 2.4 Assessment Endpoints, pg 2–16, Section 2.5 Ecological Site Conceptual Model, pg 2–18, Section 2.6 Measurement Endpoints, pg 2–18)
The OU III ERA provided an evaluation of the potential risks to the environment associated with exposure to COCs. Evaluation of ecological data was guided primarily by EPA's *Framework for Ecological Risk Assessment* (EPA 1992), the EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997), and the OU III Ecological Technical Assistance Group, which was formed under the direction of EPA Region 8. One of the initial steps of the ERA was the development of a conceptual site model. This model indicated that the contaminated media were soil, sediment, surface water, groundwater, and air. Groundwater and air were determined to be of negligible concern. Potential exposure routes included ingestion, direct contact, and inhalation, the last of which was considered to be an unimportant route. During the development of assessment and measurement endpoints, potential ecological receptors were selected; these included the deer mouse, mule deer, muskrat, southwestern willow flycatcher, spotted bat, peregrine falcon, and aquatic organisms. The southwestern willow flycatcher and peregrine falcon are Federally-listed endangered species, and the spotted bat is considered a State-sensitive species.

Table ES–9. Risk Characterization Summary: ***Current- and Future-Use Recreational and Agricultural*** *Scenario*

Assessment	OU III Setting		Background		Increment Above Background[a]		OU III Setting/Background	
	RME	CT	RME	CT	RME	CT	RME	CT
Added Cancer Risk, Nonradionuclides[b]	2.9 E–6	1.5 E–7	2.0 E–6	1.1 E–7	9 E–7	4 E–8	1.5	1.4
Added Cancer Risk, Radionuclides[c]	8.3 E–5	8.1 E–6	3.7 E–5	3.6 E–6	4.6 E–5	4.5 E–6	2.2	2.3
Hazard Index[d]	0.43	0.04	0.02	0.003	0.41	0.04	22	13
EDE (mrem/yr)	5.7	1.8	2.5	0.8	3.2	1.0	2.3	2.3

[a]Example using added cancer risk, nonradionuclides: 2.9 E–6 – 2.0 E–6 = 9 E–7.
[b]All of the risks in this category are attributable to arsenic.
[c]The risk driver in this category is external gamma.
[d]For noncarcinogenic compounds, the risk driver is uranium.

The spotted bat most likely roosts in the sandstone cliffs along Montezuma Creek and feeds on insects during evening hours. The cliff walls along Montezuma Creek and downstream of the OU III soil and sediment area provide good habitat for the bat because of the presence of perennial water within the creek.

The northern goshawk was designated a State-sensitive species after sampling for the ERA was completed. Based on the habits of the northern goshawk it is unlikely that risks posed by OU III contamination exceed those to other receptors. In addition, the northern goshawk most likely visits the OU III soil and sediment area only during the winter months to feed. Its preferred habitat is in tall stands of old-growth conifer forest, which are not prevalent in the OU III area. These birds likely winter in areas of Montezuma Canyon downstream of OU III and breed during the summer months in the Abajo Mountains.

(Appendix M, Section 2.2 Ecological Contaminants of Concern, pg 2–9)

The COCs evaluated in the ERA varied depending upon the contaminated media (soil, sediment, or surface water) and location within the OU III soil and sediment area (i.e., Upper, Middle, or Lower Montezuma Creek). The final list of COCs included arsenic, cobalt, copper, molybdenum, nitrate, lead, lead-210, radium-226, selenium, thorium-230, elemental uranium, uranium-234, uranium-235, uranium-238, vanadium, and zinc.

(Appendix M, Section 4.1 Exposure Assessment, pg 4–1)

The exposure assessment phase of the ERA included developing exposure profiles for each receptor (except benthic macroinvertebrates) and calculating dose estimates associated with each COC. Exposure estimates were based on dietary dose calculations for both nonradioactive and radioactive COCs and were based on external exposure calculations for radioactive COCs. Internal and external radiation doses were calculated for radionuclide concentrations in media at the time of sampling and after a 1,000-year period of radionuclide decay. The UCL_{95} of the mean concentration was used for calculating all exposure-point concentrations, except when this value exceeded the maximum sample value, in which case, maximum values were used. Dose to each receptor was determined using both RME and CT exposure parameters.

