U.S. Department of Energy
Grand Junction Office
2597 B 3/4 Road
Grand Junction, CO 81503

SEP 2 8 2001

Mr. Melvyn Leach, Chief
U.S. Nuclear Regulatory Commission
Fuel Cycle Licensing Branch
Division of Fuel Cycle Safety & Standards
Mail Stop T8A33
Washington, D.C. 20555-0001

Subject: Draft *Site Observational Work Plan* for the Naturita, Colorado, UMTRA Site

Dear Mr. Leach:

Enclosed is a copy of the draft *Site Observational Work Plan* for the Naturita, Colorado, UMTRA site. Please review this document and provide comments to me by November 30, 2001.

If you have any questions, please call me at (970) 248-7612.

Sincerely,

Donald R. Metzler, P.Hg.
Technical/Project Manager

Enclosure

cc w/enclosure:
M. Fliegel, NRC

cc w/o enclosure:
S. Marutzky, MACTEC-ERS
File GWNAT 1.1 (P. Taylor)

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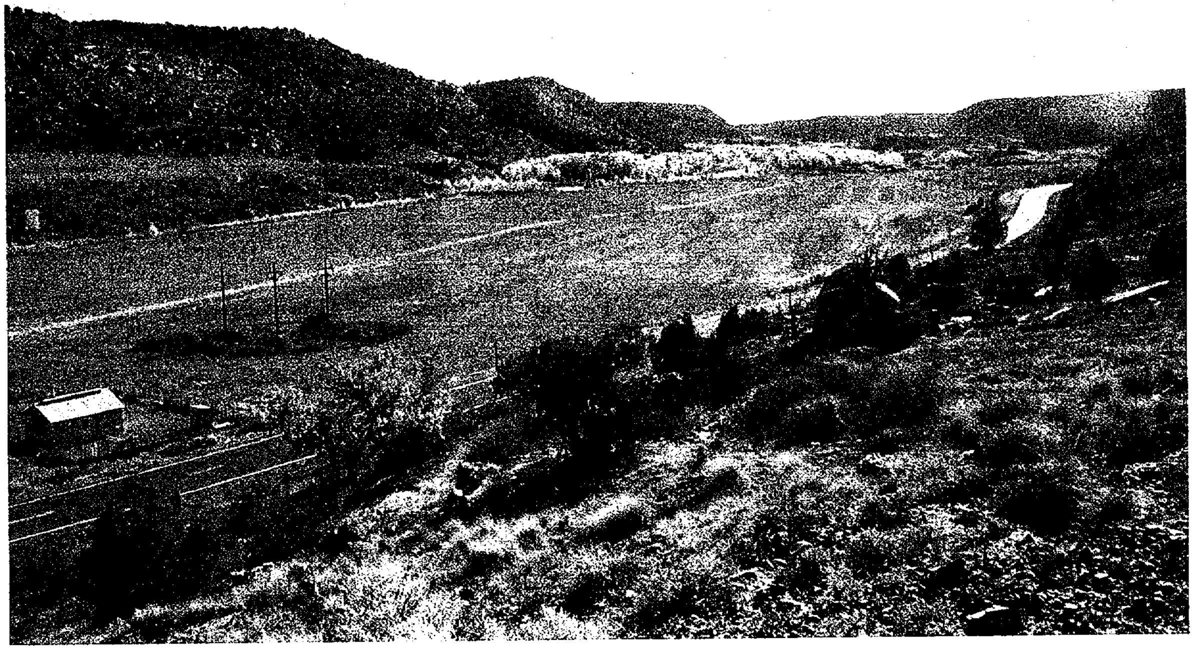
UMTRA
Ground Water Project

Site Observational Work Plan for the Naturita, Colorado, UMTRA Project Site



September 2001

Prepared by the
U.S. Department of Energy
Grand Junction Office

Work Performed Under DOE Contract No. DE–AC13–96GJ87335 for the U.S. Department of Energy
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GJO–2001–234–TAR
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UMTRA Ground Water Project

Site Observational Work Plan for the Naturita, Colorado, UMTRA Project Site

September 2001

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

Project Number UGW–511–0016–07–000
Document Number U0134400

Work Performed Under DOE Contract No. DE–AC13–96GJ87335

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Acronyms and Abbreviations

ACL	alternate concentration limit
AEC	U.S. Atomic Energy Commission
AFO	amorphous ferric oxyhydroxide
ASTM	American Society for Testing and Materials
BCF	bioconcentration factor
bgs	below ground surface
BLRA	baseline risk assessment
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter(s)
COC	constituent of concern
COPC	constituent of potential concern
DOE	U.S. Department of Energy
DOLA	Colorado Department of Local Affairs
EA	environmental assessment
EC	electrical conductivity
E-CPOC	ecological constituent of potential concern
EHPA	ethylhexyl phosphoric acid
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ESL	Environmental Sciences Laboratory
FONSI	finding of no significant impact
FR	Federal Register
ft	foot (feet)
ft/day	foot (feet) per day
ft^2/day	square feet per day
g	grams
gal	gallon(s)
gal/day	gallons per day
GCAP	Ground Water Compliance Action Plan
GJO	Grand Junction Office
gpm	gallons per minute
GMWL	Global Meteoric Water Line
HCl	hydrochloric acid
HI	hazard index
HQ	hazard quotient
IC	institutional control
K	hydraulic conductivity
K_d	distribution coefficient
kg	kilogram(s)
kW-hr	kilowatt-hour
L	liter
L/s	liter(s) per second
lb	pounds
LTMP	Long-Term Management Plan

LTSP	Long-Term Surveillance Plan
MAP	management action process
MCL	maximum concentration limit
m	meter(s)
μg/L	micrograms per liter
μm	micrometer(s)
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
mL/g	milliliters per gram
mL/min	milliliters per minute
mm	millimeter(s)
mV	millivolts
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
ORP	oxidation-reduction potential
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PEIS	Programmatic Environmental Impact Statement
PeRT	Permeable Reactive Treatment
PVC	polyvinyl chloride
RAP	Remedial Action Plan
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RO	reverse osmosis
ROD	record of decision
rpm	revolutions per minute
RRM	residual radioactive material
SDWA	Safe Drinking Water Act
SEE	Site Environmental Evaluation (database)
SOWP	Site Observational Work Plan
TAGR	Technical Approach to Ground Water Restoration
TDS	total dissolved solids
TI	Technical Impracticability
U(VI)	mobile uranium-valence plus 6
UCL_{95}	95 percent upper confidence limit
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
USC	United States Code
USGS	U.S. Geological Survey
ZVI	zero valent iron

Executive Summary

This document is the Site Observational Work Plan (SOWP) for the Naturita, Colorado, Uranium Mill Tailings Remedial Action (UMTRA) Project site. The purpose of this report is to determine the technical scope, objectives, and strategies for achieving ground water compliance with requirements established in the Uranium Mill Tailings Radiation Control Act (42 *United States Code* 7901 *et seq.*) and the United States Environmental Protection Agency's (EPA's*)* Health and Environmental Protections Standards for Uranium and Thorium Mill Tailings (Title 40, *Code of Federal Regulations,* Part 192).

The Naturita mill, located about 2 miles north of the town of Naturita along the west side of the San Miguel River, began operation in 1939 for vanadium production. It was converted to include the production of uranium during the Manhattan Project of the early 1940s, and continued to co-produce uranium and vanadium until it closed in 1958. During its life, the mill processed 704,000 tons of ore from the Uravan Mineral Belt. Most of the tailings were purchased by Ranchers Exploration and hauled several miles to another site for heap leaching in the late 1970s. From 1993 to 1998, the UMTRA surface cleanup removed another 771,400 cubic yards of residual radioactive material (RRM) to the Upper Burbank engineered disposal site at Uravan, about 15 miles to the northwest. Currently, no mill buildings remain, and the site meets the UMTRA surface standards.

The U.S. Department of Energy (DOE) began collecting data about the ground water contamination during the surface program and published a Baseline Risk Assessment in 1995. Section 6 of this SOWP updates that risk assessment. DOE has worked with the U.S. Geological Survey (USGS) to collect and analyze data from an additional 23 monitoring wells and 16 surface locations during 2000 and 2001. Results indicate that three contaminants of potential concern (COPCs)—uranium, vanadium, and arsenic—pose a potential risk to human health, and vanadium poses a potential risk to ecological receptors.

Hydrologic tests, water age determinations, and chloride analysis of the uppermost aquifer, indicate that the system receives recharge from the San Miguel River south of the site and transmits water from south to north. Subsurface flow is slower along the western side of the site away from the San Miguel River. Additionally, these analyses indicate that potentially significant amounts of water are being lost from the ground water system due to excavations down to the ground water surface in an adjoining gravel pit operation on the upgradient side of the site. If this continues, and the operation is expected to expand, the volume of ground water entering the site will continue to diminish and the estimated flushing rates will also diminish. Therefore, the rates of flushing in the ground water model are conservative. The bedrock below the alluvial aquifer consists of mudstones, siltstones to sandstones, and shales of the Brushy Basin Member of the Morrison Formation. Hydrologic tests indicate that the Brushy Basin sediments create an effective aquitard for downward migration of surface contamination and also limit upward migration of water from sandstone units below it.

Ground water flow and transport modeling indicates that arsenic will flush to the UMTRA maximum concentration limit (MCL) of 0.05 mg/L within about 10 years. Only two wells had arsenic levels slightly above the MCL, and the area containing these elevated values is small. However, uranium and vanadium have higher concentrations, are more widespread, and do not flush within the regulatory timeframe. Modeling predicts 135 years will be required for uranium to flush to 0.044 mg/L (the MCL) and more that 1,000 years will be required for vanadium to flush to 0.33 mg/L (a health-based risk concentration).

Two compliance strategies are proposed for the site: (1) natural flushing with institutional controls and continued monitoring, and (2) supplemental standards based on Technical Impracticability (TI) with institutional controls and continued monitoring as a best management practice. EPA guidance for TI applications is followed in this document. A TI demonstration is required and should incorporate factors such as feasibility, reliability, scale, safety, and costs.

The proposed TI demonstration is based on three conditions identified at the site. First, pumping water from the shallow alluvial aquifer would present a problem. Modeling indicates that even low-flow pumping rates will dry up the aquifer around the extraction well and reduce the flushing of uranium and vanadium. Additional water would have to be added to the area before pumping and removal of contaminants could occur. This process would require much time and expense. Second, vanadium is difficult to extract from ground water because of its high adsorptive qualities. Pilot tests to remove vanadium at the Rifle, Colorado, UMTRA site indicate that pumping from extraction wells produces an extremely slow rate of removal. Another indication of this high degree of adsorption is the distribution of vanadium in the subsurface. Vanadium has essentially not moved from its original position below the former tailings pile in the past 40 years. The geochemical setting at Naturita is similar to the one found at Rifle. Third, the surface program applied supplemental standards, that left RRM in place at a number of locations on the site and downgradient of the site on an adjoining vicinity property. This material was not removed because the benefit of excavation did not offset danger to workers, the cost was excessive where tailings were greater than 1 foot below the water table, and remedial action would produce excessive harm to the environment, especially along riparian areas of the San Miguel River. To eventually achieve compliance with ground water standards, this material would need to be removed from some parts of the site and adjoining vicinity property. The criteria used to leave it in place during the surface program would also be applicable to the ground water program.

To meet TI, an alternative remedial strategy must also be submitted. It should be practicable, prevent migration of contamination beyond a TI zone, and achieve cleanup standards beyond the TI zone. A TI zone is proposed that will also serve as an institutional control boundary for the site. DOE would seek a zone overlay from the Montrose County government restricting access to the ground water for domestic consumption. No one is currently drinking ground water or using it for any purpose, and no one is anticipated to be using it for drinking. One family is living downgradient in the contaminant plume and inside the TI zone. DOE will provide a source of drinking water for this family. Future sampling will ensure that humans and the environment remain safe for the duration of this TI demonstration. This strategy will be reevaluated periodically to determine if new technologies would be applicable for expediting ground water cleanup at the Naturita site.

1.0 Introduction

1.1 Purpose and Scope

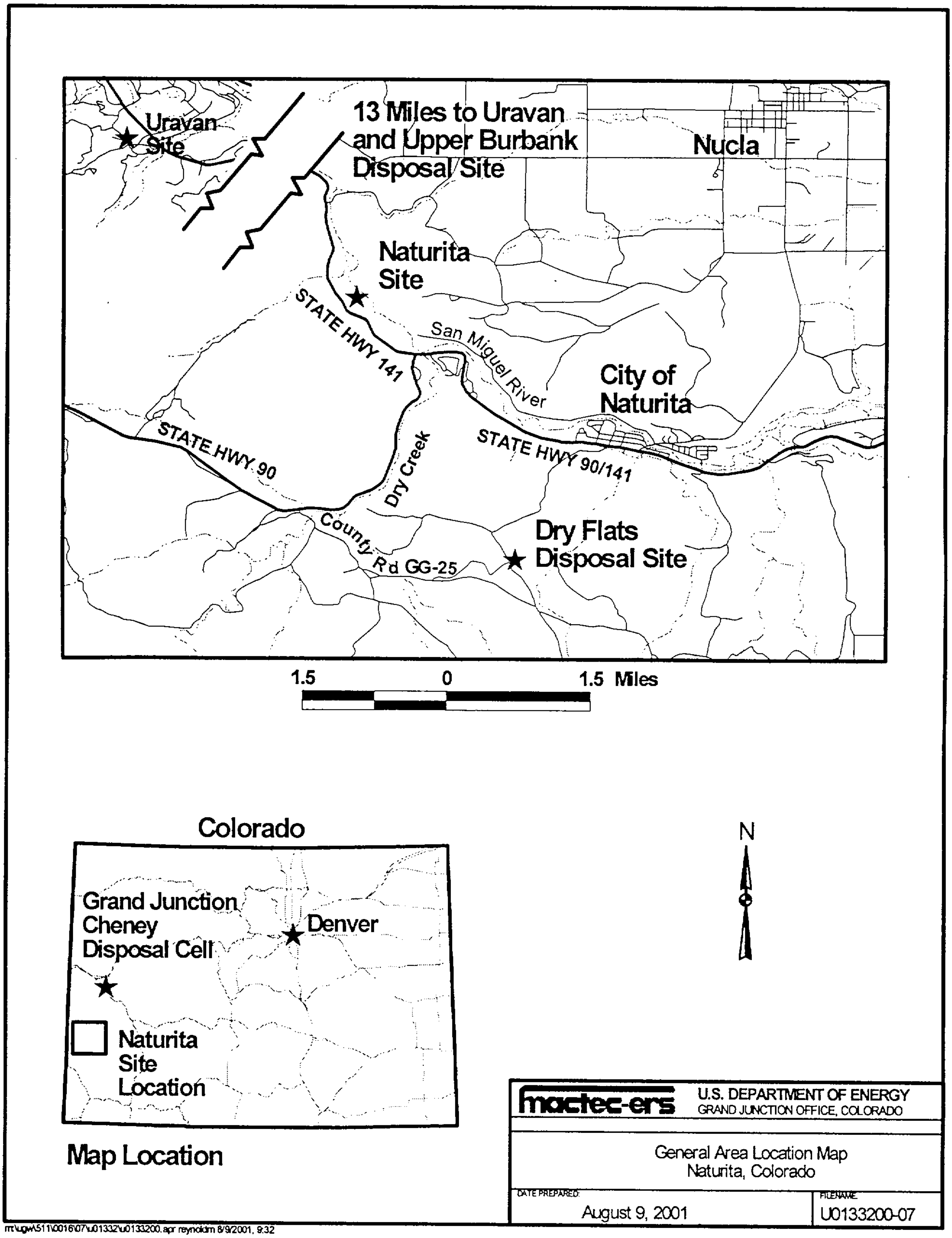
The Naturita UMTRA Project site is a former uranium and vanadium ore processing facility located about 2 miles northwest of the town of Naturita, Colorado, along Colorado State Highway 141 (Figure 1–1). The Naturita site is bounded by the San Miguel River on the east and the highway on the west. Private property borders the northern, downgradient edge of the site and the southern, upgradient portion of the site. The City of Naturita owns the central portion of the site; Chemetall Foote Corp, a German company, owns the northern and southern parts of the site.

The former tailings pile at the site was removed to a heap-leach reprocessing plant along State Highway 90, about 3 miles southeast of the intersection of Highways 90 and 1241 at Coke Oven during 1977 to 1979. After being reprocessed, the tailings were stabilized at that location with 2 to 10 feet (ft) of cover. The DOE completed surface remediation in 1997. A significant amount of residual contaminated soils and other materials that remained at the Naturita site were removed and transported to the disposal cell at Uravan; however, some contaminated materials were left in place through the application of supplemental standards. After the remedial action, the site was backfilled with clean fill material and recontoured. The land was seeded, but vegetation remains somewhat sparse.

DOE's goal is to implement a cost-effective compliance strategy that is protective of human health and the environment at the Naturita site. The proposed compliance strategies to clean up the alluvial ground water at the site are (1) no ground water remediation of constituents with concentrations that do not pose a potential risk and do not exceed EPA standards, and (2) natural flushing of ground water in combination with the application of supplemental standards for constituents with concentrations that pose a potential risk or exceed EPA standards. Institutional controls will prohibit some ground water uses during the natural flushing period, and DOE will conduct ground water monitoring to observe progress of remediation.

This SOWP documents the strategy that will allow DOE to comply with EPA ground water standards at the Naturita site and provides a mechanism for stakeholder participation and review. Site-specific data are presented that support the proposed strategy.

Compliance requirements for meeting the regulatory standards at the Naturita site are presented in Section 2.0. Site background information, including an overview and history of the former milling operation and current water and land use, are reviewed in Section 3.0. Results of the field investigations conducted at the site from 1998 through 2001 are presented in Section 4.0. Site-specific characterization of the geology, hydrology, geochemistry, and ecology are synthesized in the site conceptual model in Section 5.0. Potential human health and ecological risks associated with ground water contamination are summarized in Section 6.0, and the proposed compliance strategy to clean up the ground water and a brief analysis of alternatives are presented in Section 7.0 and Section 8.0.



mactec-ers U.S. DEPARTMENT OF ENERGY GRAND JUNCTION OFFICE, COLORADO

General Area Location Map
Naturita, Colorado

DATE PREPARED: August 9, 2001

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Figure 1–1. Site Location Map

1.2 UMTRA Ground Water Project Programmatic Documents

Programmatic documents that guide the SOWP include the *UMTRA Ground Water Project Management Action Process* (MAP) *Document* (DOE 1999a), the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996), and the *Technical Approach to Groundwater Restoration* (TAGR) (DOE 1993). The MAP states the mission and objectives of the UMTRA Ground Water Project and provides a technical and management approach for conducting the project. The PEIS is the programmatic decision-making framework for conducting the UMTRA Ground Water Project. DOE will follow PEIS guidelines to assess the potential programmatic impacts of the UMTRA Ground Water Project, to determine site-specific ground water compliance strategies, and to prepare site-specific environmental impact analyses more efficiently. Technical guidelines for conducting the ground water program are presented in the TAGR.

1.3 Relationship to Site-Specific Documents

The surface remedial action plan (RAP) (DOE 1998a) provides some site characterization information regarding the geology and ground water hydrology. This information was supplemented in developing the SOWP to strengthen the site conceptual model. After a ground water compliance strategy is selected for this site, a Ground Water Compliance Action Plan (GCAP) will be prepared to document the remediation decision. The GCAP will serve as a stand-alone modification of the RAP.

A baseline risk assessment (BLRA, DOE 1995) was prepared that identified potential public health and environmental risks at the site. Potential risks identified in the risk assessment are considered and updated in this SOWP to ensure that the proposed compliance strategy is protective of human health and the environment.

After a proposed compliance strategy is identified in the SOWP and described in the GCAP, a site-specific National Environmental Policy Act (NEPA) document (e.g., an environmental checklist or environmental assessment) will be prepared, if required by the NEPA process, to determine the potential effects, if any, of implementing the proposed compliance strategy.

End of current text

2.0 Regulatory Framework

A ground water compliance strategy is proposed for the Naturita site (see Section 7.0) to achieve compliance with EPA ground water standards applicable to Title I UMTRA Project sites. This section identifies the requirements of the Uranium Mill Tailing Radiation Control Act (UMTRCA), the EPA ground water protection standards promulgated in 40 CFR Part 192 Subpart B, NEPA, and other regulations that are applicable to the UMTRA Ground Water Project.

2.1 Uranium Mill Tailings Radiation Contrd Act

The United States Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRCA) (42 USC 7901 *et seq.*) in 1978 in response to public concerns about potential health hazards from long-term exposure to uranium mill tailings. UMTRCA authorized DOE to stabilize, dispose of, and control uranium mill tailings and other contaminated materials at inactive uranium-ore processing sites.

UMTRCA has three titles that apply to uranium-ore processing sites. Title I designates 24 inactive processing sites to undergo remediation. Title I authorizes EPA to promulgate standards and mandates remedial action in accordance with those standards. This Title also directs remedial action to be selected and performed with the concurrence of the U.S. Nuclear Regulatory Commission (NRC) in consultation with affected states and Indian tribes, authorizes DOE to enter into cooperative agreements with the affected states and Indian tribes, and directs NRC to license the disposal sites for long-term care. Title II applies to active uranium mills, and Title III applies to specific uranium mills in New Mexico. The UMTRA Ground Water Project has responsibility for administering only Title I of UMTRCA.

In 1988, Congress passed the Uranium Mill Tailings Remedial Action Amendments Act (42 USC 7922 *et seq.*), authorizing DOE to extend without limitation the time needed to complete ground water remediation activities at the processing sites.

2.2 EPA Ground Water Protection Standards

UMTRCA requires EPA to promulgate standards for protecting public health and the environment from radiological and nonradiological hazards associated with uranium-ore processing and the resulting residual radioactive materials (RRM). On January 5, 1983, EPA published standards (40 CFR Part 192) for RRM disposal and cleanup. The standards were revised and a final rule was published January 11, 1995 (60 FR 2854). This rule states that the standards established under Title I provide protection that is consistent, to the maximum extent practicable, with the requirements of the Resource Conservation and Recovery Act (RCRA).

The standards in 40 CFR 192.02 (c)(1) require that the Secretary of Energy determine which constituents listed in Appendix I are present in, or reasonably derived from, RRM. Those standards also require the Secretary to determine the areal extent of ground water contamination by listed constituent. Section 6.0, “Summary of Human Health and Ecological Risk”, of this document, complies with these requirements and identifies the constituents of concern at the Naturita site.

2.2.1 Subpart B: Standards for Cleanup of Land and Buildings

The regulations allow the option of complying with four general standards. Three are numerical standards and are set forth in 40 CFR 192.02 (c)(3) as follows:

- Background level—Concentrations of constituents in the uppermost aquifer in an area that were not affected by ore-processing activities.
- Maximum Concentration Limit (MCL)—EPA defined maximum concentrations for certain hazardous constituents in ground water; these limits are specific to the UMTRA Project. The MCLs for inorganic constituents that apply to UMTRA Project sites are given in Table 1 to Subpart A, 40 CFR 192.04 and are presented in Table 2–1 of this document.
- Alternate Concentration Limit (ACL)—An alternate concentration limit may be applied to a hazardous constituent if it does not pose a substantial present or future risk to human health or the environment, as long as the limit is not exceeded. An ACL may be applied after considering options to achieve background levels and MCLs.

Table 2–1. Maximum Concentration Limits of Inorganic Constituents in Ground Water at UMTRA Project Sites

Constituent	Maximum Concentration Limit[a]
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	.002
Molybdenum	0.1
Nitrate (as N)	10.0[b]
Selenium	0.01
Silver	0.05
Combined radium-226 and radium-228	5 pCi/L
Combined uranium-234 and uranium-238	30 pCi/L[c]
Gross alpha-particle activity (excluding radon and uranium)	15 pCi/L

[a] Concentrations reported in milligrams per liter (mg/L) unless otherwise noted.
[b] Equivalent to 44 mg/L nitrate as NO_3.
[c] Equivalent to 0.044 mg/L, assuming secular equilibrium of uranium-234 and uranium-238.
pCi/L = picocuries per liter.

Reference: 60 FR 2854.

2.3 Natural Flushing Standards

Subpart B also allows the use of natural flushing to meet EPA standards. Natural flushing allows natural ground water processes to reduce the contamination in ground water to acceptable standards (background levels, MCLs, or ACLs). Natural flushing must allow the standards to be met within 100 years. In addition, institutional controls and an adequate monitoring program must be established and maintained to protect human health during the period of natural flushing. Institutional controls would prohibit inappropriate uses of the contaminated ground water. The ground water also must not be a current or projected source of drinking water for a public water system during the period of natural flushing, and beneficial uses of ground water must be protected.

2.3.1 Subpart C: Implementation

Subpart C provides guidance for implementing methods and procedures to reasonably ensure that standards of Subpart B are met. Subpart C requires that the standards of Subpart B are met on a site-specific basis using information gathered during site characterization and monitoring. The plan to meet the standards of Subpart B must be stated in a site-specific GCAP. The plan must contain a compliance strategy and a monitoring program, if necessary.

2.4 Supplemental Standards

Under certain conditions, DOE may apply supplemental standards to contaminated ground water in lieu of background levels, MCLs, or ACLs (40 CFR Part 192). Supplemental standards may be applied if any of the following conditions are met:

- Remedial action necessary to implement Subpart A or B would pose a significant risk to workers or the public.
- Remedial action to meet the standards would directly produce health and environmental harm that is clearly excessive compared to the health and environmental benefits of remediation now or in the future.
- The estimated cost of remedial action is unreasonably high relative to the long-term benefits, and the RRM does not pose a clear present or future hazard.
- There is no known remedial action.
- The restoration of ground water quality at any processing site is technically impracticable from an engineering standpoint. Guidance for what is deemed technically impracticable is provided by EPA (1993b 1996b 2000b.
- The ground water is classified as limited-use ground water. Subpart B of 40 CFR 192 defines limited-use ground water as ground water that is not a current or potential source of drinking water because the concentration of total dissolved solids (TDS) exceeds 10,000 milligrams per liter (mg/L); there is widespread ambient contamination that cannot be cleaned up using treatment methods reasonably employed in public water systems; or the quantity of water available to a well is less than 150 gallons (gal) per day. When limited-use ground water applies, supplemental standards ensure that current and reasonably projected uses of the ground water are preserved (40 CFR Part 192).
- Radiation from radionuclides other than radium-226 and its decay products is present in sufficient quantity and concentration to constitute a significant radiation hazard from RRM.

If supplemental standards are applied, the regulations in 40 CFR 192.22 (c) also require DOE to inform anyone affected by the hazardous constituents and to solicit their comments.

One of the four cleanup standards (i.e., background, MCLs, ACLs, or supplemental standards) is selected on the basis of risk to human health and the environment. The methods available to achieve compliance include active remediation, natural flushing, no remediation, or any combination of the methods. Section 5.0, "Site Conceptual Model," presents a summary of the geology, hydrology, and geochemistry of the site. This information provides the basis to select the compliance strategy. Section 7.0. "Ground Water Compliance Strategy," presents a discussion of the proposed compliance strategies and includes a justification for selecting a natural flushing to MCL remediation strategy for arsenic, supplemental standards for vanadium and uranium, and monitoring and institutional controls (ICs) for all three constituents.

2.5 Cooperative Agreements

UMTRCA requires that compliance with the ground water standards be accomplished with the full participation of states that are paying part of the costs, and in consultation with Indian tribes on whose lands uranium mill tailings are located. UMTRCA also directs DOE to enter into cooperative agreements with the states and Indian tribes. DOE entered into a ground water cooperative agreement with the Colorado Department of Public Health and Environment in March 1998.

2.6 National Environmental Policy Act

UMTRCA is a major federal action that is subject to the requirements of NEPA (42 USC 4321 *et seq.*). Regulations of the Council on Environmental Quality (to implement NEPA) are codified in 40 CFR Part 1500; these regulations require each federal agency to develop its own implementing procedures (40 CFR 1507.3). DOE-related NEPA regulations are in 10 CFR Part 1021, "National Environmental Policy Act Implementing Procedures". DOE guidance is provided in *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993b).

Pursuant to NEPA, in 1994 DOE drafted a PEIS for the UMTRA Ground Water Project. The PEIS document was made final in October 1996. The purpose of the PEIS was to analyze the potential impacts of implementing four programmatic alternatives for ground water compliance at the designated processing sites. The preferred alternative for the UMTRA Ground Water Project was published in a Record of Decision in 1997. All subsequent action on the UMTRA Ground Water Project will comply with the Record of Decision.

2.7 Other Regulations

In addition to UMTRCA, EPA ground water standards, and NEPA, DOE must also comply with other federal regulations and executive orders that may be relevant to the UMTRA Project sites. Examples include regulations that require protection of wetlands and floodplains, threatened or endangered species, and cultural resources. Other regulations, for which the state may be delegated authority, include requirements for water discharge and waste management. Executive orders include those related to pollution prevention and environmental justice.

2.8 State Regulations

DOE must comply with state regulations where federal authority has been delegated to the state. These include compliance with state permits required for drilling, completing, and decommissioning monitoring wells; water discharge; and waste management.

2.9 DOE Orders

Several environmental, health and safety, and administrative DOE orders apply to the work being conducted under the UMTRA Ground Water Project. DOE orders prescribe the manner in which DOE will comply with federal and state laws, regulations, and guidance, and the manner in which DOE will conduct operations that are not prescribed by law. DOE guidance for complying with federal, state, and tribal environmental regulations are in DOE Order 5400.1 series, partially superseded by DOE Order 231.1. DOE Order 5400.5 requires protection of the public from radiation hazards. DOE guidance pertaining to NEPA is contained in DOE Order 451.1, and specific guidance pertaining to environmental assessments (EAs) is provided in Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements (DOE 1993b).

End of current text

3.0 Site Background

The Naturita UMTRA Project site is in western Colorado, Montrose County, approximately 2 miles north of the city of Naturita (Figure 1–1). It is situated on an elongate north-south section of floodplain between Colorado State Highway 141 on the west and the San Miguel River on the east. The site is the location of a former vanadium and uranium mill that operated intermittently from 1939 until 1958. The historical site area, a boundary used during the surface remedial action, enclosed 53 acres. The current site area is expanded to include property owned by the City of Naturita and Chemetall-Foote and now consists of 79 acres (Plate 1). This section presents an overview of the site's physical setting and climate, a history of the former milling operation and remedial actions, a summary of previous investigations, and the City of Naturita's current land use plan.

3.1 Physical Setting and Climate

The former millsite is located in the northeastern part of the Colorado Plateau Physiographic Province at the eastern edge of canyonlands country. Incised streams and large structural warps producing ridges and intervening basins characterize the area. Major physiographic features near the site include the valley occupied by the San Miguel River at an elevation of 5,355 ft and Sawtooth Ridge to the west and southwest that is slightly over 6,000 ft high.

The region has an arid to semiarid climate with high evaporation, low precipitation, low humidity, and large temperature variations. The average annual rainfall is about 13 inches per year (DOE 1995). Rainfall occurs during the summer and fall in high-intensity, short-duration, late afternoon thunderstorms that are conducive to runoff. Precipitation occurs in the winter as snowfall. Temperatures show considerable diurnal and seasonal variations. Winters are cold; average monthly temperatures are typically below freezing in December and January. Summers are warm; average monthly temperatures are in the 70s °F from June to August.

3.2 Site History

3.2.1 Milling History

Rare Metals Company built the Naturita vanadium mill about 1930 with a loan of $427,000 from the Vanadium Corporation of America (VCA). As collateral for the loan, VCA held the mortgage to the mill, and when Rare Metals failed in the mid-1930s, VCA foreclosed, performed improvements, and finally reopened the mill in 1939 (Shumway 1970). A salt-roast water-leaching process was used initially, but this was altered in 1942 to include recovery of uranium for the Manhattan Engineering District project. The ore was salt roasted and quenched in a carbonate solution, followed by carbonate leaching. Residues from this process were acidified with sulfuric acid to extract extra metals. These solutions were neutralized with excess sodium carbonate, and sludges were recirculated to reclaim additional uranium and vanadium. The carbonate leach liquor, containing uranium and vanadium, was treated with sulfuric acid and boiled to expel carbon dioxide. A filtrate containing the metals was fused with a reducing mixture of salt, soda ash, and either sawdust or fuel oil. After fusion, the ash was water-leached, dissolving vanadium and leaving the uranium. Additional steps concentrated vanadium as "red cake" (Merritt 1971).

The mill was originally designed to operate at about 150 tons per day capacity but was increased in 1954 to 350 tons per day. An overhead aerial photograph of the millsite taken in 1954 shows the mill and a large area of tailings located along the San Miguel River (Figure 3–1). The ore storage area on the west side of Colorado Highway 141 was already in use. The river shows a prominent distributary channel meandering across the vicinity property (Maupin Property) to the north. Tailings may have eroded off the millsite and may have been deposited in and along this channel. The mill closed in 1958 when the contract with the Atomic Energy Commission (AEC) expired. During the life of the mill, approximately 704,000 tons of ore was processed (Ford, Bacon, & Davis Utah 1981).

Ores for the mill were mined predominantly from the Salt Wash Member of the Morrison Formation from the Uravan Mineral Belt. Uranium and vanadium minerals were predominantly carnotite and tyuyamunite. About 51 percent of the ores came from contractor-controlled properties; the remaining 49 percent came from independent producers (Albrethsen and McGinley 1982). From 1961 to 1963, VCA operated an upgrader plant at the site, and concentrates were sent to their operations at Durango, Colorado, for further treatment. From 1963 to 1978, the millsite was used as a general headquarters for the downsizing VCA. They brought mining and milling equipment from all over the Colorado Plateau to the Naturita site and sold it to other mining interests (DOI 1994). Figure 3–2 is an overhead aerial photograph of the millsite in 1966 showing the maximum areal extent of the tailings pile. The distributary channel meandering across the vicinity property to the north is still apparent.

In the fall of 1969, Foote Mineral and the Colorado Department of Health (CDH) tried to stabilize the tailings that were next to the San Miguel River by covering them with topsoil and seeding, fertilizing, and watering the surface to allow the grass to root. This was done in part because tailings were eroding from the site during flood periods of the San Miguel River (DOI 1994). This stabilization apparently met with only limited success, because a 1974 overhead aerial view of the site shows barren tailings (Figure 3–3). The photograph was taken during spring or summer (trees are green), so any vegetation on the tailings should be visible. Buildings along Highway 141 are being used (a car is in front), and the tailings pile shows lineations, probably from the reclamation efforts. At the time approximately 704,000 tons of tailings are located on the site (Ford, Bacon, & Davis Utah 1981). A road or dike or both appear along the eastern side of the tailings pile where it contacts the San Miguel River. The distributary channel in the vicinity property has been modified and now cuts across the property farther north. The oval feature on the vicinity property was a local racetrack (named "Little Indy Speed Way") constructed by a family member of the property owner. The distributary channel has apparently deposited sediments and water in the eastern interior of the racetrack and could have deposited tailings on the vicinity property during this time.

By the 1970s, the price of uranium was attractive again, and in 1975, Foote Mineral leased a part of the millsite to the Nuclear Division of General Electric as a buying station for uranium ore. This continued into the 1980s. In 1976, Ranchers Exploration and Development Corporation bought 24 acres of tailings located on the site and removed an estimated 360,000 tons of tailings to a new location 4 miles to the south up Dry Creek. From 1977 to 1979, Ranchers heap-leached the tailings and recovered an additional 380,000 pounds of uranium and 1,840,000 pounds of vanadium (DOI 1994). In 1978 VCA merged with Foote Mineral, and the downsizing of all former VCA operations accelerated.

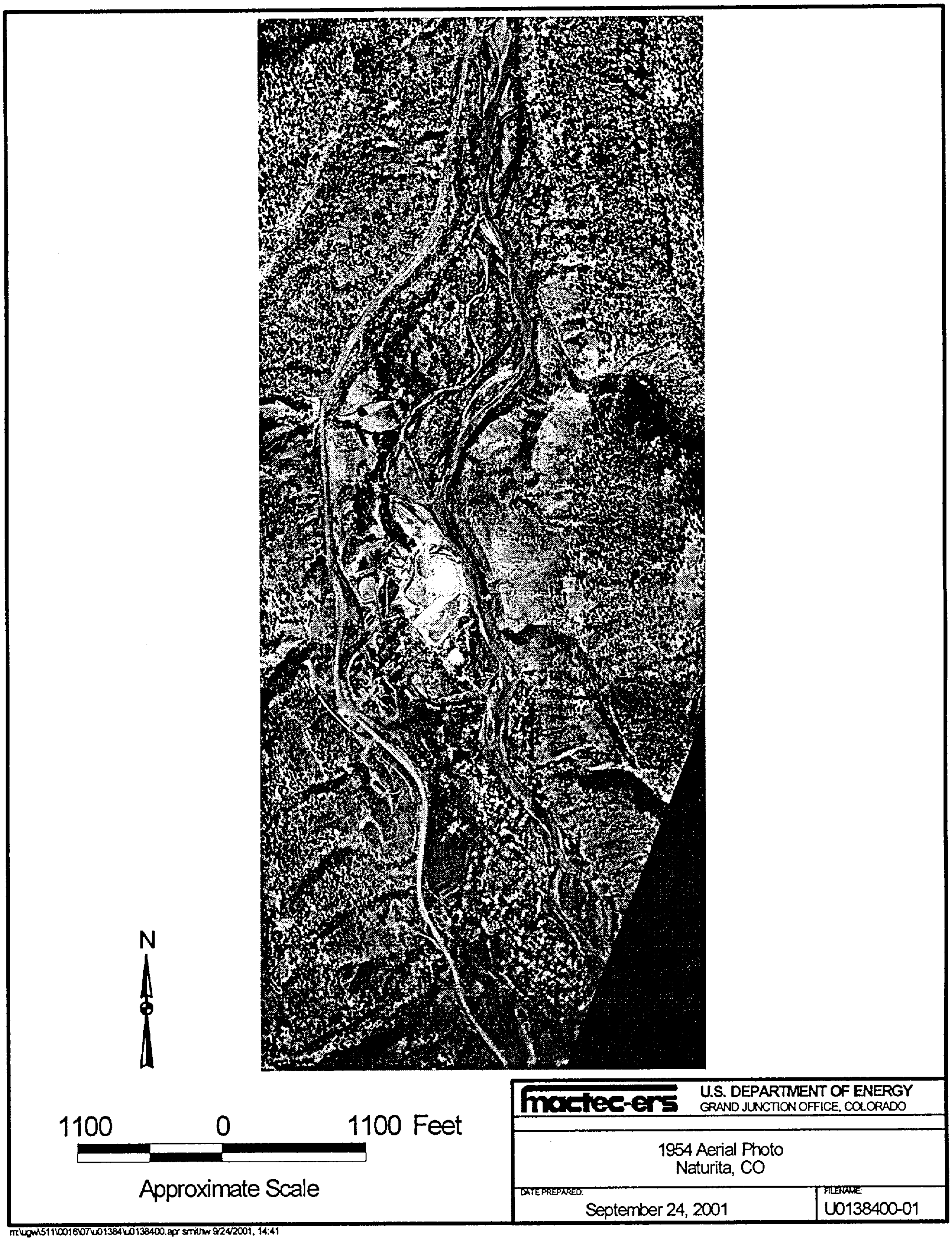

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Figure 3-1. Overhead Aerial Photograph Taken in 1954

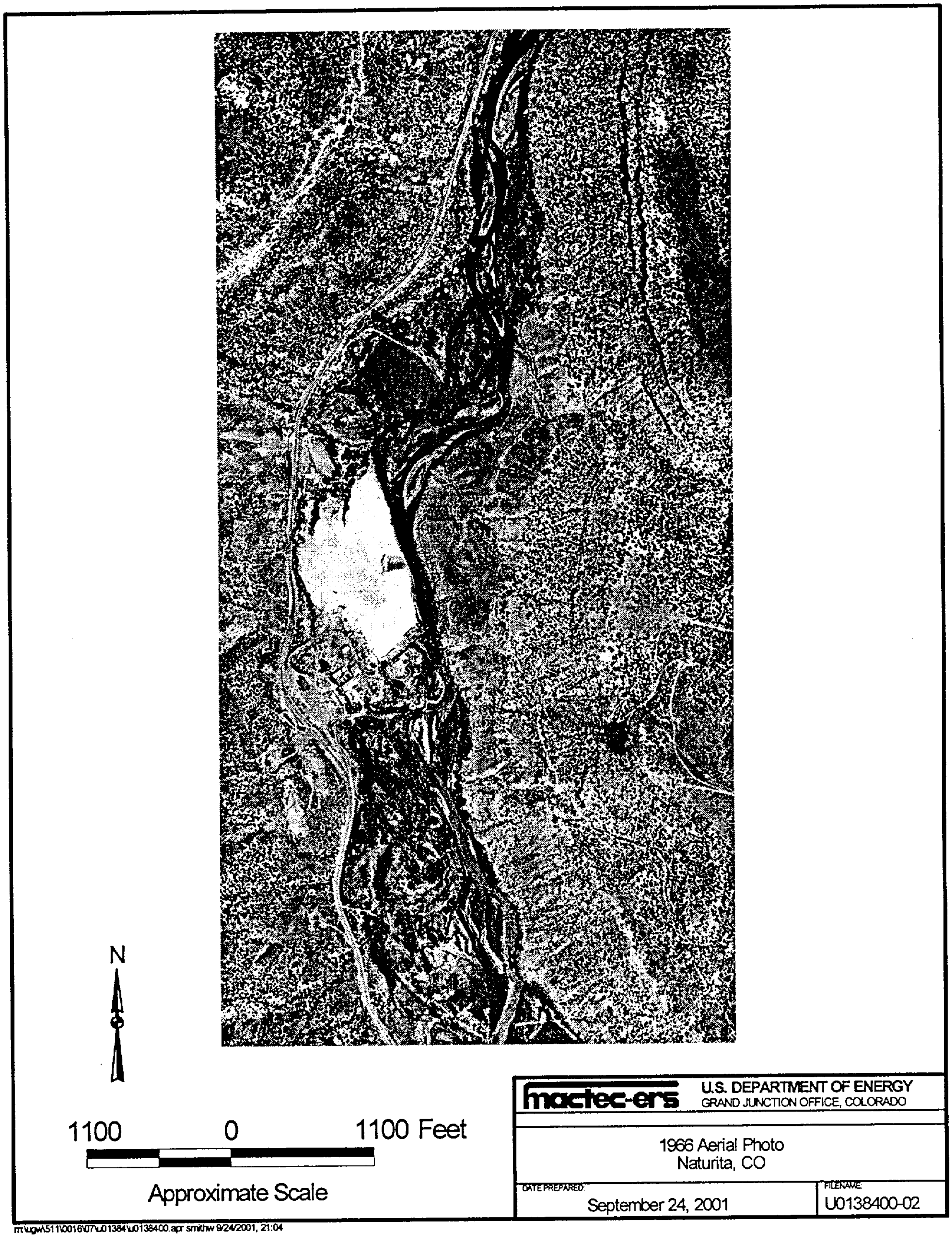

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Figure 3-2. Overhead Aerial Photograph Taken in 1966

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Figure 3-3. Overhead Aerial Photograph taken in 1974

3.2.2 Remedial Action History

Ford, Bacon, and Davis Utah performed an engineering assessment of the site for DOE in 1981 and proposed remedial actions with associated cost estimates. In 1984 and 1985, DOE again evaluated the radiological contamination at the site and supplied information to be used in the proposed remedial action that started in 1994. Figure 3–4 is an overhead aerial photograph of the millsite from 1986 that shows the former tailings pile with considerable vegetative cover. The San Miguel River has established its present course and no longer has a distributary channel crossing the vicinity property to the north and displays the unusual 90-degree turn from east to north in this area. A sand bar east of the former racetrack began to form and became vegetated with small willow saplings in the next decade. The former river channel scarp is the source for surface location 0538 (sometimes referred to as a spring).

During this time, the ownership of the mill changed several times. Foote Minerals was purchased by Cyprus Mining, who merged with Amax mining company to form Cyprus-Amax Minerals Corporation, who owned the site in 1994. Cyprus-Amax later became Cyprus-Foote, which was purchased by the German company, Chemetall, who formed the new company and became the current landowner, Chemetall Foote Corporation. Another previous landowner, Hecla Mining, who bought Ranchers Exploration in 1984, sold their property to the City of Naturita for one dollar (personal communication with Greg Hall, Naturita mayor, March 2001). Plate 1 shows the current land status for the site; Chemetall Foote owns north and south parcels and the City of Naturita owns the central portion.

The UMTRA Project surface remedial action at the site occurred between January 1993 and September 1998 (DOE 1998a). During this time, 771,400 cubic yards (yd^3) of RRM were removed from the site. The approximate breakdown is 315,520 yd^3 from the former mill yard, 10,340 yd^3 from the former ore storage area, 209,880 yd^3 from windblown areas, 225,490 yd^3 from the former tailings area, and 10,170 yd^3 from stockpiled demolition debris. In addition, a contiguous vicinity property to the north (NT-065, the Maupin property) underwent remedial action, and 93,602 yd^3 of material was removed (DOE 1998b). All material was hauled by truck to the Upper Burbank disposal cell about 15 miles to the northwest near the townsite of Uravan, Colorado. Figure 3–5 is an oblique aerial photograph from July 1994 of the mill yard before buildings were razed. It shows the former office buildings, the semicircular concrete pad used during the ore-buying era, and new trailers and equipment moved to the site to begin demolition. Figure 3–6 is an oblique aerial photograph from July 1996 of the mill yard showing the demolition of all buildings, construction of the retention pond for the decontamination pad, and an associated retention dike along the lower side of the site. Figure 3–7 is an overhead aerial photograph from May 1998 showing the final grade for the site. The RRM has been removed from the entire site, and considerable material has been removed from the vicinity property to the north, including the area of the old racetrack. Large cottonwood trees around the river bend were left at the owner's request. Figure 3–8 is an oblique aerial photograph showing the site in March 2001. Reseeding efforts have met with limited success, and another attempt will be made to address this in the fall of 2001.

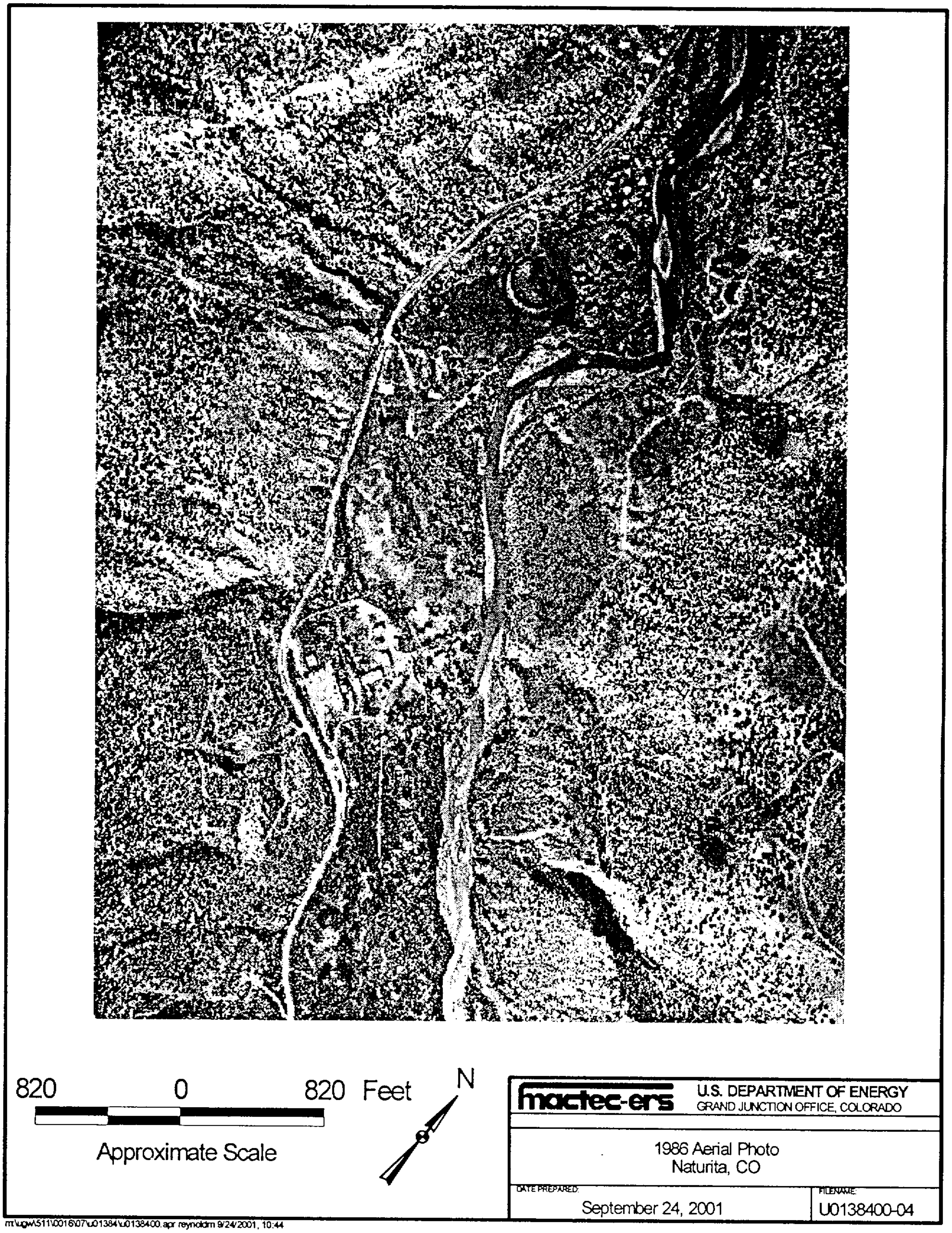

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Figure 3-4. Overhead Aerial Photograph taken in 1986