(Appendix M, Section 4.2 Ecological Effects Assessment, pg 4–24)

To assess ecological effects of the COCs, several sources of information were evaluated. Ecotoxicological data from the literature, the State of Utah's ambient water-quality criteria, various sediment-quality criteria, and radiation benchmarks were reviewed to develop ecological benchmarks. Results of histopathological analyses, chemical analyses of tissue samples, and population surveys for benthic macroinvertebrates also were evaluated.

(Appendix M, Section 5.1.1 Methods for Estimating Hazard Quotients and Hazard Indicies, pg 5–1)

Selected ecological benchmark values were then compared to estimated doses during the risk characterization phase of the ERA. The resulting HIs for all COCs were summed for all pathways to produce HQs. In general, HIs exceeding 1.0 indicate a transition between acceptable and unacceptable exposure levels. Table ES–10 presents the risk-driving exposure pathways and COCs for each receptor. Risk-driving exposure pathways are those pathways that resulted in an HI greater than 1.0. Risk-driving COCs are those COCs with HQs greater than 1.0. For aquatic organisms, HQs were less than 1.0, indicating that neither surface-water nor sediment are risk-driving exposure pathways.

(Appendix M, Section 5.2 Uncertainty Analysis, pg 5–28)

Predicted risk was compared with observed effects data (histopathological analyses, chemical analyses of tissue samples, and population surveys [for benthic macroinvertebrates]) to validate or contradict findings from the modeled estimates of risk.

Table ES–10. Risk-Driving Exposure Pathways and COCs

Receptor	Risk-Driving Exposure Pathway	Risk-Driving COCs[a]
Deer mouse	Invertebrate ingestion	Arsenic, copper, and vanadium
	Soil ingestion	Copper and vanadium
	Grass ingestion	Arsenic and copper
Mule deer	No exposure pathway resulted in an HI > 1.0[b]	No COC resulted in an HQ > 1.0
Muskrat	Grass ingestion	Arsenic, copper, and vanadium
	Soil ingestion	Vanadium
	Sediment ingestion	Vanadium
Spotted bat	Invertebrate ingestion	Arsenic, copper, selenium, and
	Soil ingestion	Vanadium
Southwestern willow flycatcher	Invertebrate ingestion	Copper, selenium, and uranium
	Soil ingestion	Uranium
Peregrine falcon	No exposure pathway resulted in a HI > 1.0	No COC resulted in an HQ >1.0
Aquatic organisms	Not applicable[c]	No COC resulted in an HQ > 1.0[d]

[a]HQs were calculated for individual COCs within an exposure pathway.
[b]The total HI (RME/NOAEL-based) for mule deer is greater than 1.0 but no one exposure pathway has an HI greater than 1.0. The HI for Montezuma Creek is equal to the HI for the reference area (Verdure Creek).
[c]Surface-water and sediment ingestions (intakes) are not typically calculated for aquatic animals in ecological risk assessments. Instead, exposure point concentrations were compared to ambient water-quality criteria and to sediment quality criteria to arrive at HQs. All comparisons to these benchmarks produce HQs less than 1.0 indicating that surface water and sediment are not risk driving media for aquatic organisms.
[d]Cobalt was the only COC that had an HQ greater than 1.0; however, cobalt was not detected in any surface-water sample (analytical results of surface-water sampling are presented in Appendix C–1 of the RI). HQs greater than 1.0 for cobalt result from detection limits greater than the toxicity benchmark.

Following is a description of the risk for each receptor.

Deer Mouse

(Appendix M, Section 5.1.2 Receptor Specific Risk Estimates, pg 5–5, applies to rest of summary)

The deer mouse is not expected to be at risk from radiation exposure because the HIs were less than 1.0. HQ and HI calculations show that the deer mouse may be at risk from arsenic, copper, and vanadium concentrations in invertebrates, soil, and grass. HI values for OU III are 1.3 to 2.5 times higher than HI values for Verdure Creek, indicating risk to the deer mouse is of possible concern.