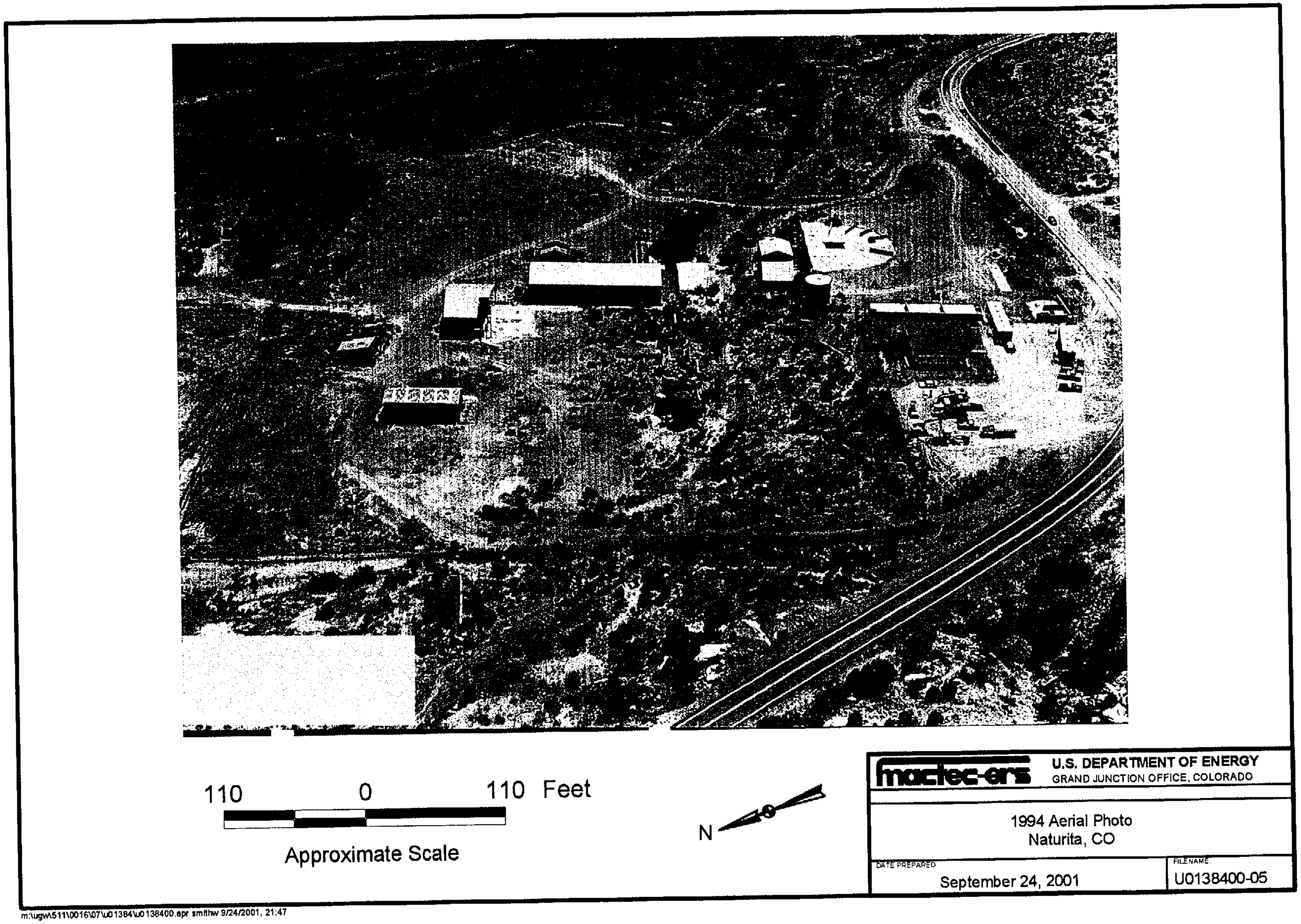

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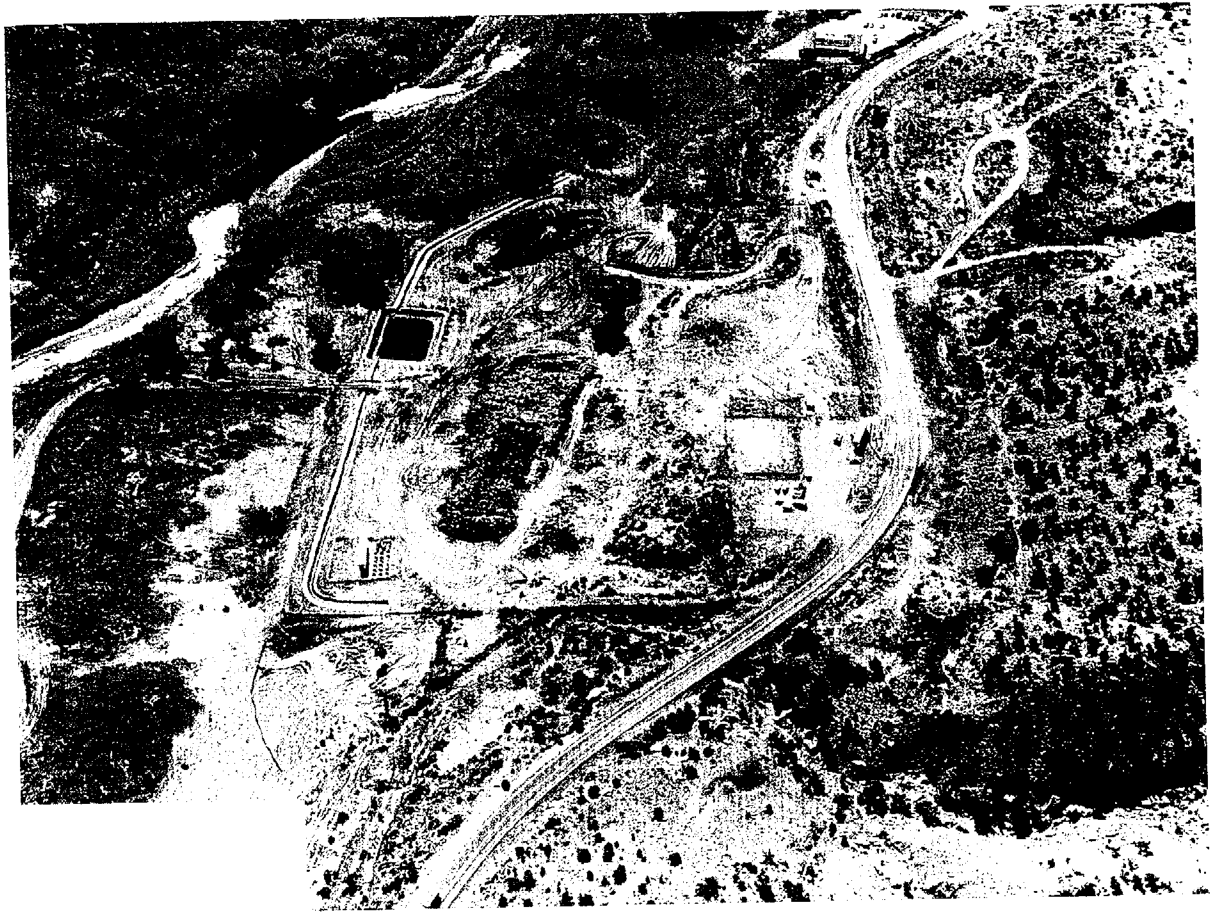
Figure 3-5. Oblique Aerial Photograph taken in 1994



mactec-ers **U.S. DEPARTMENT OF ENERGY**
GRAND JUNCTION OFFICE, COLORADO

1996 Aerial Photo
Naturita, CO

DATE PREPARED:	FILENAME:
September 24, 2001	U0138400-06

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Figure 3-6. Oblique Aerial Photograph taken in 1996

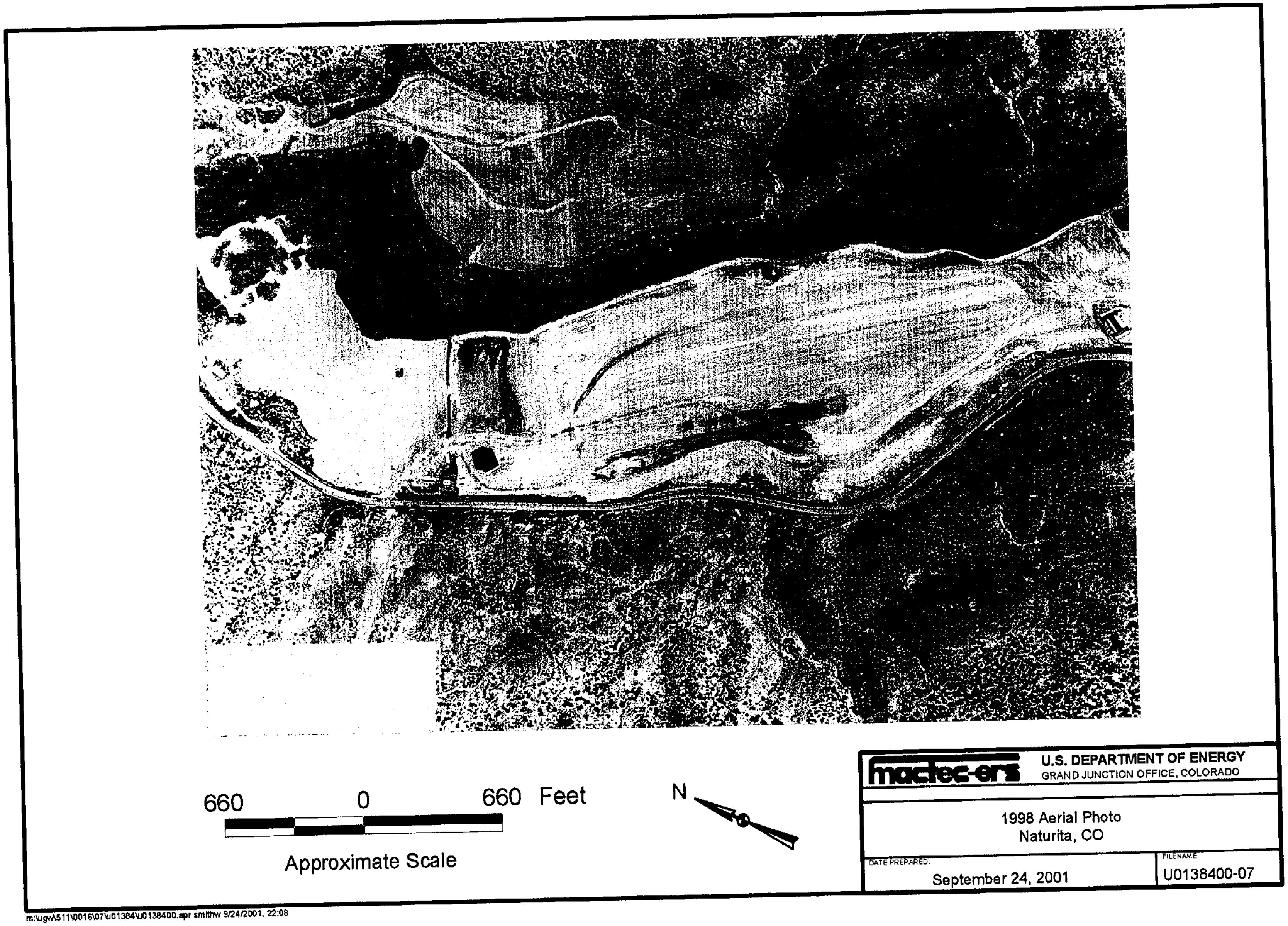

Figure 3-7. Aerial Photograph taken in 1998

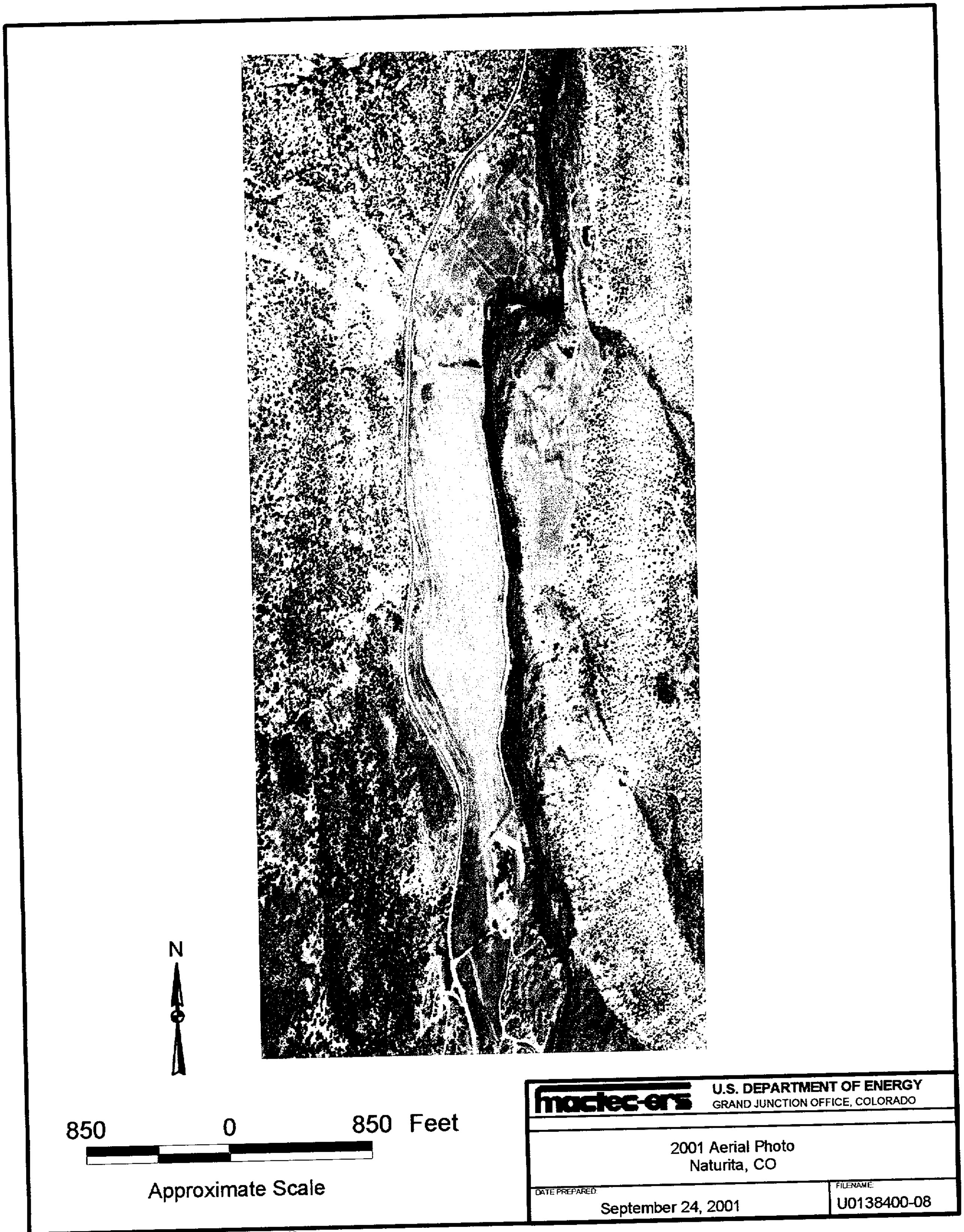

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Figure 3-8. Oblique Aerial Photograph taken in March 2001

3.2.2.1 Supplemental Standards Areas

The Naturita site is unusual because of the large amount of supplemental standards areas left during the surface cleanup (DOE 1998a). Five areas of supplemental standards, totaling 11 acres (14 percent of the total site area), were left on the site and large areas of supplemental standards, also totaling 11 acres (36 percent of the total vicinity property area), were included in the vicinity property downgradient of the site (see Figure 8–3). Just over one acre on the millsite was left because the radium-226 standard was not met after excavating to 1 ft below the water table. Other supplemental standards areas on the millsite were left because removing the RRM would produce excessive environmental harm and increased risk to workers who would have to remove it compared to the low radiological hazard. These areas were along the steep slopes of U.S. Highway 141, near high-voltage power poles, and in wetland areas adjacent to the San Miguel River.

Contamination on approximately 5 of the 11 acres on the downgradient vicinity property was left on the floodplain near the San Miguel River because the property owner did not want the area disturbed, and the harm to the environment outweighed the benefit of removing it. The area is a riparian corridor with mature cottonwoods and other habitat suitable for indigenous species. The other 6 acres on the vicinity property, where RRM is probably windblown contamination, was left along State Highway 141 because of low radioactivity and potential danger to workers who would have to work along the steep banks.

3.2.3 Previous Investigations

Merritt (1971) provides detailed descriptions of the uranium concentration process, mill by-products, and process waste streams. Albrethsen and McGinley (1982) summarize the history of the domestic uranium procurement policies and practices under the AEC. McWilliams and Schoch-Roberts (1994) discuss the VCA mill as an important historical activity in the country's nuclear energy saga and provide detailed discussions about the processing and milling history.

Coffin (1921) discusses the early radium, uranium, and vanadium mines in southwestern Colorado. Fischer and Hilpert (1952) discuss the geology of the Uravan Mineral Belt. Chenoweth (1981) reviews uranium and vanadium deposits in the Uravan Mineral Belt. Weir and others (1984) discuss the regional hydrology.

Site-specific hydrogeologic and geochemical investigations and remedial actions are described in an engineering assessment (Ford, Bacon, & Davis Utah 1981), an environmental assessment (DOE 1994), a BLRA (DOE 1995), a report by Groffman and Erskine (1996), a final RAP (DOE 1998a), a completion report (DOE 1998b), and a vicinity property completion report (DOE 1999b).

Table 3–1 is an update to Table 3.2 in the BLRA. This table shows the history of wells sampled at the site from 1998 to 2001. Only wells 0547 and 0548 remain from the surface program. Wells listed in Table 3–1 are all currently being sampled.

Table 3–1. Current Monitor Well Information

Well ID	Location	Years Sampled	Times Sampled	Interval Screened (ft)
0548	Northwest of former tailings pile	1986, 1987, 1989, 1992, 1994, 1998–2001	20	16.0–21.0
0547	Southeast of former mill yard	1986, 1987, 1989, 1992, 1994, 1998–2001	20	10.0–20.0
MAU01	Maupin property, S border	1998–2001	9	9.2–14.2
MAU02	Maupin property, S border	1998–2001	9	15.8–16.8 triple completion
MAU03	Maupin property, NE	1998–2001	9	2.2–9.2 triple completion
MAU04	Maupin property, NE	1998–2001	9	3.2–10.2
MAU05	Maupin property, S border	1998–2001	9	8.2–8.7
MAU06	Maupin property, center eastern	1999–2001	8	3.5–8.5
MAU07	Maupin property, farthest N	1999–2001	8	2.9–7.9
MAU08	Maupin property, SW border	1999–2001	8	6.2–11.2
NAT01	N boundary former tailings pile	1998–2001	9	17.0–17.5 double completion
NAT02	Former tailings pile	1998–2001	8	6.4–11.4
NAT03	Former tailings pile	1998–2001	9	6.3–11.3
NAT04	Former tailings pile	1998–2001	9	12.0–12.5 triple completion
NAT05	Former tailings pile	1998–2001	9	8.7–13.7
NAT06	Former tailings pile	1998–2001	9	11.6–12.2 triple completion
NAT07	Former tailings pile	1998–2001	9	11.8–12.3 triple completion
NAT08	Former tailings pile	1998–2001	9	6.3–11.3
NAT09	Former taillings pile	1998–2001	9	5.7–10.7
NAT10	Former tailings pile	1998–2001	9	6.8–11.8
NAT11	Former tailings pile	1998–2001	9	8.7–13.7
NAT12	Former tailings pile	1998–2001	9	13.9–14.4 double completion
NAT13	Former tailings pile	1999–2001	8	11.8–12.3 triple completion
NAT14	Former tailings pile	1999–2001	8	11.0–11.5 triple completion
NAT15	Former tailings pile	1999–2001	8	13.8–14.3 triple completion
NAT16	Former tailings pile	1999–2001	8	11.7–12.2 triple completion
NAT17	Former mill yard	1999–2001	8	10.7–11.2 triple completion
NAT18	Former mill yard	1999–2001	8	10.7–11.2 triple completion
NAT19	Former mill yard	1999–2001	8	6.0–11.0
NAT20	S site boundary	1999–2001	8	5.2–10.2
NAT21	S site boundary	1999–2001	8	9.3–9.8 triple completion
NAT22	S site boundary	1999–2001	8	9.3–9.8 triple completion
NAT23	Northern site	1999–2001	8	4.7–9.7
NAT24	Northern site	1999–2001	8	4.7–9.2
NAT25	Northern site	1999–2001	8	10.2–15.2
NAT26	NW site	1999–2001	8	10.7–15.7
NAT27	Former tailings pile	1999–2001	8	6.7–7.2 triple completion
NAT28	Former tailings pile	1999–2001	8	6.7–7.2 triple completion
NAT29	Former tailings pile	1999–2001	8	1.4–6.4
NAT30	Southern site	1999–2001	8	7.8–8.3 triple completion
DM1	Background, gravel pit	1999–2001	8	2.7–7.7

3.3 Land and Water Uses

The population of Naturita is approximately 700. The town was a center for mining radium, vanadium, and uranium for 80 years and still supports coal mining and an associated power plant. A gravel pit operated by Southwest Redimix abuts the site on the south (upgradient) side. The pit intersects the water table and may influence migration of alluvial ground water across the site. Ranching and farming are the main occupations in the valley around the millsite.

One ranch residence is adjacent to the site on the downgradient side. The residents haul drinking water for domestic use and do not have a well.

The Blessing Ditch crosses the site from south to north on the west side. This irrigation ditch was last operational in 1972. The grade for a potential ditch was established on the site during remedial action.

Land including and surrounding the former millsite is zoned agricultural. The City of Naturita identifies the land within the former millsite as having possible uses as a western park or golf course. A portion of the site is currently deeded to the town, and the remainder belongs to Chemetall Foote. Plans to transfer the Chemetall Foote property to the City are under consideration.

Currently, there are no uses for ground water at the site. The ground water in the alluvial aquifer is of lesser quality than water from the San Miguel River flowing adjacent to the site. Livestock drink from the river. No domestic wells exist in the contaminated portion of the aquifer.

End of current text

4.0 1998 to 2001 Field Investigations

4.1 Introduction

The U.S. Geological Survey (USGS) has been conducting research sponsored by NRC at the Naturita site since 1997. NRC is interested in sorptive interactions between uranium and substrate and more efficient and effective methods of measuring them. DOE teamed with the USGS to use their knowledge and sampling expertise to produce this SOWP. Therefore, most of the sampling from 1998 to 2001 was conducted by USGS and supplemented to a limited extent by DOE. Most surface and ground water analyses and soil/sediment analyses were also performed by USGS at their labs in Menlo Park, California, and Denver, Colorado. Other analyses were performed at the DOE Grand Junction Office.

4.2 Ground Water Monitoring Well Installations

The ground water monitor wells were installed by USGS with funding from NRC for a field demonstration of a uranium(VI) surface complexation model. Specifically, the wells were installed to (1) obtain an understanding of the direction and velocity of ground water flow; (2) characterize the ground water chemistry at the site, including the extent of uranium contamination; (3) investigate the role of U(VI) sorption in host sediments and rock; and (4) conduct small-scale tracer tests and aquifer tests to investigate U(VI) transport. Installation procedures, construction details, and locations for the wells are described in this section. Figure 4–1 shows monitoring well locations.

4.2.1 Wells Installed in 1998 and 1999

A total of 39 ground water monitoring wells were installed during October 1998 and June 1999. Two types of wells were installed: (1) 2-inch-diameter, single completion wells screened over a 5-ft interval at the bottom of the alluvial aquifer, and (2) 0.5-inch-diameter, multiple completion wells with two to three wells in the same borehole, each screened over a 6-inch vertical interval at different depths. All wells were drilled using the USGS drilling rig with hollow stem augers. Wells installed in June 1999 were drilled using a casing-advance method. Twenty wells were completed with 2-inch inside diameter (i.d.), flush joint, inside threaded, polyvinyl chloride (PVC) casing with size 20 slotted screen. One well was constructed with a 4-inch i.d. PVC casing for use in aquifer testing. Eighteen wells were constructed as multiple completion wells using 0.5-inch i.d. PVC casing. The multiple completion wells were constructed by setting the 0.5-inch casings at different levels in the filter pack. Each of the multiple completion wells in NAT04, NAT12, and MAU02 was separated by a 4-inch bentonite seal. For all other multiple completion wells, no seal was installed between the completion zones. All the 1998–1999 wells completed in the alluvial aquifer were less than 20 ft in depth. The screened intervals for the 4-inch and 2-inch wells is 5 ft. Screened intervals for the 0.5-inch-diameter multiple completion wells is 6 inches. The filter pack was constructed with 10 to 20 sieve silica sand placed in the annular space from the bottom of the borehole to 1 to 3 ft above the top of the well screen. A 1- to 8-ft bentonite seal was placed above the sand pack. Bentonite grout was used to fill the annular space above the seal to the ground surface, and a cement pad was poured to anchor a locking steel protective cover. Examples of well completion diagrams for the 2-inch and 0.5-inch multiple completion wells are shown in Figure 4–2 and Figure 4–3, respectively. Construction details for the wells are summarized in Table 4–1. Completion diagrams for all the wells are in Appendix A.

4.2.2 Wells Installed by DOE Before 1998

In addition to the wells installed in 1998 and 1999, DOE had previously installed two wells as part of an initial site characterization. These wells, designated 0547 and 0548, were installed in June 1986 with a direct rotary drill. Both wells have 2-inch i.d. PVC casings and are 23 ft deep. Well 0547 has a 10-ft screened interval and 0548 has a 5-ft screened interval. Both wells are capped with a locking steel cover. Drilling logs for these wells are included in Appendix B; construction details for DOE wells are summarized in Table 4–1.

4.2.3 Water Levels and Temperatures

Seasonal changes in water levels were measured 14 times in all the monitoring wells between October 1998 and June 2000. From November 2000 to March 2001, water levels were only measured in 28 wells. Depth to water was measured from the top of the PVC casing at each well at a set measuring point. Measuring point elevations above sea level are shown in Table 4–2 and were surveyed from a nearby benchmark during well installation to calculate the elevation of the water table. Water levels were monitored continuously with pressure transducers in up to six wells from November 1998 to March 2001. Water level data from the transducers were downloaded, and the instruments were recalibrated quarterly. Figure 4–4 shows the water table elevations for wells NAT02, NAT08, and NAT29. Figure 4–5 shows the water table elevations in wells NAT11, NAT23, and NAT25. Appendix C shows the daily average water levels for all wells monitored with a pressure transducer.

Seasonal changes in water temperature was recorded along with water level in wells NAT02, NAT08 and NAT29 and is shown in Figure 4–4. Water temperature was also recorded in wells NAT02, NAT11, NAT19, NAT20, NAT23, NAT26, MAU03, MAU07, MAU08, and the San Miguel River. Water temperatures for wells NAT11, NAT23, and NAT25 are shown in Figure 4–5.

4.3 Soil and Sediment Sampling

Soil and sediment samples for lithologic logging and chemical analysis were collected during installation of the ground water monitoring wells. Sediment and soil samples were collected for chemical analysis to determine distribution coefficients (K_d) and mobile fractions of site-related constituents to help characterize contaminant transport. Figure 4–6 shows the soil and sediment sampling locations. All samples were sent to the USGS Research Laboratories in Menlo Park, California, for K_d and batch leachate analysis using strict chain of custody procedures. Chemical analysis of the leachates was performed in Menlo Park and at the USGS National Water Quality Lab in Denver using the methods described in Section 4.7.2.

On July 16 and 17, 1998, a background sediment sample was collected from saturated alluvium about half way between well 0547 and well DM1 (Figure 4–6). The sample was screened in the field to remove cobbles larger than about 65 mm, and it was estimated visually that about 30–50 percent of the material scooped by the backhoe did not pass the 65 mm screen. Uranium-contaminated material from the saturated zone of the alluvial aquifer was collected from auger flights during installation of monitoring wells in October 1998. The subsurface material was air dried and sieved through 3-mm sieves.

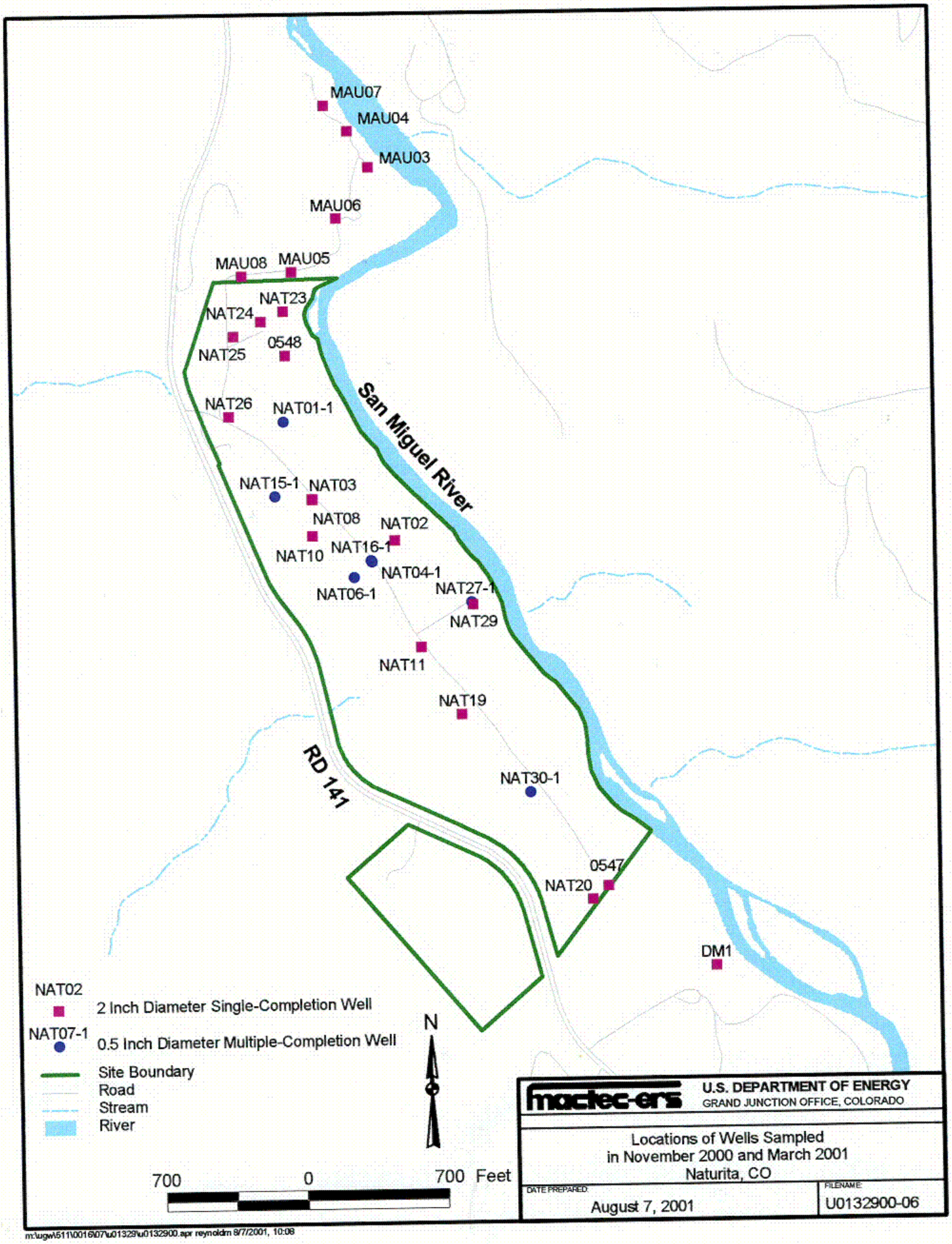

Figure 4–1. Locations of Naturita Wells Sampled in November 2000 and March 2001

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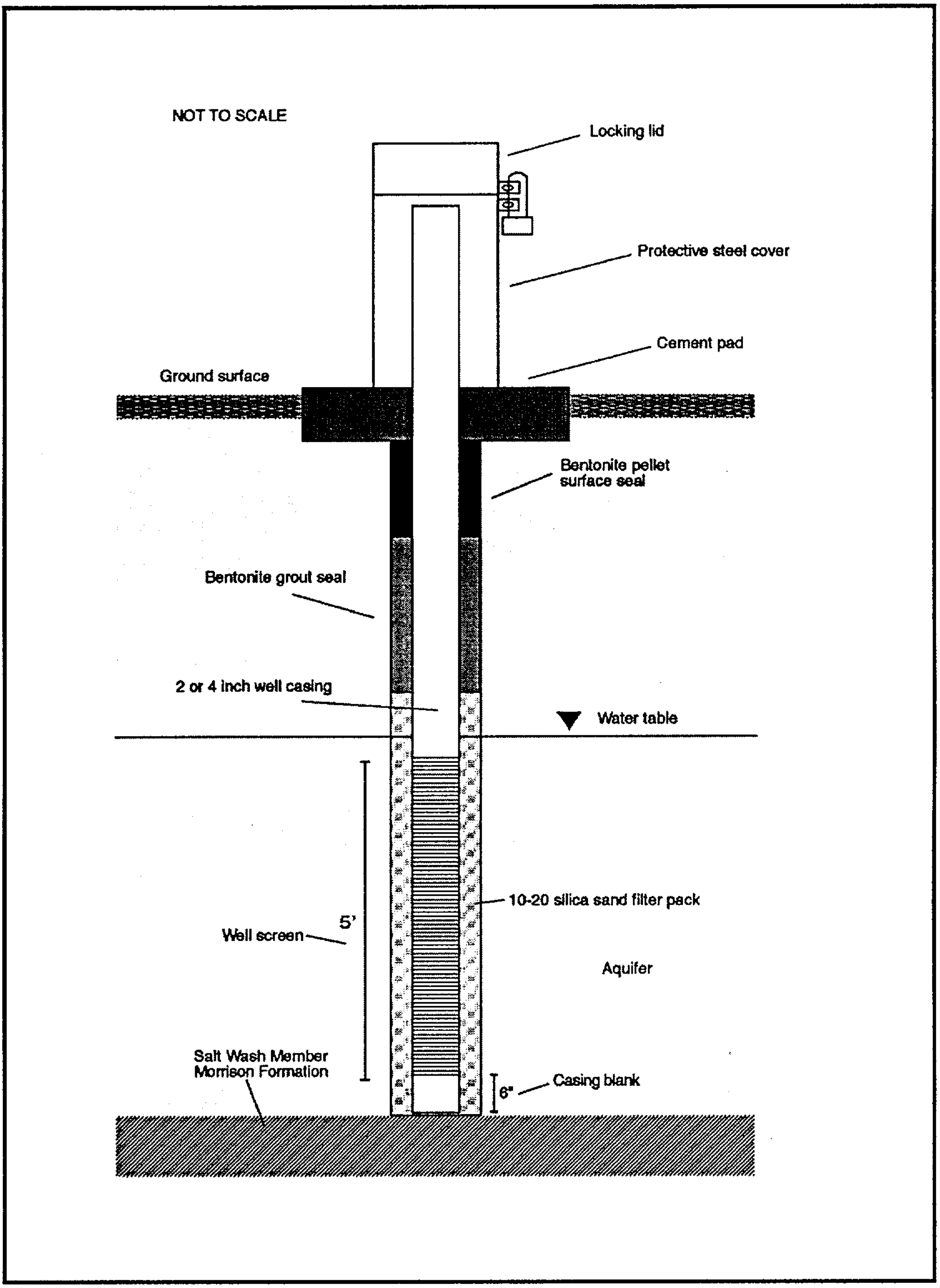


Figure 4–2. Construction Diagram for 2- and 4-inch-Diameter Monitoring Wells Installed at the Naturita Site

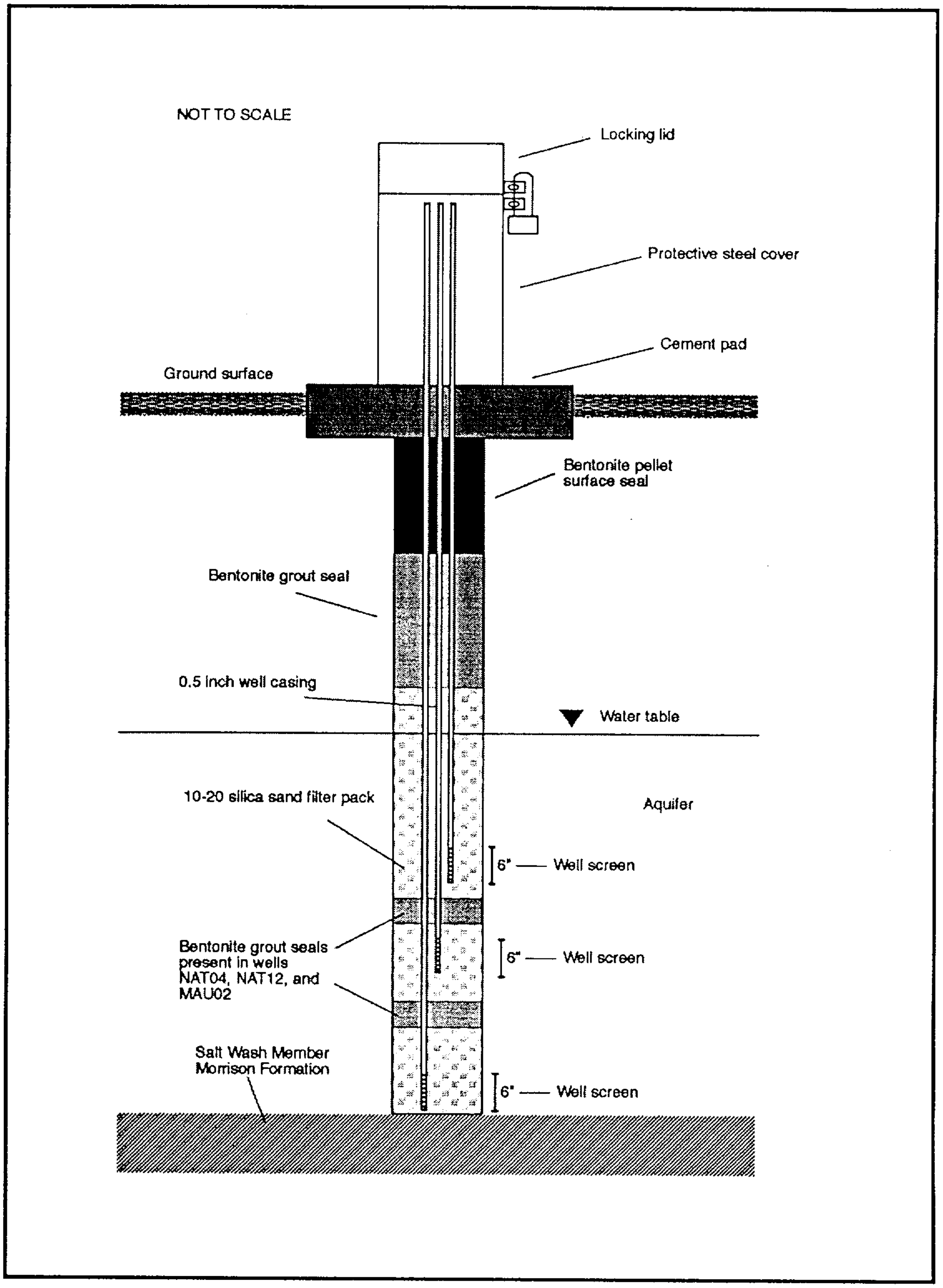


Figure 4–3. Construction Diagram for 0.5-inch-Diameter Multiple Completion Wells Installed at the Naturita Site

Table 4–1. Construction Details for Monitoring Wells Installed at the Naturita UMTRA Site

Location Code	North Coordinate, State Plane	East Coordinate, State Plane	Elevation of Land Surface, ft	Borehole Depth, ft	Borehole Diameter, inches	Elevation of Top of Casing, ft	Casing Length, ft	Casing Diameter, Inches	Depth Below Land Surface, ft	Screen length, ft	Flow Code	Zone of Completion	Status
NAT01-1	588657	1106298	5288.11	18.0	14.0	5290.76	20.32	0.5	17.0	0.50	O	Al	Active
NAT01-2	588659	1106298	5288.11	18.0	14.0	5290.61	15.37	0.5	12.2	0.50	O	Al	Active
NAT02	588073	1106846	5287.37	11.5	9.0	5289.42	13.88	2.0	6.5	5.00	O	Al	Active
NAT03	588278	1106435	5286.57	11.6	9.0	5288.37	13.43	2.0	6.3	5.00	O	Al	Active
NAT04-1	587968	1106729	5288.42	12.5	9.0	5290.53	14.78	0.5	12.0	0.50	O	Al	Active
NAT04-2	587968	1106729	5288.42	10.7	9.0	5290.62	13.07	0.5	10.2	0.50	O	Al	Active
NAT04-3	587968	1106729	5288.42	8.7	9.0	5290.62	11.07	0.5	8.2	0.50	O	Al	Active
NAT05	588284	1106251	5287.63	14.0	9.0	5289.73	16.13	2.0	8.7	5.00	O	Al	Active
NAT06-1	587888	1106640	5288.88	12.3	9.0	5291.73	15.32	0.5	11.8	0.50	O	Al	Active
NAT06-2	587888	1106640	5288.88	9.9	9.0	5291.73	12.92	0.5	9.4	0.50	O	Al	Active
NAT06-3	587888	1106641	5288.88	6.1	9.0	5291.71	9.10	0.5	5.6	0.50	O	Al	Active
NAT07-1	588368	1106567	5285.73	12.5	9.0	5287.93	14.87	0.5	12.0	0.50	O	Al	Active
NAT07-2	588368	1106567	5285.73	10.8	9.0	5287.81	13.05	0.5	10.3	0.50	O	Al	Active
NAT07-3	588368	1106567	5285.73	8.7	9.0	5287.63	10.77	0.5	8.2	0.50	O	Al	Active
NAT08	588276	1106438	5286.30	12.0	12.0	5288.00	13.33	4.0	6.0	5.00	O	Al	Active
NAT09	588281	1106432	5286.52	11.0	9.0	5288.42	13.03	2.0	6.3	5.00	O	Al	Active
NAT10	588095	1106437	5287.28	12.0	9.0	5289.18	14.03	2.0	6.8	5.00	O	Al	Active
NAT11	587546	1106970	5291.23	14.0	10.0	5293.73	16.63	2.0	8.8	5.00	O	Al	Active
NAT12-1	588592	1106197	5289.84	14.6	9.0	5291.64	16.57	0.5	14.1	0.50	O	Al	Active
NAT12-2	588592	1106198	5289.84	10.3	9.0	5291.65	12.28	0.5	9.8	0.50	O	Al	Active
NAT13-1	587550	1106965	5291.50	12.5	4.0	5294.22	15.19	0.5	11.8	0.50	O	Al	Active
NAT13-2	587550	1106965	5291.50	10.5	4.0	5294.14	13.11	0.5	9.8	0.50	O	Al	Active
NAT13-3	587550	1106965	5291.50	8.5	4.0	5294.22	11.19	0.5	7.8	0.50	O	Al	Active
NAT14-1	587556	1106961	5291.34	11.7	4.0	5294.58	15.01	0.5	11.0	0.50	O	Al	Active
NAT14-2	587556	1106961	5291.34	10.4	4.0	5294.56	13.69	0.5	9.8	0.50	O	Al	Active
NAT14-3	587556	1106961	5291.34	8.4	4.0	5294.57	11.70	0.5	7.8	0.50	O	Al	Active
NAT15-1	588292	1106251	5287.96	14.5	4.0	5290.25	16.76	0.5	13.8	0.50	O	Al	Active
NAT15-2	588292	1106251	5287.96	12.5	4.0	5290.25	14.76	0.5	11.8	0.50	O	Al	Active
NAT15-3	588292	1106251	5287.96	10.5	4.0	5290.25	12.76	0.5	9.8	0.50	O	Al	Active
NAT16-1	587975	1106725	5288.43	12.3	4.0	5291.16	15.10	0.5	11.7	0.50	O	Al	Active
NAT16-2	587975	1106725	5288.43	10.5	4.0	5291.10	13.14	0.5	9.8	0.50	O	Al	Active
NAT16-3	587975	1106725	5288.43	8.5	4.0	5291.16	11.20	0.5	7.8	0.50	O	Al	Active
NAT17-1	587226	1107161	5293.65	11.3	4.0	5295.97	13.69	0.5	10.7	0.50	O	Al	Active
NAT17-2	587226	1107161	5293.65	9.3	4.0	5295.97	11.69	0.5	8.7	0.50	O	Al	Active
NAT17-3	587226	1107161	5293.65	7.3	4.0	5295.97	9.69	0.5	6.7	0.50	O	Al	Active
NAT18-1	587221	1107166	5293.66	11.3	4.0	5296.34	14.05	0.5	10.7	0.50	O	Al	Active
NAT18-2	587221	1107166	5293.66	9.3	4.0	5296.34	11.05	0.5	8.7	0.50	O	Al	Active
NAT18-3	587221	1107166	5293.66	7.3	4.0	5296.34	10.05	0.5	6.7	0.50	O	Al	Active
NAT19	587215	1107170	5293.82	11.3	4.0	5296.58	14.09	2.0	6.0	5.00	O	Al	Active
NAT20	586300	1107808	5301.43	10.5	4.0	5304.46	13.56	2.0	5.2	5.00	O	Al	Active
NAT21-1	586305	1107804	5301.47	10.0	4.0	5304.27	12.93	0.5	9.3	0.50	O	Al	Active
NAT21-2	586305	1107804	5301.47	8.0	4.0	5304.27	10.77	0.5	7.3	0.50	O	Al	Active
NAT21-3	586305	1107804	5301.47	6.0	4.0	5304.27	8.77	0.5	5.3	0.50	O	Al	Active
NAT22-1	586312	1107800	5301.47	10.0	4.0	5304.27	12.77	0.5	9.3	0.50	O	Al	Active
NAT22-2	586312	1107800	5301.47	8.0	4.0	5304.27	10.77	0.5	7.3	0.50	O	Al	Active
NAT22-3	586312	1107800	5301.47	6.0	4.0	5304.27	8.77	0.5	5.3	0.50	O	Al	Active

Table 4–1 (continued). Construction Details for Monitoring Wells Installed at the Naturita UMTRA Site

Location Code	North Coordinate, State Plane	East Coordinate, State Plane	Elevation of Land Surface, ft	Borehole Depth, ft	Borehole Diameter, Inches	Elevation of Top of Casing, ft	Casing Length, ft	Casing Diameter, inches	Depth Below Land Surface, ft	Screen length, ft	Flow Code	Zone of Completion	Status
NAT23	589202	1106300	5283.07	10.0	4.0	5285.43	12.39	2.0	4.7	5.00	O	Al	Active
NAT24	589155	1106188	5285.11	9.5	4.0	5287.70	12.12	2.0	4.2	5.00	O	Al	Active
NAT25	589082	1106053	5289.39	15.5	4.0	5291.88	18.02	2.0	10.2	5.00	O	Al	Active
NAT26	588685	1106027	5293.23	16.0	4.0	5295.54	18.34	2.0	10.7	5.00	O	Al	Active
NAT27-1	587764	1107221	5289.81	7.3	4.0	5292.79	10.35	0.5	6.7	0.50	O	Al	Active
NAT27-2	587764	1107221	5289.81	5.3	4.0	5292.79	8.35	0.5	4.7	0.50	O	Al	Active
NAT27-3	587764	1107221	5289.81	3.3	4.0	5292.79	6.35	0.5	2.7	0.50	O	Al	Active
NAT28-1	587759	1107225	5289.88	7.3	4.0	5292.61	10.10	0.5	6.7	0.50	O	Al	Active
NAT28-2	587759	1107225	5289.88	5.3	4.0	5292.61	8.10	0.5	4.7	0.50	O	Al	Active
NAT28-3	587759	1107225	5289.88	3.3	4.0	5292.61	6.10	0.5	2.7	0.50	O	Al	Active
NAT29	587752	1107229	5290.08	6.8	4.0	5292.89	9.54	2.0	1.4	5.00	O	Al	Active
NAT30-1	586831	1107504	5297.04	8.5	4.0	5300.05	11.48	0.5	7.8	0.50	O	Al	Active
NAT30-2	586831	1107504	5297.04	6.5	4.0	5300.02	9.45	0.5	5.8	0.50	O	Al	Active
NAT30-3	586831	1107504	5297.04	4.5	4.0	5300.00	7.43	0.5	3.8	0.50	O	Al	Active
MAU01	589377	1106207	5283.19	14.5	9.0	5284.89	16.53	2.0	9.5	5.00	D	Al	Active
MAU02-1	589365	1106377	5282.44	16.5	9.0	5284.54	18.77	0.5	16.0	0.50	D	Al	Active
MAU02-2	589365	1106377	5282.46	11.2	9.0	5284.56	13.47	0.5	10.7	0.50	D	Al	Active
MAU02-3	589365	1106377	5282.46	9.6	9.0	5284.56	7.87	0.5	9.1	0.50	D	Al	Active
MAU03	589907	1106726	5275.29	9.5	10.0	5277.64	12.18	2.0	2.5	5.00	D	Al	Active
MAU04	590085	1106620	5274.10	10.5	9.0	5275.80	12.53	2.0	3.5	5.00	D	Al	Active
MAU05	589394	1106342	5282.13	9.0	9.0	5284.33	11.53	2.0	8.5	5.00	D	Al	Active
MAU06	589655	1106565	5279.43	8.8	4.0	5281.85	11.25	2.0	3.5	5.00	D	Al	Active
MAU07	590209	1106507	5273.16	8.3	4.0	5275.90	10.97	2.0	2.9	5.00	D	Al	Active
MAU08	589375	1106097	5283.51	11.5	4.0	5286.44	14.46	2.0	6.2	5.00	D	Al	Active
0502	586923	1106997	5348.90	249.0	6.0	5350.30	249.00	2.0	229.3	20.00	U	JS	Destroyed
0503	586588	1107630	5301.10	165.0	6.0	5302.50	165.00	2.0	140.0	25.00	U	JS	Destroyed
0505	587411	1107326	5297.90	24.0	6.0	5300.90	23.00	2.0	16.0	5.00	O	AL	Destroyed
0506	587257	1107057	5304.70	27.0	6.0	5306.30	27.00	2.0	22.5	5.00	O	AL	Destroyed
0546	586414	1107771	5302.10	23.0	6.0	5304.10	17.00	2.0	10.0	5.00	U	AL	Destroyed
0547	586276	1107988	5303.10	23.0	6.0	5304.80	22.00	2.0	10.0	10.00	U	Al	Active
0548	588903	1106435	5288.70	23.0	2.0	5290.40	14.60	2.0	16.0	5.00	O	Al	Active
0549	586184	1107902	5302.40	15.0	5.6	5304.50	17.00	2.0	11.5	5.00	U	AL	Destroyed
0616	587957	1106403	5288.50	7.6	ND	5290.90	10.00	3.0	2.5	2.50	O	AL	Destroyed
0619	588211	1106716	5288.90	8.0	ND	5291.10	10.00	3.0	7.5	2.50	O	AL	Destroyed
0630	588017	1107115	5289.80	7.5	ND	5292.50	10.00	3.0	7.5	2.50	O	AL	Destroyed
0632	587614	1106880	5289.00	8.0	ND	5291.70	10.00	3.0	7.5	2.50	O	AL	Destroyed
0637	587659	1107178	5288.50	5.5	ND	5291.30	8.00	3.0	5.5	2.50	O	AL	Destroyed
0656	588367	1106400	5287.90	9.0	ND	5288.90	10.00	3.0	7.5	2.50	O	AL	Destroyed
DM1	585970	1108417	5302.74	8.0	4.0	5305.95	11.24	2.0	2.7	5.00	U	Al	Active