Overall uncertainty associated with assessment of risks to the deer mouse is moderately high. The ERA is probably biased toward overestimation of risks to the deer mouse. The TRVs for arsenic and copper are both based on drinking water studies, and the TRV for vanadium is based on a gavage study; these types of studies tend to increase the bioavailability of inorganics relative

to that expected from their presence in food or soil. The results of the studies were not revised to account for the increased bioavailability. Therefore, the TRVs for these metals are likely overly conservative. The sampling bias toward contaminated areas of OU III has a strong effect on the risk calculations for the deer mouse because of its small home range since contamination drops sharply with distance from the stream. Depending on the actual proportion of the deer mouse population living in uncontaminated areas, population-level effects are likely to be either substantially lower or somewhat lower than indicated by the HI.

Although risk to the deer mouse may be of possible concern, because of the very conservative assumptions, the actual potential for adverse effects is expected to be low.

Mule Deer

For mule deer, all HQs and HIs are less than 1.0 with the exception of the HI for the RME/NOAEL chemical exposure scenario. Because all but one of the HIs were less than 1.0, the mule deer is not expected to be at risk from radiation exposure or chemical COCs. Chemical analyses from tissue did not indicate that the mule deer was concentrating COCs in its muscle, liver, and kidney tissues. Limited clinical and pathological observations of mule deer tissue samples by EPA and UDEQ indicated that the tissues were normal, except that the majority of the on-site bucks had deformed antler growth. Although some antlers were sufficiently deformed to impede foraging and field of view, thereby increasing possible losses to predation, field observations indicate that there is an ample population of deer in the Montezuma Creek area. Therefore, it is believed that currently there is no negative effect on population from deformed antlers. The potential adverse effects to mule deer are considered to be of no concern.

Muskrat

The muskrat is not expected to be at risk from radiation exposure because the HIs were less than 1.0. However, HQ and HI calculations show that the muskrat may be at risk from arsenic, copper, and vanadium concentrations in grass, sediment, and soil. HI values for OU III are 1.8 times higher than HI values for Verdure Creek. Because HIs for chemical exposure are greater than 1.0, risk to the muskrat is considered to be of possible concern.

Overall uncertainty associated with assessment of risks to the muskrat is moderately high. The ERA is probably biased toward overestimation of risks to the muskrat. The TRVs for arsenic and copper are both based on drinking water studies, and the TRV for vanadium is based on a gavage study; these types of studies tend to increase the bioavailability of inorganics relative to that expected from their presence in food or soil. The results of the studies were not revised to account for the increased bioavailability. Therefore, the TRVs for these metals are likely overly conservative.

The assumption that grass is the primary food source of muskrats is incorrect. Muskrats forage primarily on algae and tubers of aquatic plants (EPA 1993). Because COC concentrations in sediment are lower than COC concentrations in soil, COC concentrations in aquatic plants that grow in sediment are expected to be lower than COC concentrations in grasses that grow in soil. Therefore, by assuming that grasses are the primary food source of muskrats, the risk calculations are probably overestimating risk to the muskrat. In addition, because muskrat spend

most of their time in the aquatic environment, and aquatic HQs were less than 1.0, the potential for adverse effects to the muskrat is expected to be low and of no concern.

Spotted Bat

The spotted bat is not expected to be at risk from radiation exposure because radiation exposure to the deer mouse, muskrat, and mule deer yielded HIs less than 1.0. Spotted bat receive a lower radiation dose than deer mouse, muskrat, and mule deer because the spotted bat ingest a smaller percentage of soil and sediment in their diet and spend less time on the ground and in direct contact with soil and sediment. HQ and HI calculations show that the spotted bat may be at risk from arsenic, copper, selenium, and vanadium concentrations in invertebrates and soil. HI values for OU III are 1.5 to 1.6 times higher than HI values for Verdure Creek. The spotted bat is listed as a State-sensitive species in Utah. Because HIs for chemical exposure are greater than 1.0, risk to the spotted bat is considered to be of possible concern.