Flow Codes

D	downgradient
O	on site
U	upgradient

Zones of Completion

Al	Alluvium
Js	Jurassic Salt Wash Formation

Table 4–2. Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
NAT01-1	11/18/98	5279.12
	12/18/98	5279.24
	01/27/99	5279.14
	02/24/99	5278.85
	03/22/99	5279.57
	05/13/99	5280.44
	06/07/99	5280.39
	09/02/99	5280.14
	09/20/99	5279.68
	11/10/99	5279.26
	02/28/00	5279.10
	06/13/00	5280.07
	11/29/00	5279.02
	02/27/01	5278.99
NAT01-2	11/18/98	5279.14
	12/18/98	5279.28
	01/27/99	5279.16
	02/24/99	5278.87
	03/22/99	5279.58
	05/13/99	5280.49
	06/07/99	5280.41
	09/02/99	5280.21
	09/20/99	5279.77
	11/10/99	5279.28
	02/28/00	5279.13
	06/13/00	5280.09
NAT02	11/17/98	5282.04
	12/18/98	5282.12
	01/27/99	5282.03
	02/24/99	5281.60
	03/22/99	5282.65
	05/13/99	5283.38
	06/07/99	5283.35
	09/02/99	5283.15
	09/20/99	5282.58
	11/10/99	5282.17
	02/28/00	5282.06
	06/13/00	5282.94
	11/29/00	5281.80
	02/29/01	5281.92
NAT03	11/18/98	5280.24
	12/18/98	5280.36
	01/27/99	5280.25
	02/24/99	5279.89
	03/22/99	5280.80
	05/13/99	5281.62
	06/07/99	5281.52
	09/02/99	5281.41
	09/20/99	5280.85
	11/09/99	5280.43
	02/28/00	5280.27
	06/13/00	5281.28
	11/29/00	5280.15
	02/27/01	5280.11
NAT04-1	11/17/98	5281.95
	12/18/98	5282.00
	01/27/99	5281.88
	02/24/99	5281.52
	03/22/99	5282.49
	05/13/99	5283.24
	06/07/99	5283.13
	09/02/99	5282.98
NAT04-1 (cont.)	09/20/99	5282.48
	11/09/99	5281.99
	02/28/00	5281.92
	06/13/00	5282.81
	11/28/00	5281.80
	02/28/01	5281.97
NAT04-2	11/17/98	5282.03
	12/18/98	5282.04
	01/27/99	5281.93
	02/24/99	5281.55
	03/22/99	5282.53
	05/13/99	5283.29
	06/07/99	5283.17
	09/02/99	5283.01
	09/20/99	5282.52
	11/09/99	5282.04
	02/28/00	5281.97
	06/13/00	5282.89
NAT04-3	11/17/98	5282.00
	12/18/98	5282.06
	01/27/99	5281.94
	02/24/99	5281.55
	03/22/99	5282.55
	05/13/99	5283.30
	06/07/99	5283.19
	09/02/99	5283.01
	09/20/99	5282.52
	11/09/99	5282.04
	02/28/00	5281.97
	06/13/00	5282.89
NAT05	11/18/98	5280.23
	12/18/98	5280.24
	01/27/99	5280.18
	02/24/99	5279.94
	03/22/99	5280.60
	05/13/99	5281.54
	06/07/99	5281.44
	09/02/99	5281.31
	09/20/99	5280.79
	11/09/99	5280.32
	02/28/00	5280.17
	06/13/00	5281.17
NAT06-1	11/17/98	5281.83
	12/18/98	5281.79
	01/27/99	5281.68
	02/24/99	5281.33
	03/22/99	5282.23
	05/13/99	5283.03
	06/07/99	5282.93
	09/02/99	5282.81
	09/20/99	5282.28
	11/09/99	5281.78
	02/28/00	5281.73
	06/13/00	5282.65
	11/29/00	5281.58
	02/28/01	5281.68
NAT06-2	11/17/98	5281.81
	12/18/98	5281.78
	01/27/99	5281.66
	02/24/99	5281.31
	03/22/99	5282.22
NAT06-2 (cont.)	05/13/99	5283.02
	06/07/99	5282.92
	09/02/99	5282.81
	09/20/99	5282.28
	11/09/99	5281.77
	02/28/00	5281.73
	06/13/00	5282.63
NAT06-3	11/17/98	DRY
	12/18/98	DRY
	01/27/99	DRY
	02/24/99	DRY
	03/22/99	DRY
	05/13/99	DRY
	06/07/99	5283.09
	09/02/99	5282.99
	09/20/99	5282.95
	11/09/99	DRY
	02/28/00	DRY
	06/11/00	DRY
NAT07-1	11/18/98	5280.25
	12/18/98	5280.43
	01/27/99	5280.31
	02/24/99	5279.91
	03/22/99	5280.89
	05/13/99	5281.63
	06/07/99	5281.51
	09/02/99	5281.43
	09/20/99	5280.88
	11/09/99	5280.48
	02/28/00	5280.32
	06/13/00	5281.25
NAT07-2	11/18/98	5280.22
	12/18/98	5280.40
	01/27/99	5280.27
	02/24/99	5279.89
	03/22/99	5280.86
	05/13/99	5281.60
	06/07/99	5281.50
	09/02/99	5281.41
	09/20/99	5280.86
	11/09/99	5280.43
	02/28/00	5280.29
	06/13/00	5281.22
NAT07-3	11/18/98	5280.23
	12/18/98	5280.43
	01/27/99	5280.30
	02/24/99	5279.92
	03/22/99	5280.89
	05/13/99	5281.63
	06/07/99	5281.49
	09/02/99	5281.43
	09/20/99	5280.87
	11/09/99	5280.44
	02/28/00	5280.30
	06/13/00	5281.23
NAT08	11/18/98	5280.27
	12/18/98	5280.38
	01/27/99	5280.26
	02/24/99	5279.89
	03/22/99	5280.74
	05/13/99	5281.57

Table 4–2 (continued). Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
NAT08 (cont.)	06/07/99	5281.47
	09/02/99	5281.42
	09/20/99	5280.83
	11/09/99	5280.43
	02/28/00	5280.30
	06/13/00	5281.14
	11/29/00	5280.17
	02/27/01	5280.14
NAT09	11/18/98	5280.27
	12/18/98	5280.37
	01/27/99	5280.28
	02/24/99	5279.91
	03/22/99	5280.82
	05/13/99	5281.62
	06/07/99	5281.51
	09/02/99	5281.42
	09/20/99	5280.89
	11/09/99	5280.42
	02/28/00	5280.28
	06/13/00	5281.27
NAT10	11/18/98	5280.62
	12/18/98	5280.72
	01/27/99	5280.64
	02/24/99	5280.33
	03/22/99	5281.14
	05/13/99	5281.99
	06/07/99	5281.91
	09/02/99	5281.73
	09/20/99	5281.23
	11/09/99	5280.73
	02/28/00	5280.64
	06/13/00	5281.59
	11/29/00	5280.56
	02/27/01	5280.49
NAT11	11/17/98	5283.98
	12/18/98	5284.15
	01/27/99	5284.02
	02/24/99	5283.75
	03/22/99	5284.60
	05/13/99	5285.52
	06/07/99	5285.43
	09/02/99	5285.26
	09/20/99	5284.67
	11/09/99	5284.11
	02/28/00	5284.12
	06/13/00	5285.04
	11/28/00	5284.05
	02/28/01	5284.13
NAT12-1	11/18/98	5279.14
	12/18/98	5279.15
	01/27/99	5279.09
	02/24/99	5278.89
	03/22/99	5279.31
	05/13/99	5280.33
	06/07/99	5280.32
	09/02/99	5280.07
	09/20/99	5279.68
	11/10/99	5279.20
	02/28/00	5279.01
	06/13/00	5279.98
NAT12-2	11/18/98	5279.41
NAT12-2 (cont.)	12/18/98	5279.35
	01/27/99	5279.38
	02/24/99	DRY
	03/22/99	5279.33
	05/13/99	5280.39
	06/07/99	5280.33
	09/02/99	5280.13
	09/20/99	5279.69
	11/10/99	DRY
	02/28/00	DRY
	06/13/00	5280.00
NAT13-1	09/02/99	5285.25
	09/20/99	5284.67
	11/09/99	5284.12
	02/28/00	5284.12
	06/13/00	5285.08
NAT13-2	09/02/99	5285.23
	09/20/99	5284.66
	11/09/99	5284.10
	02/28/00	5284.08
	06/13/00	5285.07
NAT13-3	09/02/99	5285.25
	09/20/99	5284.67
	11/09/99	5284.12
	02/28/00	5284.11
	06/13/00	5285.09
NAT14-1	09/02/99	5285.24
	09/20/99	5284.69
	11/09/99	5284.11
	02/28/00	5284.11
	06/13/00	5285.08
NAT14-2	09/02/99	5285.22
	09/20/99	5284.67
	11/09/99	5284.11
	02/28/00	5284.10
	06/13/00	5285.07
NAT14-3	09/02/99	5285.23
	09/20/99	5284.68
	11/09/99	5284.12
	02/28/00	5284.11
	06/13/00	5285.09
NAT15-1	09/02/99	5281.35
	09/20/99	5280.82
	11/09/99	5280.37
	02/28/00	5280.21
	06/13/00	5281.20
	11/29/00	5280.15
	02/27/01	5280.08
NAT15-2	09/02/99	5281.32
	09/20/99	5280.80
	11/09/99	5280.33
	02/28/00	5280.19
	06/13/00	5281.16
NAT15-3	09/02/99	5281.33
	09/20/99	5280.79
	11/09/99	5280.33
	02/28/00	5280.20
NAT15-3 (cont.)	06/13/00	5281.15
NAT16-1	09/02/99	5282.95
	09/20/99	5282.45
	11/09/99	5281.98
	02/28/00	5281.93
	06/13/00	5282.82
	11/28/00	5281.73
	02/28/01	5281.96
NAT16-2	09/02/99	5282.94
	09/20/99	5282.46
	11/09/99	5281.99
	02/28/00	5281.92
	06/13/00	5282.81
NAT16-3	09/02/99	5283.00
	09/20/99	5282.51
	11/09/99	5282.03
	02/28/00	5281.98
	06/13/00	5282.85
NAT17-1	09/02/99	5289.57
	09/20/99	5288.94
	11/09/99	5288.29
	02/28/00	5288.16
	06/13/00	5289.23
NAT17-2	09/02/99	5289.57
	09/20/99	5288.93
	11/09/99	5288.29
	02/28/00	5288.15
	06/13/00	5289.22
NAT17-3	09/02/99	5289.57
	09/20/99	5288.93
	11/09/99	5288.30
	02/28/00	5288.15
	06/13/00	5289.22
NAT18-1	09/02/99	5289.56
	09/20/99	5288.89
	11/09/99	5288.28
	02/28/00	5288.14
	06/13/00	5289.20
NAT18-2	09/02/99	5289.55
	09/20/99	5288.88
	11/09/99	5288.26
	02/28/00	5288.12
	06/13/00	5289.19
NAT18-3	09/02/99	5289.55
	09/20/99	5288.85
	11/09/99	5288.24
	02/28/00	5288.11
	06/13/00	5289.18
NAT19	09/02/99	5289.58
	09/20/99	5288.90
	11/09/99	5288.24
	02/28/00	5288.13
	06/13/00	5289.22
	11/28/00	5287.94
	02/28/01	5287.99

Table 4–2 (continued). Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
NAT20	09/02/99	5296.64
	09/20/99	5295.97
	11/08/99	5295.12
	02/28/00	5295.18
	06/13/00	5295.51
	11/28/00	5294.20
	02/28/01	5294.84
NAT21-1	09/02/99	5296.66
	09/20/99	5295.98
	11/08/99	5295.14
	02/28/00	5295.20
	06/13/00	5295.48
NAT21-2	09/02/99	5296.66
	09/20/99	5295.98
	11/08/99	5295.15
	02/28/00	5295.22
	06/13/00	5295.47
NAT21-3	09/02/99	5296.66
	09/20/99	5296.01
	11/08/99	DRY
	02/28/00	DRY
	06/09/00	DRY
NAT22-1	09/02/99	5296.63
	09/20/99	5295.97
	11/08/99	5295.11
	02/28/00	5295.19
	06/13/00	5295.45
NAT22-2	09/02/99	5296.63
	09/20/99	5295.97
	11/08/99	5295.12
	02/28/00	5295.19
	06/13/00	5295.46
NAT22-3	09/02/99	5296.63
	09/20/99	5295.95
	11/08/99	DRY
	02/28/00	DRY
	06/13/00	DRY
NAT23	09/02/99	5278.44
	09/20/99	5277.85
	11/09/99	5277.53
	02/28/00	5277.38
	06/13/00	5278.08
	11/30/00	5277.07
	02/27/01	5277.10
NAT24	09/02/99	5279.55
	09/20/99	5279.06
	11/09/99	5278.72
	02/28/00	5278.53
	06/13/00	5279.41
	11/30/00	5278.29
	03/01/01	5278.37
NAT25	09/02/99	5279.46
	09/20/99	5278.99
	11/10/99	5278.58
	02/28/00	5278.44
	06/13/00	5279.33
	11/30/00	5278.27
NAT25 (cont.)	03/01/01	5278.31
NAT26	09/02/99	5279.89
	09/20/99	5279.44
	11/10/99	5278.97
	02/28/00	5278.79
	06/13/00	5279.74
	11/29/00	5278.59
	03/01/01	5278.60
NAT27-1	09/02/99	5286.04
	09/20/99	5285.40
	11/09/99	5284.87
	02/28/00	5284.84
	06/13/00	5285.77
	11/28/00	5284.70
	02/28/01	5284.80
NAT27-2	09/02/99	5286.07
	09/20/99	5285.43
	11/09/99	5284.92
	02/28/00	5284.87
	06/13/00	5285.78
NAT27-3	09/02/99	DRY
	09/20/99	DRY
	11/09/99	DRY
	02/28/00	DRY
	06/10/00	DRY
NAT28-1	09/02/99	5286.06
	09/20/99	5285.44
	11/09/99	5284.92
	02/28/00	5284.87
	06/13/00	5285.80
NAT28-2	09/02/99	5286.06
	09/20/99	5285.43
	11/09/99	5284.91
	02/28/00	5284.87
	06/13/00	5285.80
NAT28-3	09/02/99	DRY
	09/20/99	DRY
	11/09/99	DRY
	02/28/00	DRY
	06/10/00	DRY
NAT29	09/02/99	5285.91
	09/20/99	5285.36
	11/09/99	5284.87
	02/28/00	5285.00
	06/13/00	5285.75
	11/28/00	5284.94
	02/28/01	5284.75
NAT30-1	09/02/99	5292.88
	09/20/99	5292.28
	11/09/99	5291.66
	02/28/00	5291.64
	06/13/00	5292.39
	11/28/00	5291.02
	02/28/01	5291.28
NAT30-2	09/02/99	5292.93
	09/20/99	5292.35
NAT30-2 (cont.)	11/09/99	5291.71
	02/28/00	5291.70
	06/13/00	5292.44
NAT30-3	09/02/99	DRY
	09/20/99	DRY
	11/09/99	DRY
	02/28/00	DRY
	06/09/00	DRY
MAU01	11/19/98	5274.52
	12/18/98	5274.61
	01/27/99	5274.60
	02/24/99	5274.51
	03/22/99	5274.79
	05/13/99	5275.78
	06/07/99	5275.51
	09/02/99	5275.31
	09/20/99	5274.72
	11/09/99	5274.63
	02/28/00	5274.59
	06/13/00	5274.73
MAU02-1	11/19/98	5274.43
	12/18/98	5274.50
	01/27/99	5274.49
	02/24/99	5274.38
	03/22/99	5274.72
	05/13/99	5275.75
	06/07/99	5275.45
	09/02/99	5275.26
	09/20/99	5274.66
	11/09/99	5274.55
	02/28/00	5274.50
	06/13/00	5274.61
MAU02-2	11/19/98	5274.48
	12/18/98	5274.57
	01/27/99	5274.56
	02/24/99	5274.40
	03/22/99	5274.77
	05/13/99	5275.78
	06/07/99	5275.47
	09/02/99	5275.30
	09/20/99	5274.69
	11/09/99	5274.58
	02/28/00	5274.52
	06/13/00	5274.71
MAU02-3	11/19/98	5274.47
	12/18/98	5274.57
	01/27/99	5274.56
	02/24/99	5274.43
	03/22/99	5274.78
	05/13/99	5275.78
	06/07/99	5275.47
	09/02/99	5275.30
	09/20/99	5274.70
	11/09/99	5274.58
	02/28/00	5274.52
	06/13/00	5274.71
MAU03	11/19/98	5271.71
	12/18/98	5271.81
	01/27/99	5271.80
	02/24/99	5271.60

Table 4–2 (continued). Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
MAU03 (cont.)	03/22/99	5272.05
	05/13/99	5272.56
	06/07/99	5272.20
	09/02/99	5272.34
	09/20/99	5271.80
	11/09/99	5271.84
	02/28/00	5271.82
	06/13/00	5271.50
	11/30/00	5271.75
	03/01/01	5271.85
MAU04	11/19/98	5269.58
	12/18/98	5269.63
	01/27/99	5269.67
	02/24/99	5269.56
	03/22/99	5269.75
	05/13/99	5269.97
	06/07/99	5269.75
	09/02/99	5269.91
	09/20/99	5269.66
	11/09/99	5269.75
	03/01/01	5269.75
	02/28/00	5269.77
	06/13/00	5269.35
	11/30/00	5269.55
MAU05	11/19/98	5274.37
	12/18/98	5274.46
	01/27/99	5274.46
	02/24/99	5274.33
	03/22/99	5274.65
	05/13/99	5275.63
	06/07/99	5275.34
	09/02/99	5275.16
	09/20/99	5274.57
	11/09/99	5274.47
	02/28/00	5274.47
	06/13/00	5274.56
	11/30/00	5274.18
	03/01/01	5274.38
MAU06	09/02/99	5274.22
	09/20/99	5273.57
	11/09/99	5273.61
	02/28/00	5273.60
	06/13/00	5273.27
	11/30/00	5273.36
	03/01/01	5273.56
MAU07	09/02/99	5269.61
	09/20/99	5269.22
	11/09/99	5269.38
	02/28/00	5269.37
	06/13/00	5268.82
	12/01/00	5269.08
	03/01/01	5269.47
MAU08	09/02/99	5276.28
	09/20/99	5275.76
	11/09/99	5275.62
	02/28/00	5275.56
	06/13/00	5275.89
	11/30/00	5275.34
	03/01/01	5275.55

0547	06/16/86	5295.51

Well ID	Date	Water Table Elevation (ft above sea level)
0547 (cont.)	02/24/99	5295.06
	03/22/99	5295.15
	05/13/99	5296.14
	06/07/99	5296.22
	09/02/99	5296.63
	09/20/99	5295.93
	11/09/99	5295.05
	02/28/00	5295.12
	06/13/00	5295.41
	11/28/00	5294.25
	02/25/01	5294.84
0548	06/17/86	5281.95
	02/24/99	5278.41
	03/22/99	5279.19
	05/13/99	5279.85
	06/07/99	5281.70
	09/02/99	5279.62
	09/20/99	5279.15
	11/10/99	5278.72
	02/28/00	5278.58
	06/13/00	5279.50
	11/29/00	5278.48
	02/27/01	5278.35
DM1	09/02/99	5298.32
	09/20/99	5297.77
	11/10/99	5297.67
	02/28/00	5297.83
	06/13/00	5297.29
	12/01/00	5297.48
	03/02/01	5297.90

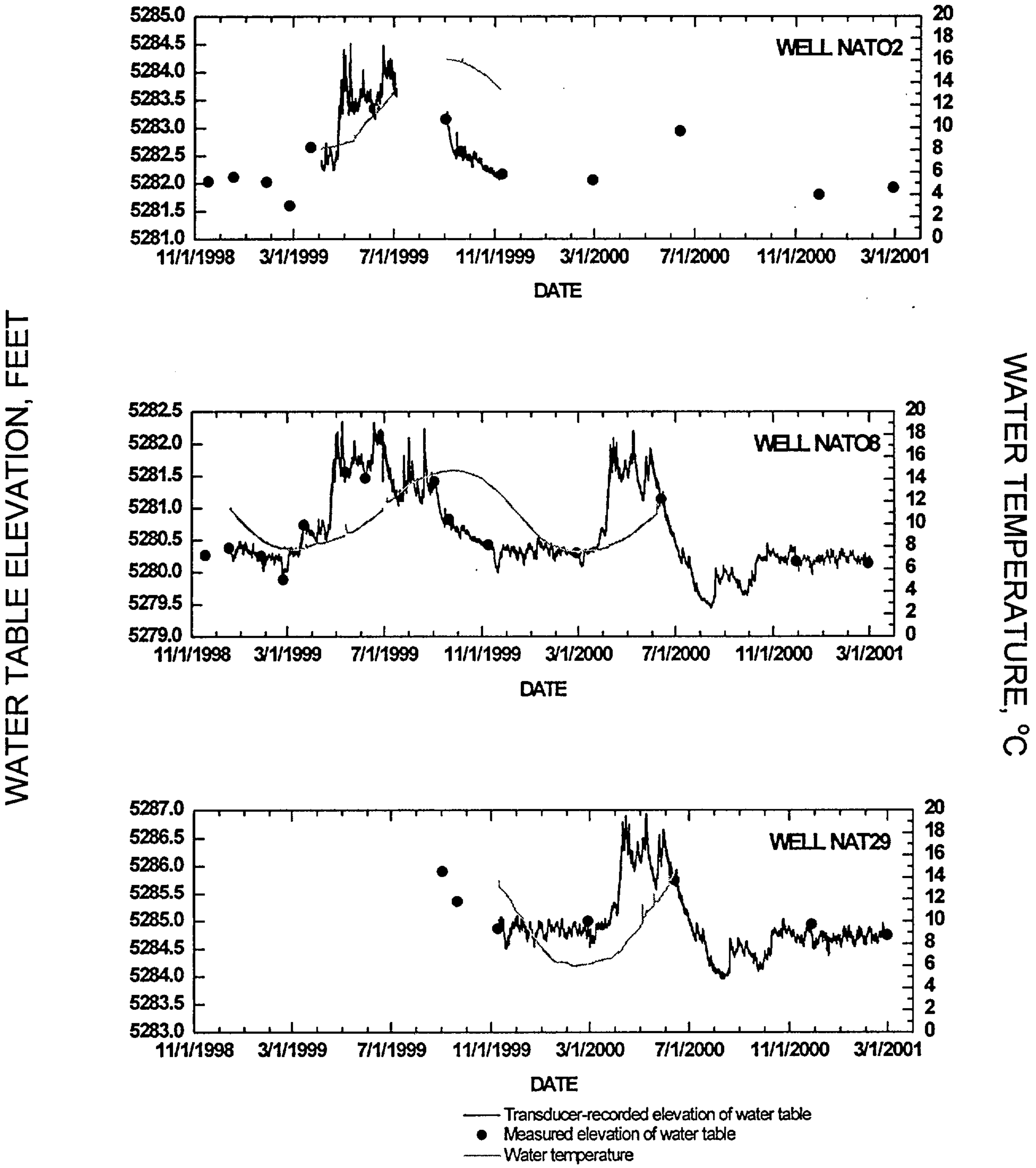


Figure 4–4. Water Level and Water Temperature Recorded in Wells NAT02, NAT08, and NAT29 at the Naturita Site

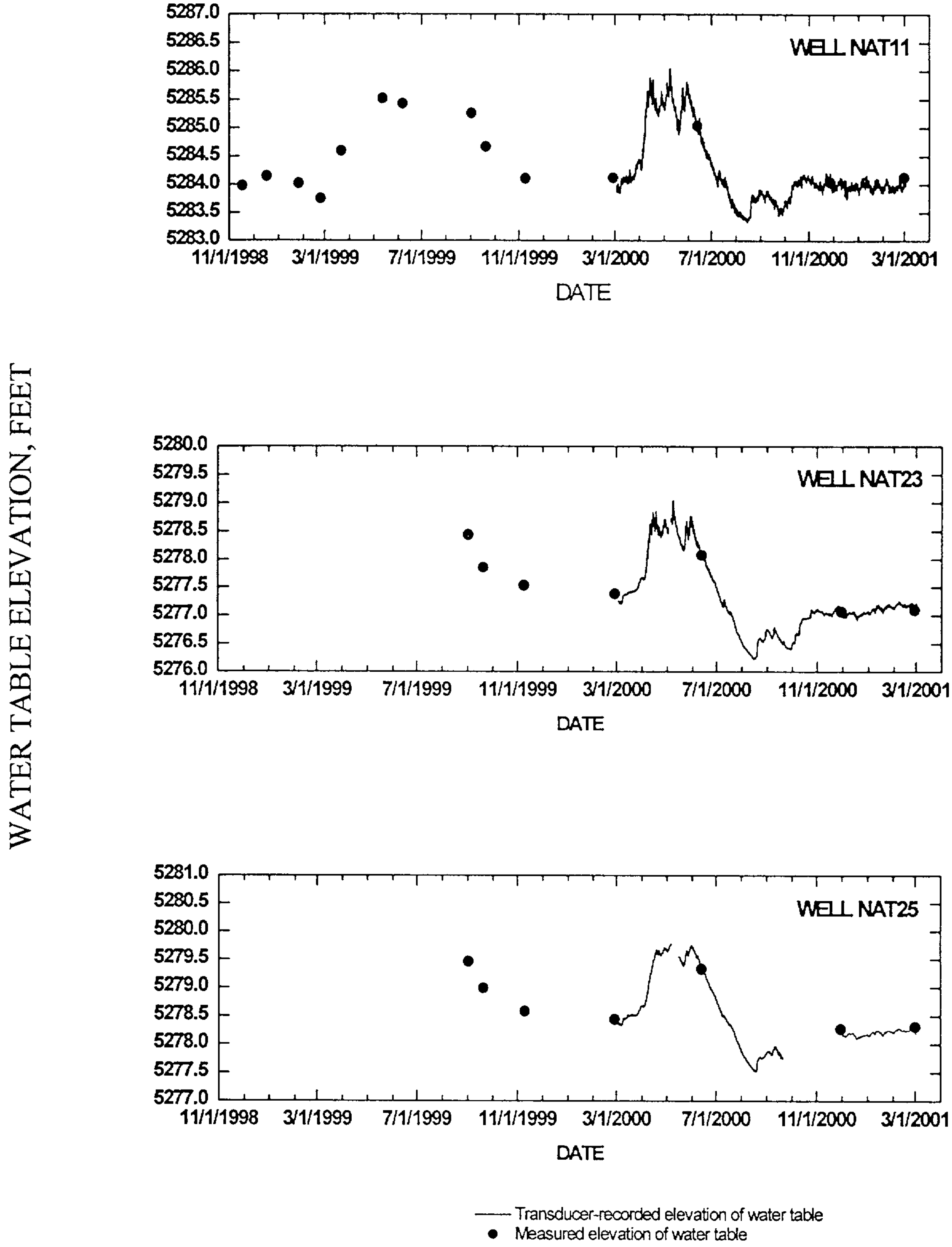


Figure 4–5. Water Table Elevation for Wells NAT11, NAT23, and NAT25

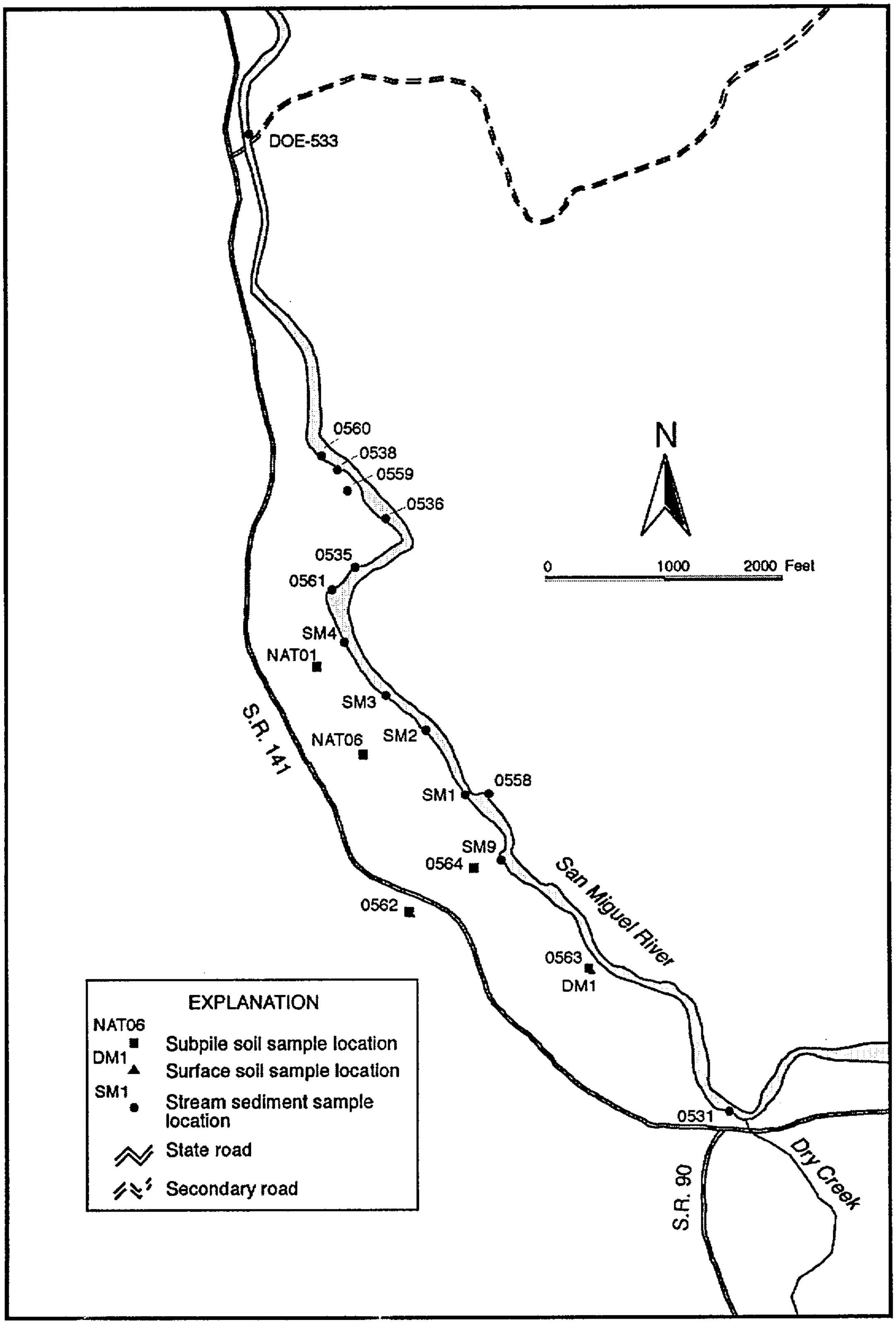


Figure 4–6. Soil and Sediment Sampling Locations

DOE collected additional soil samples in March 2001 with a backhoe. Samples from locations 0564 and 0563 were collected at the water table, which was at a depth of 6 and 5 ft below land surface, respectively. At location 0562, which is southwest of the site and above the alluvial aquifer, the sample was collected from below the fill material at a depth of 2 ft below land surface. This location is a former ore storage area that was remediated under the surface program. Samples were collected from the backhoe bucket and placed in a sealed plastic bag. During excavation, the clean fill that had been emplaced during reclamation was placed in one pile and the native subsurface material in another. When the hole was refilled, the native material was placed in first and was covered by the clean fill.

Surface composite and stream bottom sediment samples were collected during December 2000 and January 2001. Surface and stream sediment samples were collected with a clean shovel and placed in a sealed plastic bag. Samples were composited from a 10-ft radius at each sample location. Approximately 2.5 pounds of sample were collected at each site.

4.4 Lithologic Logging

Lithologic descriptions of the alluvial material were recorded from drill cuttings during installation of monitoring wells NAT13 through NAT30, DM1, MAU07, and MAU08 in June 1999. No attempt was made at split barrel sampling due to the difficulty in retrieving unconsolidated silt, sand, and gravel. No attempt was made at lithologically logging the underlying Salt wash Member of the Morrison Formation. Appendix B presents the lithologic well logs recorded by the site geologist.

4.5 Distribution Coefficient (K_d) Analysis

The K_d is a bulk parameter that has been used with some success to describe the retardation of contaminant movement in an aquifer system. Laboratory measurements to estimate the K_d for selected analytes were performed on alluvial material to support computer-modeling efforts in characterizing subsurface contaminant transport at the Naturita site. The analysis presented here was performed by the GJO Environmental Sciences Laboratory according to standard procedures used at UMTRA Ground Water Project sites (MACTEC 1999). Analyses using a somewhat different methodology were also performed by the USGS; these are presented in Appendix E.

4.5.1 Method of Solution

Laboratory analyses were performed according to procedure MAC 3017 (MACTEC 1999), which is slightly modified from American Society for Testing and Materials (ASTM) procedure D 4646–87 (ASTM 1993), for two site-related contaminants of potential concern (COPCs): uranium and vanadium. This procedure is a 24-hour test and obtains a parameter that is an estimate of the K_d—the distribution ratio (R_d). K_d and R_d are defined identically, though K_ds are considered to be equilibrium values and R_ds may or may not represent equilibrium. R_d is one of the most commonly used estimates for the K_d.

The procedure involves placing a sample representative of a location (e.g., soil, sediments, cuttings, core) into a solution representative of contaminated ground water with which the material is likely to come in contact. The ground water solution is agitated for 24 hours and then centrifuged. The supernatant solution is analyzed and compared to the contaminant concentrations of the original solution. The difference between the two is assumed to be adsorbed to the sample. The linear adsorption isotherm distribution coefficient is generally defined as

$$C_{soil} = K_d \times C_{water}, \text{ which can be rearranged to } K_d = C_{soil}/C_{water},$$

or the ratio of the concentration of the contaminant in soil (or other material of interest) to the concentration of the contaminant in water at equilibrium. Therefore, the higher the K_d, the greater the retardation of contaminant movement in ground water.

The procedure requires analysis of only the solutions (and no actual soil samples) used in the experiments. Site samples collected from background areas or uncontaminated site samples are generally used, and all contaminant loss in the final solution is attributed to sample adsorption.

4.5.1.1 Sample Selection

A sample of background alluvial material (>5 kg) was collected above the water table approximately 30 ft west of background well DM1 (Figure 4–6) on August 22, 2001. The sample was considered uncontaminated because concentrations of dissolved uranium in water samples from well DM1 (and decommissioned DOE wells nearby) were always near the background uranium concentrations in the San Miguel River. The background sample of alluvium was screened in the field to remove cobbles larger than about 65 mm, and it was estimated visually that about 50 percent of the material scooped by the backhoe did not pass the 65-mm screen.

4.5.1.2 Sample Preparation and Processing

The sample was air dried at room temperature. The greater than 6.6 mm fraction was removed based on visual examination. The remainder of the sample was sieved to separate the <2 mm fraction. Of the sample submitted for laboratory analysis, approximately 51 percent of the grain size was <2 mm, 15 percent was between 6.6 mm and 2 mm, and the remaining 34 percent was >6.6 mm.

A 2.5 L sample of San Miguel River water was collected for use in the K_d determinations. Because the San Miguel River is the primary source of recharge for the alluvial aquifer, it is assumed that river water upgradient of the site is representative of uncontaminated alluvial aquifer water. The water sample was filtered through a 0.45 µm filter and refrigerated until ready for use. An aliquot of the San Miguel River sample was spiked with vanadium and uranium to produce a 1 mg/L concentration of each. Three spiked water samples were retained as control samples—one sample was simply refrigerated before analysis; the other two were processed in the same manner as the samples for K_d determinations but without inclusion of soil.

To prepare samples for K_d analysis, 8 samples of soil ranging from 0.5 g to 30 g were each placed in 125-mL Nalgene bottles; 100 mL of spiked water was added to each sample. These samples, along with the two spiked water samples without soil, were placed on a rotating stir bar (8 rpm) for 24 hours. Samples were then removed from the stir bar, centrifuged, filtered through a 0.45 µm filter, and acidified before submission to the Analytical Chemistry Laboratory for uranium and vanadium analysis. Unprocessed water samples were also analyzed as control samples.

4.5.1.3 Sample Results

Analytical results are presented in Tables 4–3 and 4–4. Table 4–3 contains results of the control sample analysis. Results indicate that only minor amounts of uranium and vanadium occur in San Miguel River water. Little difference exists between processed and unprocessed spiked samples; concentrations of uranium and vanadium in sample NAT-DM1-B1 were determined to be suitable for use as initial concentrations for purposes of performing K_d calculations.

Table 4–3. Laboratory Analytical Results for Control Water Samples

Sample ID	Sample Description	Solution Volume (mL)	Target Concentration (mg/L)		Analyzed Concentration (mg/L)	
			U	V	U	V
NAT-DM1-R	Unprocessed San Miguel River (SMR) water—no spikes	100	na	na	0.0024	0.0061
NAT-DM1-P	Unprocessed SMR with spikes	100	1.0	1.0	0.913	0.971
NAT-DM1-B1*	Processed spiked SMR water	100	na	na	0.91	0.98
NAT-BM1-B2	Processed spiked SMR water	100	na	na	0.925	0.982

*Used for initial concentrations
na = not applicable
Note: initial pH of spiked SMR sample was 6.94; alkalinity was 110 mg/L $CaCO_3$

Table 4–4 presents the analyses of final solutions contacted with differing masses of site soils. Based on the volume and concentration of water samples used, the mass of sorbed uranium and vanadium was calculated for each sample.

Table 4–4. Analytical Results for Soil-Contacted Solutions

Sample ID	Solution Volume (mL)	Sample Mass (g)	Final Solution Concentration (mg/L)		Mass Sorbed (mg)	
			U	V	U	V
NAT-DM1-0.5	100	0.5	0.89	0.9	0.002	0.008
NAT-DM1-1.0	100	1.0	0.885	0.781	0.0025	0.0199
NAT-DM1-2.5	100	2.5	0.861	0.568	0.0049	0.0412
NAT-DM1-5	100	5.0	0.808	0.327	0.0102	0.0653
NAT-DM1-10	100	10.0	0.746	0.149	0.0164	0.0831
NAT-DM1-20	100	20.0	0.66	0.0627	0.025	0.09173
NAT-DM1-25	100	25.0	0.643	0.0496	0.0267	0.09304
NAT-DM1-30	100	30.0	0.616	0.038	0.0294	0.0942

4.5.1.4 R_d Calculation

R_ds are calculated using the analytical data summarized in Table 4–4 and the equation:

$$R_d = \frac{(A - B)V}{(M_s)B}$$

where

A = total initial concentration (mg/L) of the COPCs in the test solution,
B = final concentration of the COPCs in the solution after 24 hours in contact with the soil sample (mg/L),
V = volume of solution (mL),
M_s = mass of soil sample (grams), and
R_d = distribution ratio (milliliters per gram [mL/g]).

Results of the calculations are presented in Table 4–5.

Table 4–5. Results of R_d Calculations

Sample ID	Sample mass (g)	R_d—Uranium mL/g	R_d—Vanadium mL/g
NAT-DM1-0.5	0.5	4.49	17.78
NAT-DM1-1.0	1.0	2.82	25.48
NAT-DM1-2.5	2.5	2.28	29.01
NAT-DM1-5	5.0	2.52	39.94
NAT-DM1-10	10.0	2.20	55.77
NAT-DM1-20	20.0	1.89	73.15
NAT-DM1-25	25.0	1.66	75.03
NAT-DM1-30	30.0	1.59	82.63

Results of the R_d calculations show considerable variation, particularly for vanadium. The variation appears to be, in part, correlated with mass of soil used in the procedure. Higher R_d values were obtained with smaller soil masses for uranium; the opposite relationship is noted for vanadium. Results are generally consistent with those obtained at other UMTRA Ground Water Project sites. Uranium typically has a higher mobility than vanadium and is found over a greater areal extent; vanadium plumes are normally more confined. At the Naturita site, the uranium plume extends off site for a considerable distance downgradient; elevated concentration of vanadium are restricted to the site itself (see Section 5.3.3.2 for further discussion).

Because the procedure for estimating K_d values uses only the <2 mm fraction, it is likely that the K_ds overestimate adsorptive properties of the entire aquifer system (Kaplan and others 2000; EPA 1999). A common way of modifying the values to account for this is to assume that the >2 mm fraction has a K_d of 0 and to adjust the values proportionally. For the Naturita site, it was noted that approximately 50 percent of the alluvial material collected for analysis was greater than 2 mm in size; therefore, a more realistic estimate of K_ds for the site may be considerably less than the calculated R_d values. The major quantitative use for the K_d estimates is in the ground water fate and transport modeling. To account for uncertainty in K_d estimates, a stochastic model was used that incorporates a range of K_d values.

4.6 Soil and Sediment Analysis

All radioactive tailings were removed from the Naturita site during 1977 to 1979. Contaminated soils and surface materials were removed from the site in 1997, and the excavated areas were backfilled with clean, clay-sized material. At that point, no radioactive materials were left. However, it is possible that contaminants have leached into the soils below the depth of remediation. These soils could contaminate infiltrating ground water and prolong the cleanup effort.

4.6.1 Subpile Soil Sample Selection

Samples were collected from two boreholes drilled in October 1998 and from three DOE excavations in March 2001. Section 4.2 describes the sample collection methods. Uranium-contaminated borehole samples from wells NAT01 and NAT06 were collected in the area of the former tailings pile. Location 0562 is in an old ore storage location; 0563 represents an upgradient background site; and 0564 is in the former mill yard area. Figure 4–6 shows these sampling locations.

4.6.2 Surface Soil and Sediment Sample Selection

Surface soil samples were collected from two locations to verify complete removal of contaminated material from the site. The samples were collected from a former ore storage area at location 0562 and from an off-site location within a 10-ft radius of well DM1 to represent background (location 0563). Because the alluvial aquifer at the site discharges to the San Miguel River, it is important to characterize any potential for contamination to the river. Therefore, stream sediment samples were collected near the riverbank at locations 0531, SM9, 0558, SM1, SM2, SM3, SM4, 0561, 0535, 0536, 0560, and 0533. Sediment samples were also collected from a ground water seep in an abandoned river channel near the San Miguel River at sites 0538 and 0559 (Figure 4–6).

4.6.3 Sediment and Soil Sample Preparation and Extraction

Chemical extractions were used to evaluate the potential leachable amounts of contaminants present. Each sample was extracted using a 5 percent nitric acid solution. The acid solution is used to remove most amorphous oxides that most likely contain adsorbed contaminants. The solution will not remove contaminants locked in recalcitrant minerals such as apatites or other heavy mineral grains. The acid treatment also dissolves carbonate minerals and releases any adsorbed cations.

The following extraction procedure was used at the USGS lab in Menlo Park:

1. Air dry the sample (no oven heat).
2. If desired, sieve the sample. Samples are usually sieved to less than 2 mm because sieved samples are easier to work with; also, because the contamination is more concentrated in the finer fractions, the sieved samples provide a more sensitive indicator of the contamination.
3. Place 2 g ± 10 mg of soil in a centrifuge tube (or divide evenly between two 50-mL centrifuge tubes; use a riffle splitter so that both splits are equivalent).

4. Place 100 mL (or 50 mL in each of the 50-mL tubes) of the test solution (e.g., 5 percent nitric acid) in the centrifuge tube.
5. Agitate end over end for 4 hours ± 20 minutes.
6. Remove the tubes from the shaker and centrifuge for sufficient time to settle most of the 2 µm particles (about 30 minutes at 3,000 rpm).
7. Decant into a 200-mL volumetric flask.
8. Add a second 100-mL portion of test solution to the residue.
9. Agitate end over end for 30 ± 5 minutes.
10. Remove the tubes from the shaker and centrifuge for sufficient time to settle most of the 2 µm particles (about 30 minutes at 3,000 rpm).
11. Decant into the same 200-mL volumetric flask (step 7).
12. Fill to volume with test solution.
13. Filter the 200-mL decantate through a 0.45 µm filter.
14. Measure pH and oxidation-reduction potential.
15. Preserve as needed and submit for chemical analysis.
16. Calculate the soil concentration in milligrams per kilogram (mg/kg) from the concentration in the decantate:

$$\frac{200\text{ mL solution}}{2\text{ g soil}} \times \frac{\mu\text{g decantate}}{\text{L}} \times \frac{\text{L}}{1{,}000\text{ mL}} \times \frac{\text{mg}}{1{,}000\ \mu\text{g}} \times \frac{1{,}000\text{ g}}{\text{kg}} = \text{mg}/\text{kg}$$

4.6.4 Stream and Seep Sediment Concentration Results

Table 4–6 shows a summary of contaminant concentrations from stream sediment and ground water seep sediment samples collected at the Naturita site in November and December 2000. Figure 4–7 through Figure 4–12 show concentrations of arsenic, cadmium, molybdenum, selenium, uranium, and vanadium, respectively, in these sediments. Appendix C shows a complete listing of the constituents measured in the samples and in one blank extraction.

4.6.4.1 Arsenic in Sediments

Concentrations of arsenic shown in Figure 4–7 are at or near background concentrations measured at location 0531. Concentrations from all samples are below the common range of soil concentrations cited by Rose, Hawkes, and Webb (1979). This suggests that there has been no transport of arsenic surficially or by ground water to the stream sediments.

4.6.4.2 Cadmium in Sediments

Figure 4–8 shows that concentrations of cadmium in the stream sediment samples were generally elevated over the background level measured at location 0531. Concentrations at the sample locations were also higher than the range commonly found in soils (Rose, Hawkes, and Webb 1979). Sediments and samples collected from the ground water seep area have concentrations that are in the normal range and near background for stream sediment. Surface soil collected at background location 0563 had the highest concentration of cadmium measured, and the concentration in the subpile soil was very close to the detection limit. No cadmium was detected at any other subpile soil sampling location (Section 4.5.5.2). The elevated cadmium concentrations in the stream sediment samples may be due to windborne transport or surface runoff from the former tailings pile.

Table 4–6. Mass of Contaminant Extractable by 5 percent Nitric Acid Solution per Mass of Sediment

Sample Site	Sample type	Location	As (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mo (mg/kg)	Mn (mg/kg)	Se (mg/kg)	U (mg/kg)	V (mg/kg)
		Upgradient Samples								
0531	stream sediment	San Miguel River	1.83	0.56	2,307	<0.40	367	0.18	0.53	6.56
		On-Site Samples								
0538	stream sediment	ground water seep	2.60	0.62	1,921	1.51	721	0.14	8.90	9.54
0559	stream sediment	ground water seep	2.83	0.53	1,532	2.19	278	0.14	12.50	7.94
0535	stream sediment	San Miguel River	1.80	0.62	2,104	0.78	413	0.19	0.67	5.96
0536	stream sediment	San Miguel River	1.91	0.65	3,004	0.74	389	0.24	0.80	5.20
0558	stream sediment	San Miguel River	1.87	0.47	2,699	0.76	278	0.23	1.27	6.11
0560	stream sediment	San Miguel River (main channel)	1.94	0.60	3,519	0.62	479	0.26	2.27	5.97
0561	stream sediment	San Miguel River	2.01	0.60	2,514	0.70	428	0.21	1.45	7.06
SM1	stream sediment	San Miguel River	1.27	0.75	2,541	0.47	291	0.26	0.76	1.22
SM2	stream sediment	San Miguel River	1.66	0.88	3,256	0.55	341	0.27	1.78	1.70
SM3	stream sediment	San Miguel River	2.15	1.13	2,608	0.50	372	0.23	0.77	1.74
SM4	stream sediment	San Miguel River	1.60	0.85	2,899	0.45	357	0.25	0.80	0.77
SM9	stream sediment	San Miguel River	1.98	1.07	3,186	0.60	427	0.26	0.82	0.44
		Downgradient Samples								
0533	stream sediment	San Miguel River	2.14	0.70	3,148	0.54	498	0.24	1.00	5.26