Overall uncertainty associated with assessment of risks to the spotted bat is high. The ERA is probably biased toward overestimation of risks to the spotted bat. The TRVs for arsenic, copper, and selenium are based on drinking water studies, and the TRV for vanadium is based on a gavage study; these types of studies tend to increase the bioavailability of inorganics relative to that expected from their presence in food or soil. The results of the studies were not revised to account for the increased bioavailability. Therefore, the TRVs for these metals are likely overly conservative. Also, the assumption that spotted bats spend all their time in Upper and Middle Montezuma Creek is probably overly conservative. Most bats do not have such small home ranges. Although risk to the spotted bat may be of possible concern, because of the very conservative assumptions, the actual potential for adverse effects is expected to be low and of no concern.

Southwestern Willow Flycatcher

The southwestern willow flycatcher is not expected to be at risk from radiation exposure because radiation exposure to the deer mouse, muskrat, and mule deer yielded HIs less than 1.0. The southwestern willow flycatcher receive a lower radiation dose than the deer mouse, muskrat, and mule deer because the southwestern willow flycatcher ingest a smaller percentage of soil and sediment in their diet and spend less time on the ground and in direct contact with soil and sediment. HQ and HI calculations suggest that the southwestern willow flycatcher may be at risk from copper, selenium, and uranium concentrations in invertebrates, soil, and surface water. HI values for OU III are 1.6 to 3.3 times higher than HI values for Verdure Creek. The southwestern willow flycatcher is a federally listed endangered species.

Overall uncertainty associated with assessment of risks to the southwestern willow flycatcher is high. The ERA probably is biased toward overestimation of risks to the southwestern willow flycatcher. Because toxicity data were not available for flycatchers, a substantial uncertainty factor was applied to literature data for quail to obtain the uranium TRV for the southwestern willow flycatcher. The TRVs for copper and selenium are based on drinking water studies; this type of study tends to increase the bioavailability of inorganics relative to that expected from their presence in food or soil. The TRV for uranium is based on a direct injection study; this route of exposure ensures 100 percent absorption and so artificially elevates the apparent

bioavailability. Absorption, and therefore toxicity, of uranium in the diet or soil will be much lower. The results of these studies were not revised to account for the increased bioavailability. These factors are likely to make the copper, selenium, and uranium TRVs overly conservative. Histopathological and chemical analyses of liver and kidney tissues from a surrogate species, the cliff swallow, did not indicate that the surrogate was either being adversely affected by COCs or concentrating COCs in its tissues. It is inferred that the dose modeling and resulting HIs were overly conservative, and therefore, risk to the southwestern willow flycatcher is considered to be of no concern.

Peregrine Falcon

The peregrine falcon is not expected to be at risk from radiation exposure because radiation exposure to the deer mouse, muskrat, and mule deer yielded HIs less than 1.0. The peregrine falcon receive a lower radiation dose than the deer mouse, muskrat, and mule deer because the peregrine falcon ingest a smaller percentage of soil and sediment in their diet and spend less time on the ground and in direct contact with soil and sediment. The peregrine falcon is not expected to be at risk from chemical COCs because HIs were also less than 1.0. Risk to the peregrine falcon is considered to be of no concern. Overall uncertainty associated with assessment of risks to the peregrine falcon is moderate; the assessment shows that peregrine falcons are not at risk even when very conservative factors are used. The ERA is probably biased toward overestimation of risks to the peregrine falcon. In addition, the peregrine falcon has not been identified in OU III.

Benthic Macroinvertebrates

Risk to benthic macroinvertebrates may be considered a possible concern because analysis of benthic macroinvertebrate samples showed uptake of arsenic, molybdenum, uranium, and vanadium. However, where aquatic benchmarks were available for these COCs, the HQs were less than 1.0. This indicates that the uptake should not produce an adverse effect. Differences in benthic community structure observed during population surveys can be attributed to differences in habitat between OU III and Verdure Creek. Habit differences include stream gradient, channel characteristics, riparian characteristics, and nutrient levels. Nutrient level differences may be due to the proximity of Montezuma Creek to human interferences such as runoff from the municipal golf course and irrigated land and drainage from the municipal water treatment lagoons.

In summary, none of the receptors are at unacceptable risk from radiation exposure. Only impacts to the aquatic community may be of possible concern for chemical exposure. There is little likelihood that the OU III COCs are negatively affecting the other receptors.

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