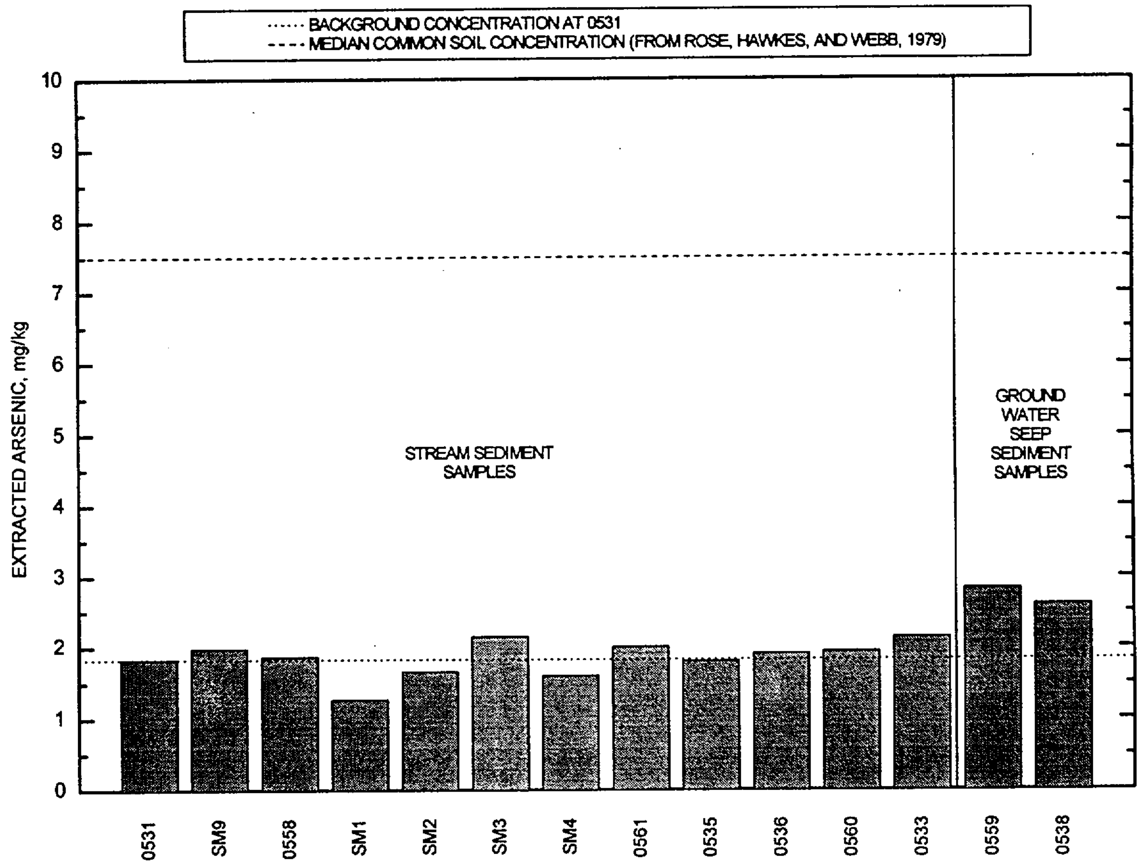


Figure 4–7. Arsenic Concentrations in Sediment

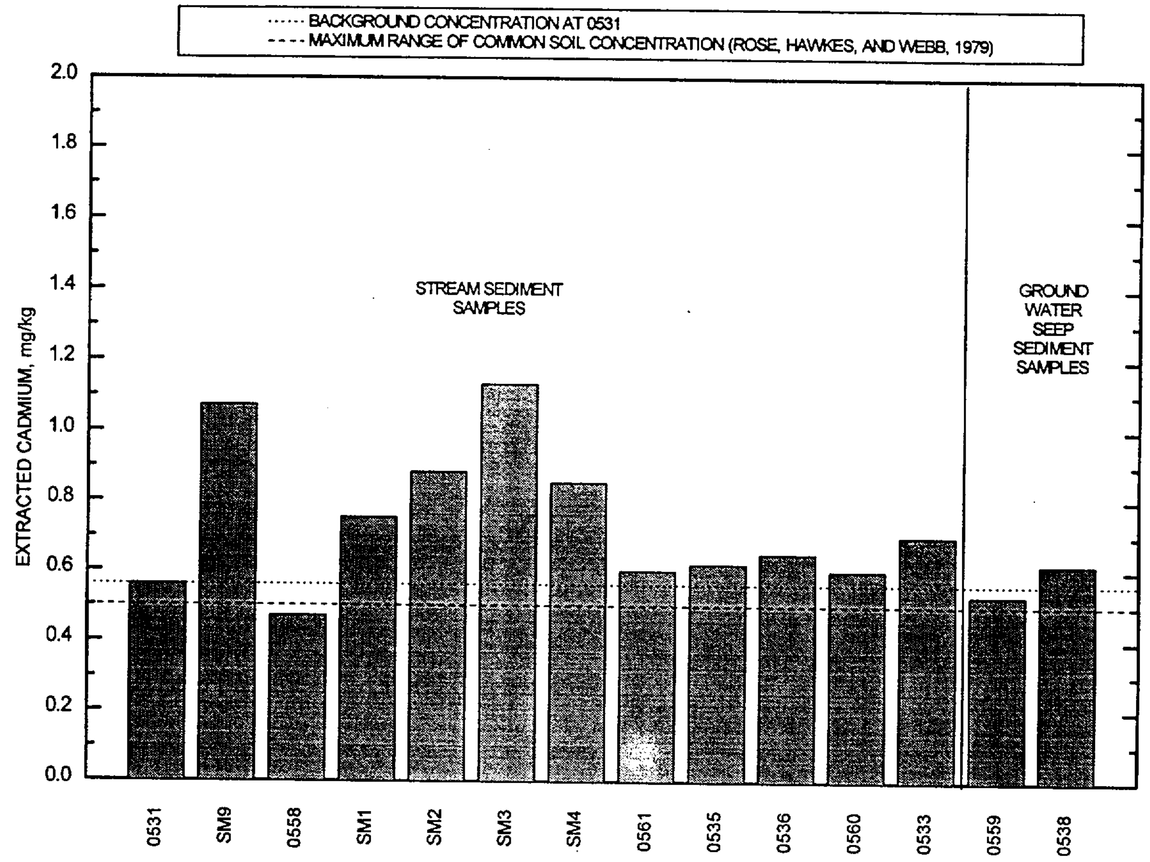


Figure 4–8. Cadmium Concentrations in Sediment

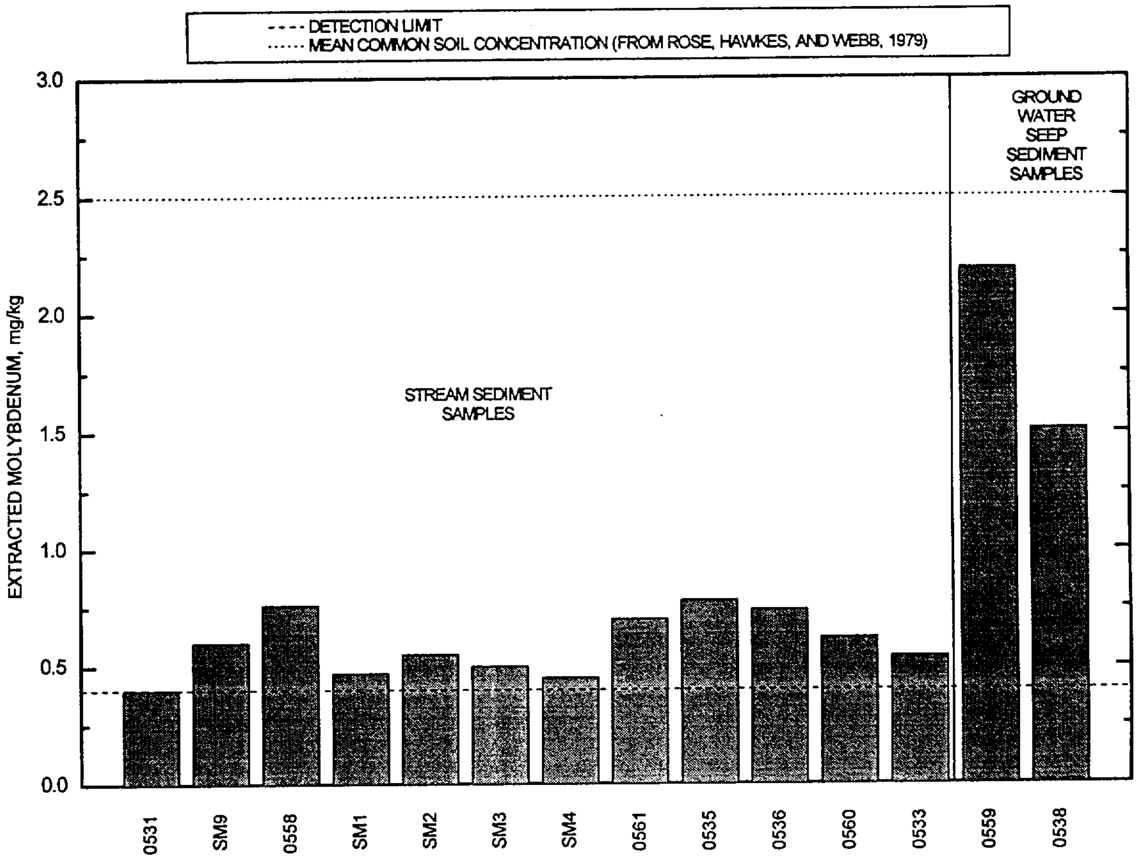


Figure 4–9. Molybdenum Concentrations in Sediment

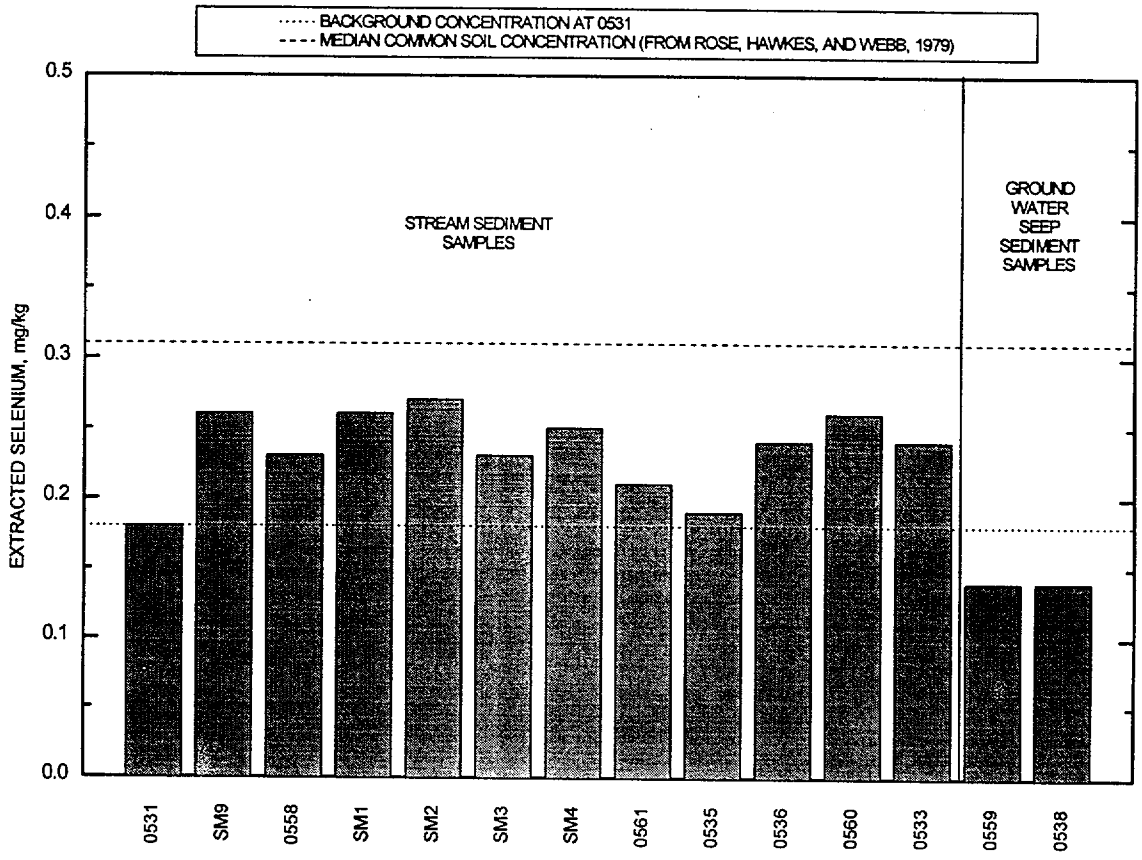


Figure 4–10. Selenium Concentrations in Sediment

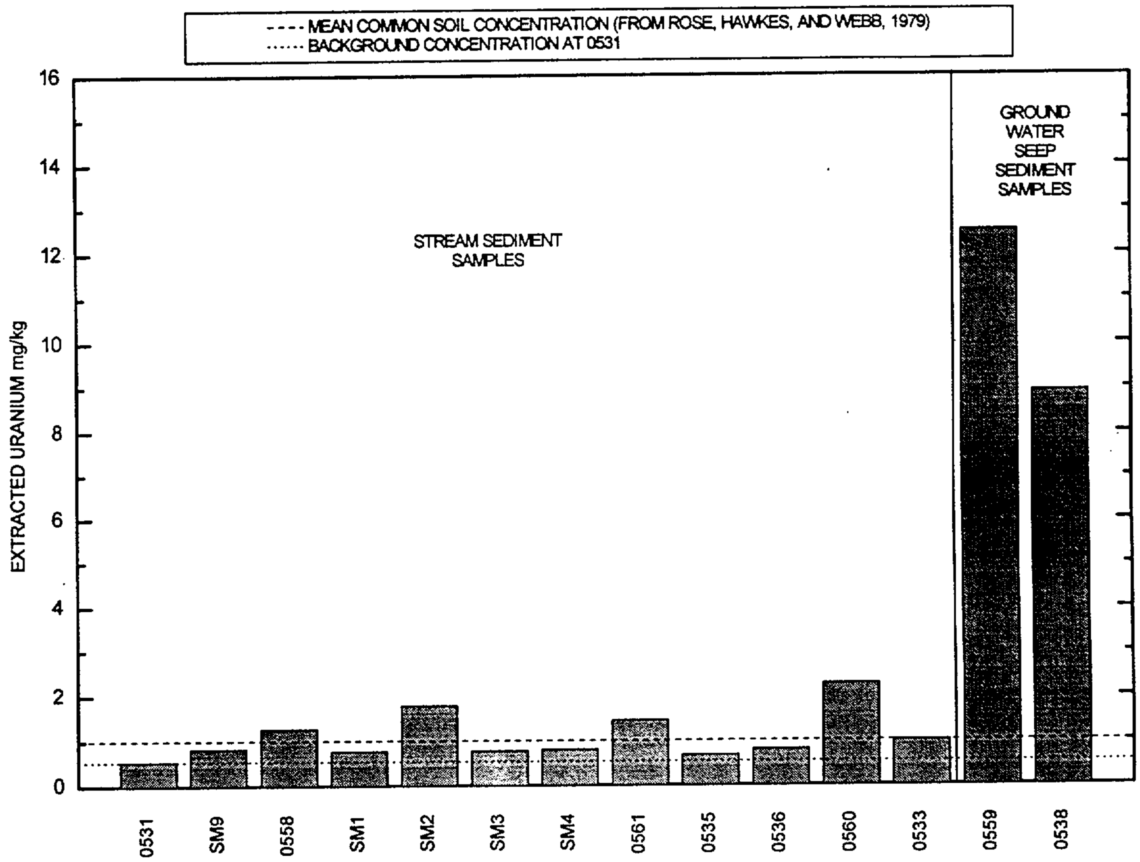


Figure 4–11. Uranium Concentrations in Sediment

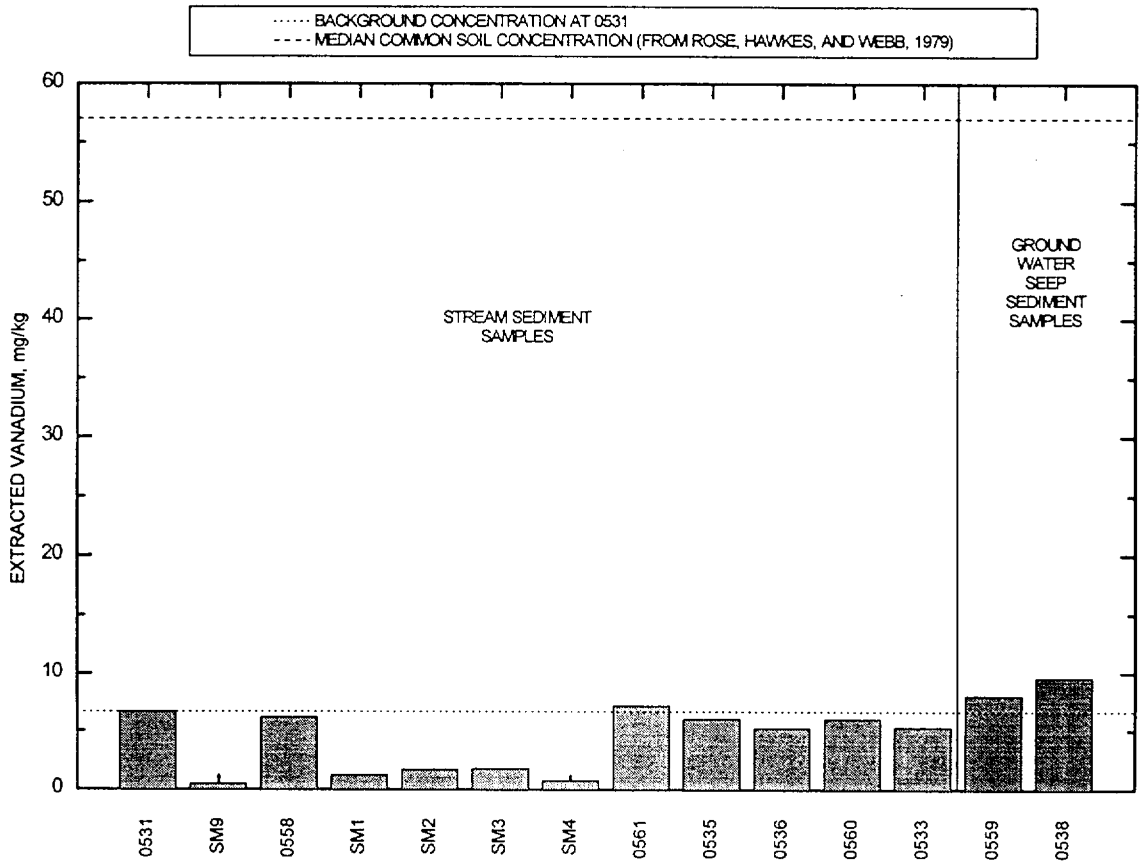


Figure 4–12. Vanadium Concentrations in Sediment

4.6.4.3 Molybdenum in Sediments

Concentrations of molybdenum (Figure 4–9) were all above the background value measured at location 0531 (concentration was below detection limit at 0531). However, concentrations were all lower than those in typical soils (Rose, Hawkes, and Webb 1979). The highest concentrations were in samples from the ground water seep sediments. This suggests a small amount of molybdenum may be transported by the alluvial aquifer, but very little is being retained by the sediments, making them an insignificant source of contamination.

4.6.4.4 Selenium in Sediments

As shown in Figure 4–10, selenium concentrations in all stream sediment samples were slightly elevated above the background concentration measured at location 0531. Concentrations in sediment from the ground water seep area were below background concentrations, and concentrations at all locations were lower than those in typical soils (Rose, Hawkes, and Webb 1979). This suggests that no site-related selenium is in the stream sediments.

4.6.4.5 Uranium in Sediments

Uranium concentrations in all samples of stream sediment and ground water seep sediment were elevated over those measured at background location 0531 (Figure 4–11). Samples from locations 0558, SM2, 0561, and 0560 all had uranium concentrations greater than typical soil concentrations (Rose, Hawkes, and Webb 1979). The highest concentrations were in the ground water seep sediments. Concentrations in the seep sediment samples were approximately 17 to 24 times greater than those measured in the upgradient stream sediment background sample. Because this area is in a low-lying area of the river floodplain, the potential exists for these contaminated sediments to be transported downstream during flooding.

4.6.4.6 Vanadium in Sediments

Concentrations of vanadium shown in Figure 4–12 are all near or below the background value measured at location 0531. Concentrations are also much lower than those in typical soils (Rose, Hawkes, and Webb 1979). This suggests that there is no site-related contamination from vanadium in stream sediments or surface soils.

4.6.5 Surface and Subpile Soil Concentration Results

Table 4–7 shows a summary of contaminant concentrations from surface and subpile soil samples collected at the Naturita site. Figure 4–13 through Figure 4–16 show concentrations of arsenic, selenium, uranium, and vanadium, respectively, in these soils. Appendix C shows a complete listing of the constituents measured in the samples and in one blank extraction.

4.6.5.1 Arsenic in Surface and Subpile Soils

With the exception of samples NAT01 and NAT06, which were collected in the area of the former tailings pile, all arsenic concentrations in soil were below the background value measured at location 0563. No surficial arsenic contamination appears to be present at background location 0563 or in the former ore storage area at location 0562. Arsenic concentration in a sample from location 0564, which is in the former mill yard area, was lower than the background

Table 4–7. Mass of Contamination Extraction by 5 Percent Nitric Acid Solution per Mass of Soil

Sample Site	Sample type	Location	As (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Se (mg/kg)	U (mg/kg)	V (mg/kg)
		Upgradient Samples								
DM1	surface soil	background soil	3.19	1.66	1,535	427	0.49	0.21	3.23	9.28
0563	subpile soil	background soil near DM1	18.9	0.44	1,415	195	<0.4	1.40	1.00	6.05
		On-Site Samples								
0562	surface soil	former ore storage area	0.52	<.40	410	224	1.21	0.20	3.30	9.74
0562	subpile soil	former ore storage area	4.50	<0.40	310	285	<0.4	5.80	0.34	1.76
0564	subpile soil	former mill yard area	8.70	<0.40	1,198	361	<0.4	1.30	1.28	8.37
NAT01	subpile soil	former tailings area	20.9	<0.40	1,874	259	<0.4	1.80	6.02	5.35
NAT06	subpile soil	former tailings area	24.0	<0.40	2,071	117	<0.4	5.70	6.50	412

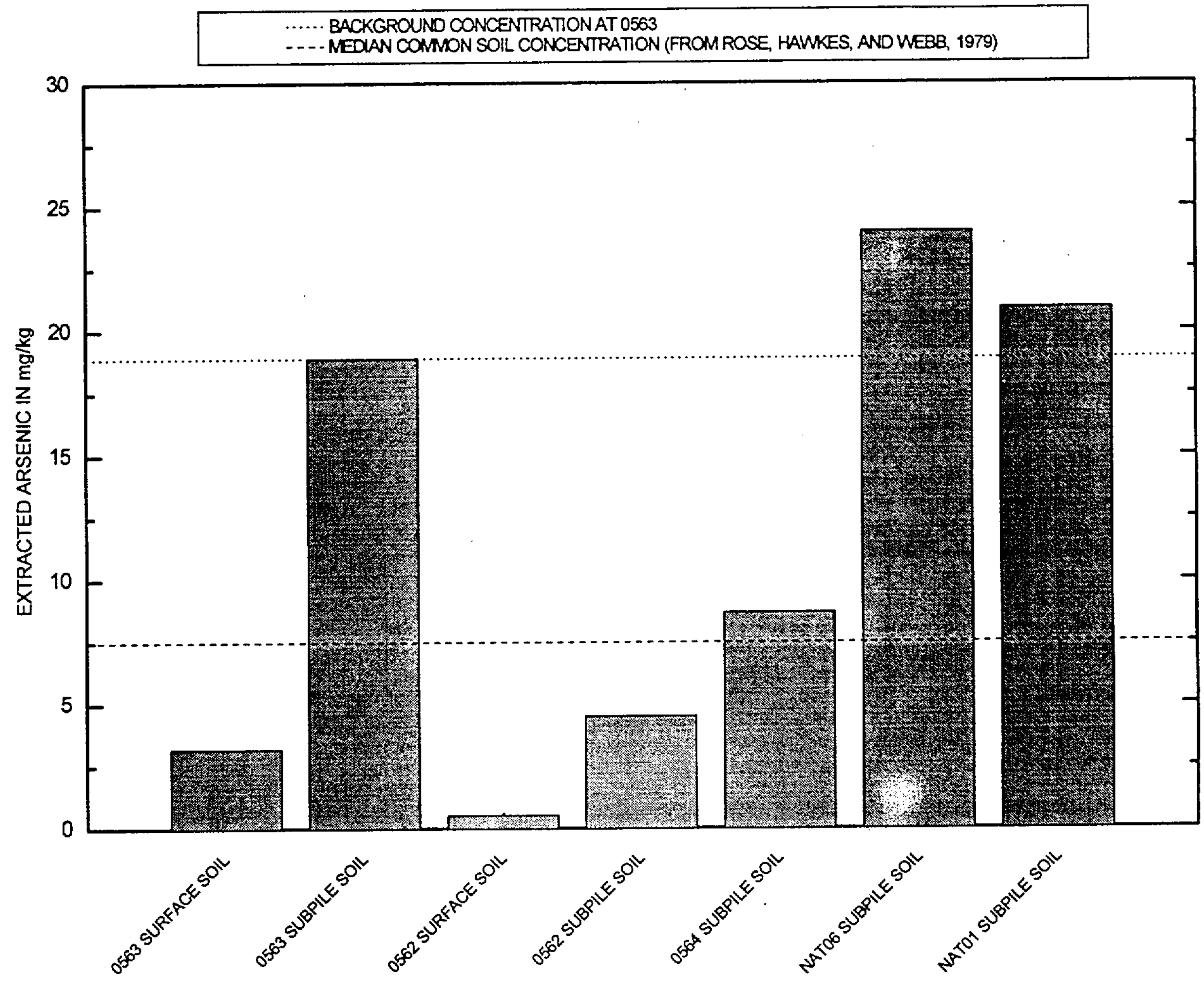


Figure 4–13. Arsenic Concentrations in Surface and Subpile Soil Samples

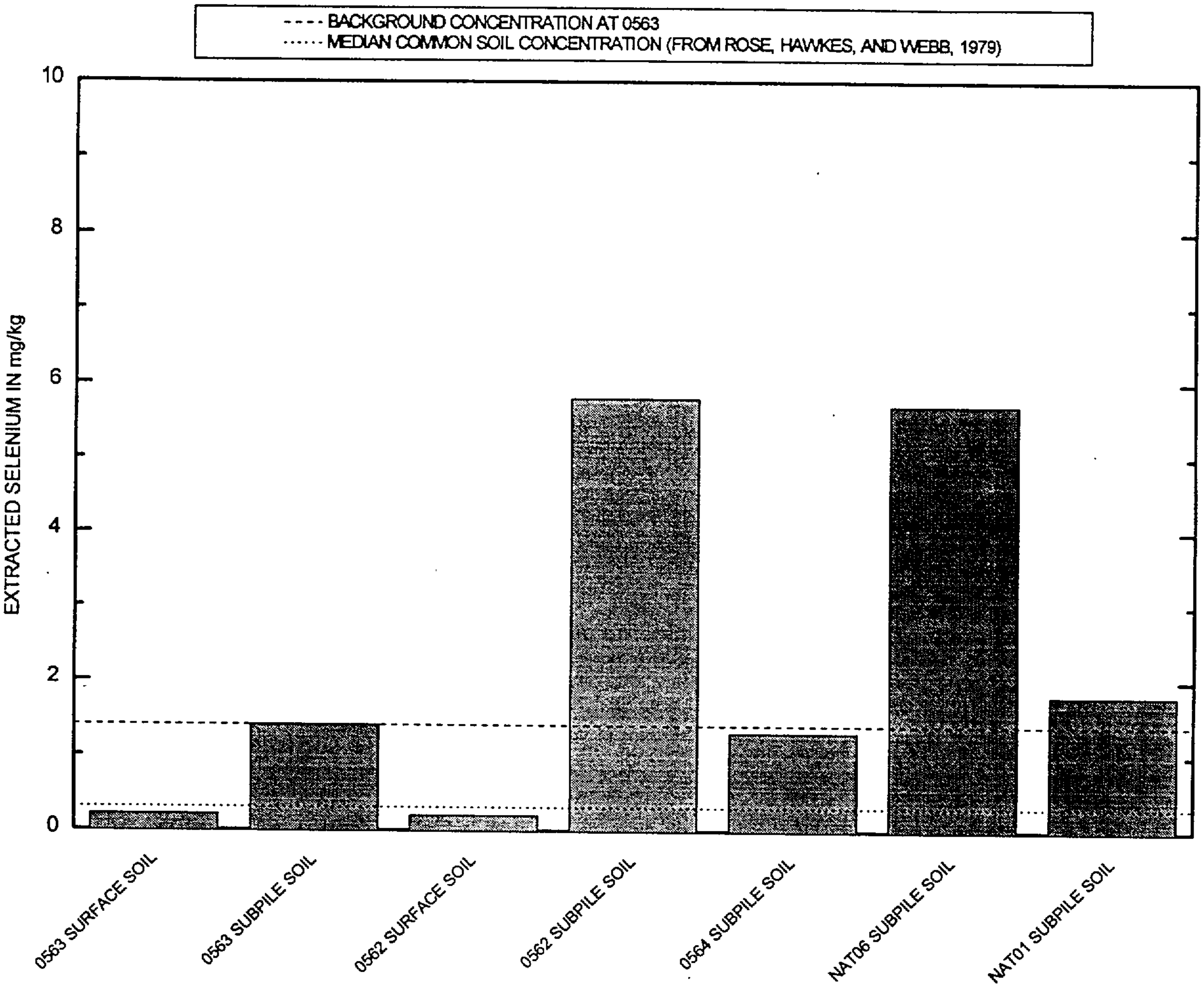


Figure 4–14. Selenium Concentrations in Surface and Subpile Soil Samples

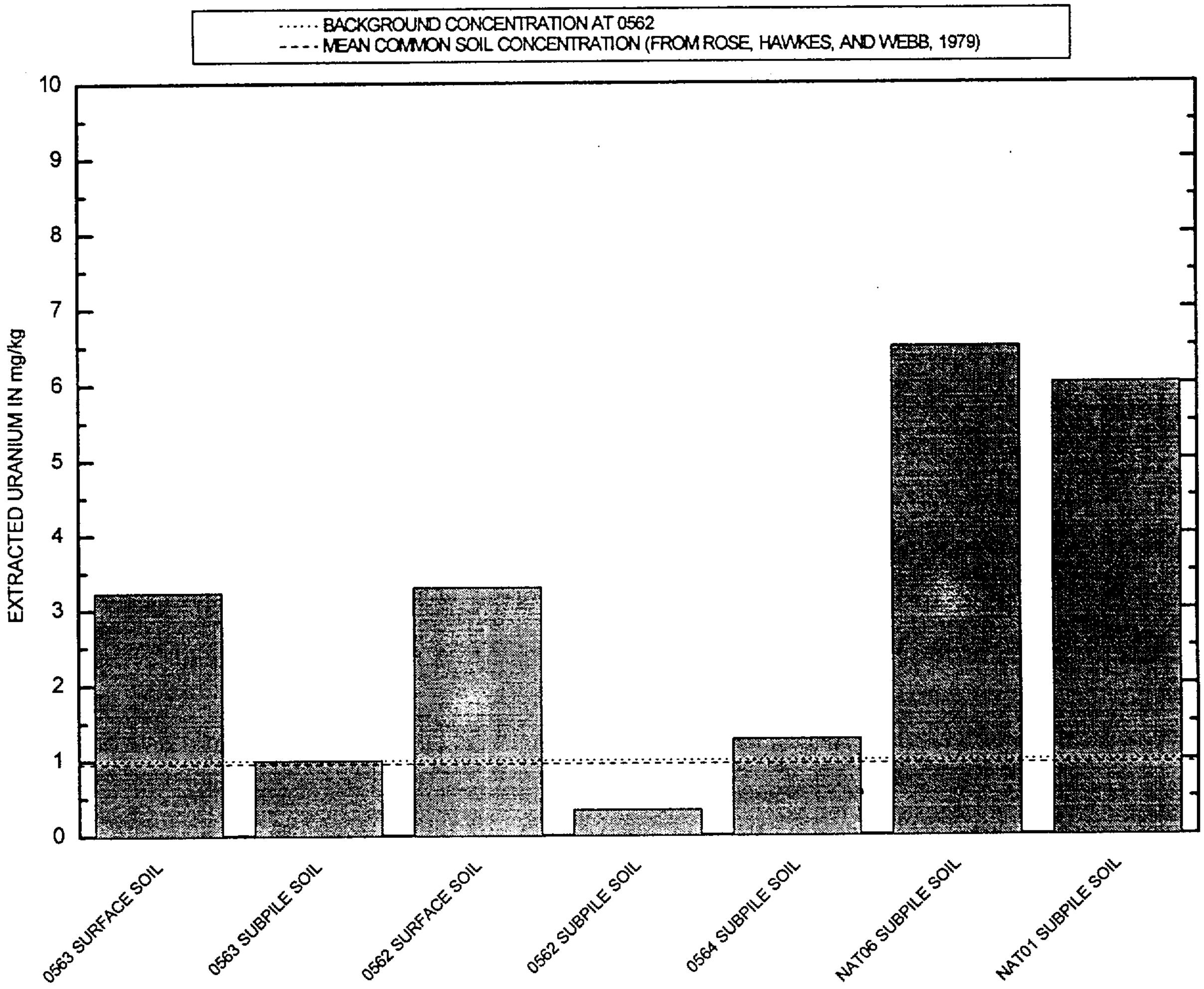


Figure 4–15. Uranium Concentrations in Surface and Subpile Soil Samples

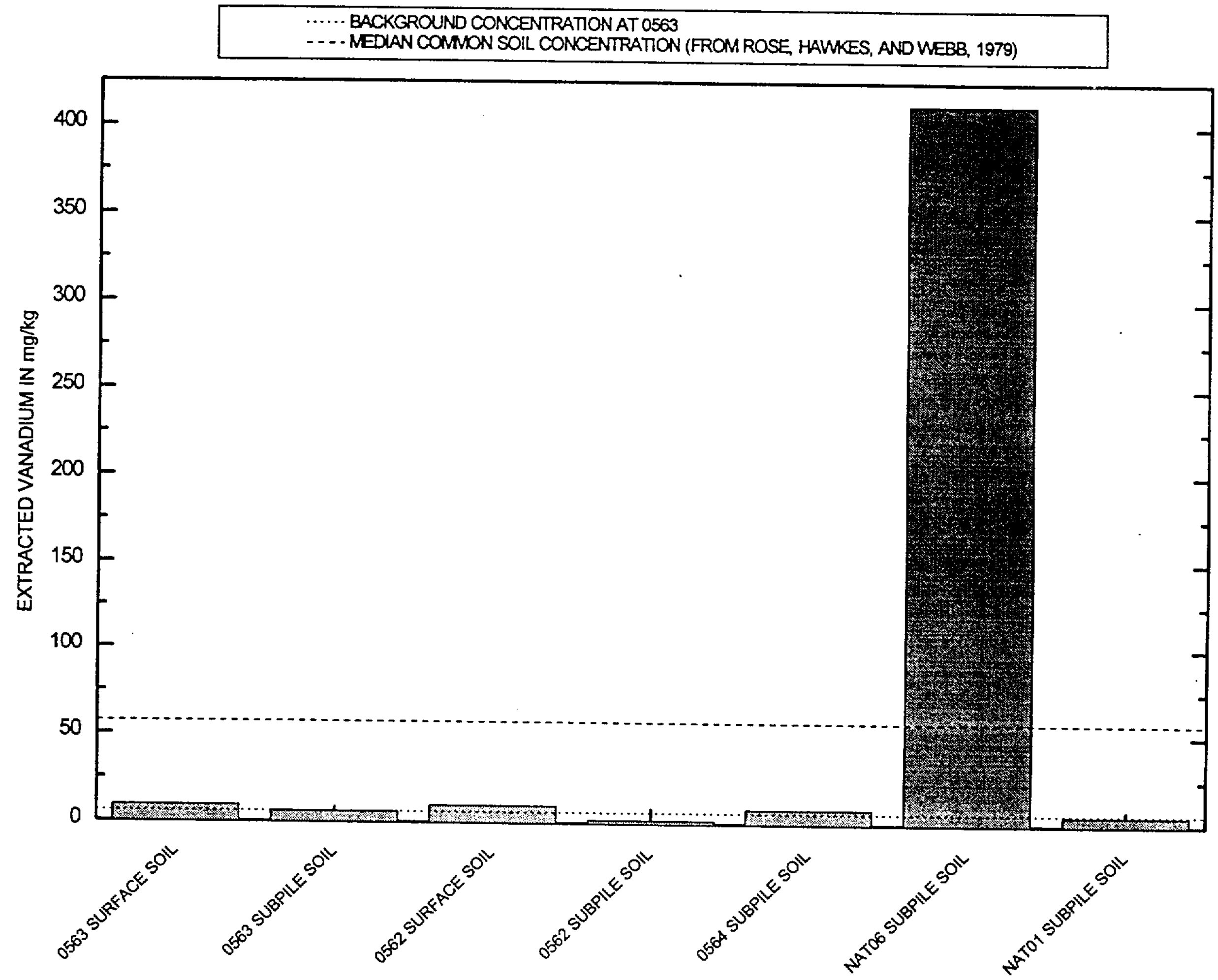


Figure 4–16. Vanadium Concentrations in Surface and Subpile Soil Samples

level. Concentrations in samples from NAT01 and NAT06 were only slightly higher than background values, and any future contamination from those sources would be difficult to distinguish from the natural background concentration.

4.6.5.2 Cadmium in Surface and Subpile Soils

Measurable cadmium was only detected in soil samples from location 0563 (Table 4–7). The subpile concentration was very close to the detection limit, but the surface concentration was almost four times greater. Although no cadmium was measured in any other soil sample, it was detected in most stream sediment samples (Section 4.6.4.2). This suggests that cadmium was transported to the river and location 0563 by wind or surface runoff.

4.6.5.3 Molybdenum in Surface and Subpile Soils

No molybdenum was detected in any of the subpile soil samples collected at the Naturita site (Table 4–7). The two surface soil samples at locations 0562 and 0563 had concentrations of 0.49 and 1.21 mg/kg molybdenum, respectively. These concentrations are in the range of average soil abundance cited by Rose, Hawkes, and Webb (1979).

4.6.5.4 Selenium in Surface and Subpile Soils

Selenium concentrations in all subpile soil samples depicted in Figure 4–14 are 4 to 18 times greater than the mean typical soil concentration (Rose, Hawkes, and Webb 1979). Concentrations at locations 0562, NAT01, and NAT06 are all elevated over the background concentrations measured at location 0563. Location 0562 is not connected to the alluvial aquifer, and contaminants in soil at that location do not pose a significant future threat to ground water. Samples from location NAT01 had selenium levels that were only slightly elevated over the background concentration. Location NAT06 is in the area of the former tailings pile and has the highest concentration of selenium of any of the alluvial aquifer subpile soils. However, due to the reducing conditions of the ground water at this location, it is believed that most of the selenium will remain adsorbed to the sediments. Increased flushing of the alluvial aquifer could change the oxidation-reduction potential of the ground water and potentially desorb selenium from sediments near well NAT06.

4.6.5.5 Uranium in Surface and Subpile Soils

Concentrations of uranium in surface soil at background location 0563 and the former ore storage area at 0562 are approximately the same and are elevated over the background level at location 0563 (Figure 4–15). The fact that both values are elevated over those of their respective subpile soil analyses suggests some degree of windborne contamination. Location 0564, which is in the area of the former mill yard (Table 4–7), has only slightly higher concentrations of uranium than that measured in the background sample. Samples taken at NAT01 and NAT06 in the area of the former tailings pile have the highest concentrations of uranium. This indicates that significant leachable uranium is still present in subpile soils and could represent a future source of uranium contamination.

4.6.5.6 Vanadium in Surface and Subpile Soils

The subpile soil sample collected at well NAT06 had a significantly higher concentration of vanadium than any other sampled location at the Naturita site (Figure 4–16). Samples from all locations except NAT06 had vanadium concentrations that were at or near the background concentration. Drill cuttings from well NAT06 had a vanadium concentration an order of magnitude greater than background levels. Due to its low mobility, the vanadium contamination in the subpile soils is probably limited to the extent of the former tailings pile area and will most likely remain there for a considerable length of time.

4.7 Water Sampling and Analysis

From August 1998 through June 2000, ground water at the Naturita site was sampled to support research by the USGS for the NRC on surface complexation modeling. During November 2000 and March 2001 and continuing into June and September 2001, samples were collected to monitor the nature and extent of ground water contamination at the site for the DOE UMTRA Ground Water Project. Because the two projects have different goals, different sets of wells were sampled. Also, at times, different sampling and analytical procedures were used. All sampling during the NRC sampling period was performed in accordance with the *U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data* (USGS 1998). All sampling during the DOE UMTRA Ground Water Project monitoring phase was performed in accordance with the *Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1997b).

Monitoring wells and surface water sites were sampled quarterly. Sampling for the surface complexation modeling study was conducted from August 1998 through June 1999. Samples from wells 0547 and 0548 were collected in August 1998. Samples were collected from 22 wells and one surface water location during November 1998. Six wells were dry and could not be sampled. Twenty-four ground water samples and one surface water sample were collected in March 1999. Four wells were dry and could not be sampled. During June 1999, 26 wells and one surface water location were sampled. Two wells did not contain water and could not be sampled. In late June and early July 1999, additional monitor wells were installed at the site. In September 1999 and March 2000, 60 ground water wells and one surface water site were sampled. During that time, 12 wells were dry and were not sampled. Well DM1 was also not sampled at that time. Seventy-four ground water wells, including DM1 and one surface water location, were sampled in June 2000. The wells that were dry were always the shallowest of a nested set of wells. Alluvial water was present at all locations during each sampling round.

DOE funded and the USGS conducted monitoring during November 2000 and February 2001. For that monitoring phase, 28 ground water and 14 surface water samples were collected. None of the wells selected by DOE for monitoring were dry during the November 2000 and February 2001 sampling. Additional sampling is planned for June and September 2001.

4.7.1 Ground Water Sampling Procedures

Before samples were collected, about three casing volumes of water were purged from each well with a peristaltic pump. Two-inch-diameter wells were purged and sampled through dedicated 0.5-inch-diameter PVC tubes with a 6-inch screen on the bottom. These tubes were set in the casing to sample 2.5 ft from the bottom of the well where possible. This depth is set at the middle of the screened interval. Half-inch-diameter wells were connected directly to the pump tubing. Samples from these wells were collected from the 6-inch screened interval at the bottom of the well casing. All purging and sampling was done through a peristaltic pump using low-diffusion Norprene tubing. All field measurements except turbidity (pH, specific conductance, oxidation-reduction potential, water temperature, and dissolved oxygen) were monitored continuously during purging with a flow-through chamber attached to a Hydrolab Mini-Sonde

Water Quality Multi-probe. Turbidity was measured with a Hach portable turbidity monitor every half gallon in 0.5-inch-diameter wells, and every gallon in 2-inch-diameter wells. Turbidity was only monitored during the DOE UMTRA monitoring phase of the project. After purging was completed, water samples for anion analysis were filtered on site using a 0.45-µm capsule filter and collected in field-rinsed, 4-ounce polyethylene bottles. Samples for cation analysis were also filtered on site and collected in 4-ounce, acid-rinsed bottles. After collection, these samples were preserved with ultra-pure concentrated nitric acid. During the DOE monitoring phase, an additional nutrient sample was filtered and collected in an amber polyethylene bottle that was kept on ice until analysis. Ferrous iron (Fe^{2+}) was measured colormetrically in the field using a Chemetrics photometer. This was done by first filling a small vial with unfiltered sample water, then immediately breaking a small ampoule containing a reactive solution in the vial. The ampoule is under a negative pressure and therefore draws sample water into the ampoule where it mixes with the reactive solution. After a one minute reaction time, the ampoule is placed in the photometer, which measures the ionic concentration of the constituent. Alkalinity as $CaCO_3$ in filtered (0.45 µm) water samples was generally measured on site with a Hach digital titrator and 1.6 normal sulfuric acid. During the February 2001 sampling, alkalinity was measured in the lab using an auto-titrator due to malfunction of equipment in the field.

4.7.2 Analytical Laboratory Sample Analysis

Water analyses were conducted at the USGS Research Laboratories in Menlo Park, California, and at the USGS National Water Quality Lab (NWQL) in Denver. Dissolved uranium was measured by kinetic phosphorescence analysis (KPA) at the Menlo Park lab. Al, As, B, Ba, Br, Ca, Cd, Co, Cr, Cu, Fe, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Se, Si, Sr, V, and Zn concentrations were measured by inductively coupled plasma optical emission spectrometry (Standard Methods 1992). The potassium concentration was measured by direct air-acetylene flame atomic absorption spectrometry. Chloride, nitrate, and sulfate concentrations were measured by ion chromotography (Standard Methods 1992). For comparison during the DOE UMTRA monitoring phase, 10 samples were sent to the NWQL for uranium analysis by inductively coupled plasma–mass spectrometry (ICP–MS). All samples collected for DOE UMTRA monitoring were analyzed for arsenic and selenium at the NWQL using ICP–MS. Table 4–8 presents a summary of the methods used for water analysis at the two labs. Results from all surface and ground water analyses are listed in Appendices C and B, respectively.

4.7.3 Quality Assurance and Quality Control Samples

One process blank sample and one field replicate were collected for each sampling trip during the NRC sampling period. During the DOE UMTRA monitoring, a process blank and field replicate were collected for every 20 samples. Field replicates were collected immediately after collection of a regular sample using the same filter and equipment. Process blanks were collected from a bottle of USGS-prepared inorganic blank standard by pumping through the Norprene tubing and 0.45 µm filter with the peristaltic pump.

Table 4–8. Summary of Methods Used for Water Analysis

Analyte	Detection Limit	Analytical Instrument	Lab	Sample phase
Al	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
As	0.18 µg/L	ICP-MS	USGS-NWQL	DOE UMTRA
As	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
B	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Ba	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Br	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Ca	0.065 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Cd	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Co	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Cr	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Cu	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Fe	0.015 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Li	0.014 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Mg	0.08 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Mn	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Mo	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Na	0.06 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Ni	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
P	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Pb	0.10 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Se	0.36 µg/L	ICP-MS	USGS-NWQL	DOE UMTRA
Se	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Si	0.01 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Sr	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
U	0.018 µg/L	ICP-MS	USGS-NWQL	DOE UMTRA
U	0.50 µg/L	KPA	USGS-Menlo	NRC, DOE UMTRA
V	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Zn	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
K	0.01 mg/L	AA	USGS-Menlo	NRC, DOE UMTRA
Cl	0.005 mg/L	IC	USGS-Menlo	NRC, DOE UMTRA
NO_3	0.01 mg/L	IC	USGS-Menlo	NRC, DOE UMTRA
SO_4	0.005 mg/L	IC	USGS-Menlo	NRC, DOE UMTRA

USGS-Menlo	USGS Menlo Park Research Lab
USGS-NWQL	USGS National Water Quality Lab
KPA	Kinetic phosphorescence analysis
ICP-MS	Inductively coupled plasma–mass spectrometry
ICP-OES	Inductively coupled plasma–optical emission spectrometry
AA	Atomic absorption spectrometry
IC	Ion chromatography

4.8 Alluvial Aquifer Tests

Estimates of the alluvial aquifer properties are necessary to develop a better understanding of the site hydrogeologic characteristics that could influence contaminant migration in ground water and to develop input parameters in a ground water flow and solute transport model. Both hydraulic and bromide tracer tests were conducted at the Naturita site to determine aquifer properties.

4.8.1 Aquifer Test Procedure

Slug tests were performed on wells at the Naturita site during November 9 through 11, 1999, and during May 17 through 19, 2000. Three to four slug test replicates were done on each well. To perform the tests, a pressure transducer was suspended in the well. A slug with a known displacement volume attached to a thin rope was lowered into the well and the water level was allowed to stabilize. The displacement volume of the slug used in each well was dependent on the height of the water column in the well. The slug was then rapidly removed from the well, and water level recovery and elapsed time were recorded with a pressure transducer. Replicate slug tests were performed after water levels recovered to their pre-test equilibrium values.

Actual displacement of each slug was usually smaller than the measured displacement in the well for the first 0.5 to 0.75 seconds. After 0.75 to 0.9 seconds, disturbance of the water surface ceased, and measured displacement was more in line with the actual displacement. The effective casing radius for most tests seemed to be the actual casing radius. Elapsed time and normalized displacement data for each slug test were then analyzed with AQTESOLV software. The Bouwer-Rice solution (Bouwer and Rice 1976) for unconfined aquifers was used to determine all hydraulic conductivity values.

4.8.2 Aquifer Test Analysis

The Bouwer-Rice slug test solution was used in AQTESOLV to compute hydraulic conductivity. A “double straight line” effect can be seen in displacement-time graphs for wells NAT03 (tests 1 and 2), NAT19, and NAT24. In this situation, it is believed that the water levels dropped sufficiently below the top of the screened intervals to allow direct drainage from the sand packs into the well casings (Bouwer 1989). The initial straight line is the result of sand pack drainage. The second straight line in the graphs was controlled by the hydraulic conductivity of the aquifer, and hydraulic conductivity values were derived from the slopes of these lines.

4.8.3 Aquifer Test Results

Table 4–9 summarizes hydraulic conductivity values computed for each slug test along with the mean, standard deviation, and standard error of the tests performed. No attempt was made to compute hydraulic conductivity values for wells NAT20 and NAT23 due to suspect data. Conductivity values for wells MAU03 (May 2000) and MAU04 should be regarded as estimates due to the shapes of the displacement-time graphs, which made analysis problematic. Hydraulic conductivity for wells analyzed at the Naturita site ranges from 18.9 ft/day in well MAU07 to 333 ft/day in well NAT09. The average hydraulic conductivity measured during the November 1999 tests is 83 ft/day. The average hydraulic conductivity measured during the May 2000 test is 106 ft/day. This range of values is typical for an alluvial aquifer characterized by mixed sand and gravel. Domenico and Schwartz (1990) report a range of hydraulic conductivities from 0.24 to 137 ft/day for medium sand and from 82 to 8,200 ft/day for gravel.

Table 4–9. Summary of Hydraulic Conductivity Values Determined from Slug Tests

Well	Date	Slug Test 1, ft/day	Slug Test 2, ft/day	Slug Test 3, ft/day	Slug Test 4, ft/day	Average Hydraulic Conductivity, ft/day	Standard Deviation, ft/day	Standard Error %
MAU03	May-00	17	38	22	nd	26	11	42.7
MAU03	Nov-99	85	70	104	nd	86	17	19.6
MAU04	May-00	27	18	12	nd	19	7	38.3
MAU07	Nov-99	16	27	26	nd	23	6	26.2
NAT02	Nov-99	nd	29	41	nd	35	8	24.1
NAT03	May-00	104	90	nd	nd	97	10	10.0
NAT03	Nov-99	96	85	nd	nd	91	8	9.0
NAT05	May-00	66	84	60	nd	70	13	18.1
NAT05	Nov-99	76	67	nd	nd	72	6	8.7
NAT09	May-00	288	325	386	nd	333	50	14.9
NAT10	Nov-99	38	30	27	nd	32	6	18.3
NAT11	May-00	108	115	105	nd	109	5	4.7
NAT11	Nov-99	93	81	90	95	90	6	6.8
NAT19	May-00	153	107	128	nd	129	23	17.8
NAT23	Nov-99	246	313	295	nd	285	35	12.2
NAT24	May-00	23	66	67	nd	52	25	48.8
NAT25	May-00	113	126	116	nd	118	7	5.8
NAT-25	Nov-99	24	44	32	nd	33	10	29.9

nd No data

4.8.4 Bromide Tracer Tests

In addition to the hydraulic conductivity values measured directly with slug tests, bromide tracer tests were conducted in June and July 1999 to estimate the hydraulic conductivity of the aquifer. The tracer tests were performed by first pumping 60 gallons of water from a well, then adding a measured amount of potassium bromide to the water, then injecting the water back into the well. Samples were collected from the injection well at regular intervals to monitor the disappearance of bromide from the well. In some tests, downgradient wells were also sampled to monitor bromide migration.

The estimated hydraulic conductivity values obtained from the bromide disappearance tests were calculated by first developing an empirical correlation between hydraulic conductivity and bromide disappearance half-life. The correlation shown in Figure 4–17 was developed from eight wells where both slug tests and bromide tracer tests were performed. Additional hydraulic conductivity values were then estimated using the equation shown in Figure 4–17 at wells NAT06–1, NAT07–1, NAT09, NAT11, NAT12–1, NAT20, NAT26, and NAT30–1 where bromide disappearance tests had been conducted. Table 4–10 shows the half-life for bromide disappearance for each well tested and the estimated hydraulic conductivity.

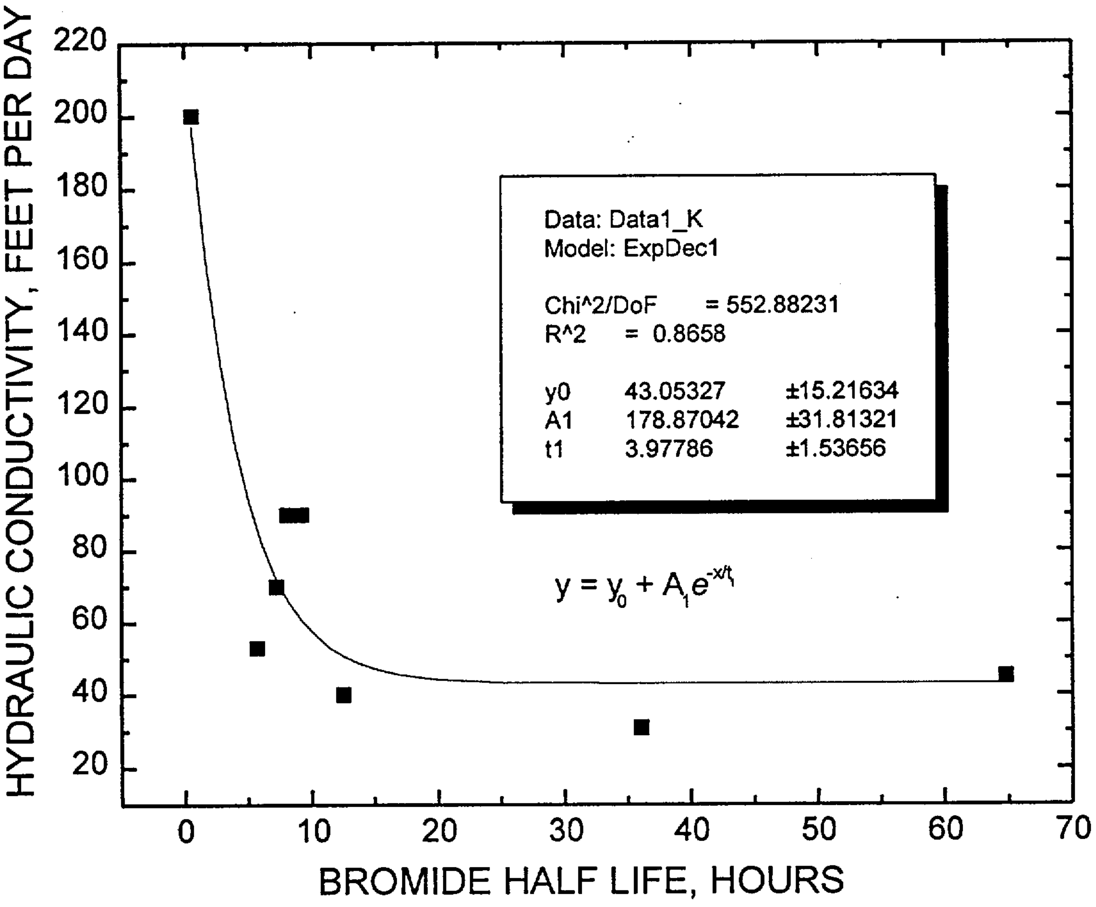


Figure 4–17. Plot Showing Relationship Between Hydraulic Conductivity and Bromide Injection Half-life

Table 4–10. Summary of Hydraulic Conductivity Values Estimated from Bromide Tracer Tests

Well	Bromide Half-Life, hours	Estimated hydraulic conductivity, ft/day
NAT06-1	5.5	88
NAT07-1	14.9	47
NAT12-1	22.1	44
NAT20	0.2	215
NAT26	46.5	43
NAT30-1	0.9	184

4.8.5 Hydraulic Conductivity Estimated from Tritium-Helium Results

In June 2000 a subset of the wells at the Naturita site was sampled for the purpose of determining the age of the ground water. Twelve wells were sampled for age dating by the tritium-helium method (see Section 5.3.4 for a detailed description of the tritium-helium age dating technique). Table 4–11 shows the tritium-helium ages for eight wells. The age of ground water is defined as the time since water was isolated from the atmosphere (Freeze and Cheery 1979). Table 4–11 also shows flow path lengths calculated with MODPATH. Although flow modeling suggests long path lines for wells MAU04 and MAU07, the geochemical signature of the ground water in these wells suggests a significant inflow of fresh water from the San Miguel River (see Section 5.3.3.2). Therefore, the path lines from wells MAU04 and MAU07 may actually originate near NAT25. Average velocities listed in Table 4–11 were calculated using the recharge age and the MODPATH calculated flow path lengths. The estimated velocities range from 0.21 ft/day at MAU07 (along the short flow path) to approximately 2.4 ft/day at DM1 and at MAU04 (along the long flow path). The hydraulic conductivity values calculated from Darcy's law, a porosity of 0.25, and an average sitewide gradient of 0.0044 ft/ft are also listed in Table 4–11. The values range from 12 to 139 ft/day with a mean of 47 ft/day.

Table 4–11. Velocities and Hydraulic Conductivities Estimated from the Tritium-Helium Age Dating Results

Location	Tritium/ Helium Age	Length of Recharge Path(ft)	Average Velocity (ft/day)	Hydraulic Conductivity (ft/day)	Comments
DM1	0.2	174	2.38	135	
MAU04	5.6	4,991	2.44	139	
		840[a]	0.41	23	Assumes recharge from bend in river
MAU07	12.4	5,466	1.21	69	
		944[a]	0.21	12	Assumes recharge from bend in river
NAT19	9.2	2,955	0.88	50	
NAT23	13.5	5,520	1.12	64	
NAT24	33.9	5,465	0.44	25	
NAT25	28.2	5,440	0.53	30	
NAT29	5.8	2,202	1.04	59	

[a] Values are based on the assumed shorter flow path to MAU04 and MAU07.

4.8.6 Hydraulic Conductivity Summary

Figure 4–18 shows a map of hydraulic conductivity values from slug tests, bromide tracer tests, and tritium-helium age dating that were measured and estimated at the Naturita site. When plotted spatially, the hydraulic conductivity at the Naturita site is roughly distributed into two zones, a "high K zone" located at the southern end of the site with values greater than 100 ft/day, and a "low K zone" at the northern end with values less than 100 ft/day. The boundary between the two zones falls roughly at the extent of the former tailings area.

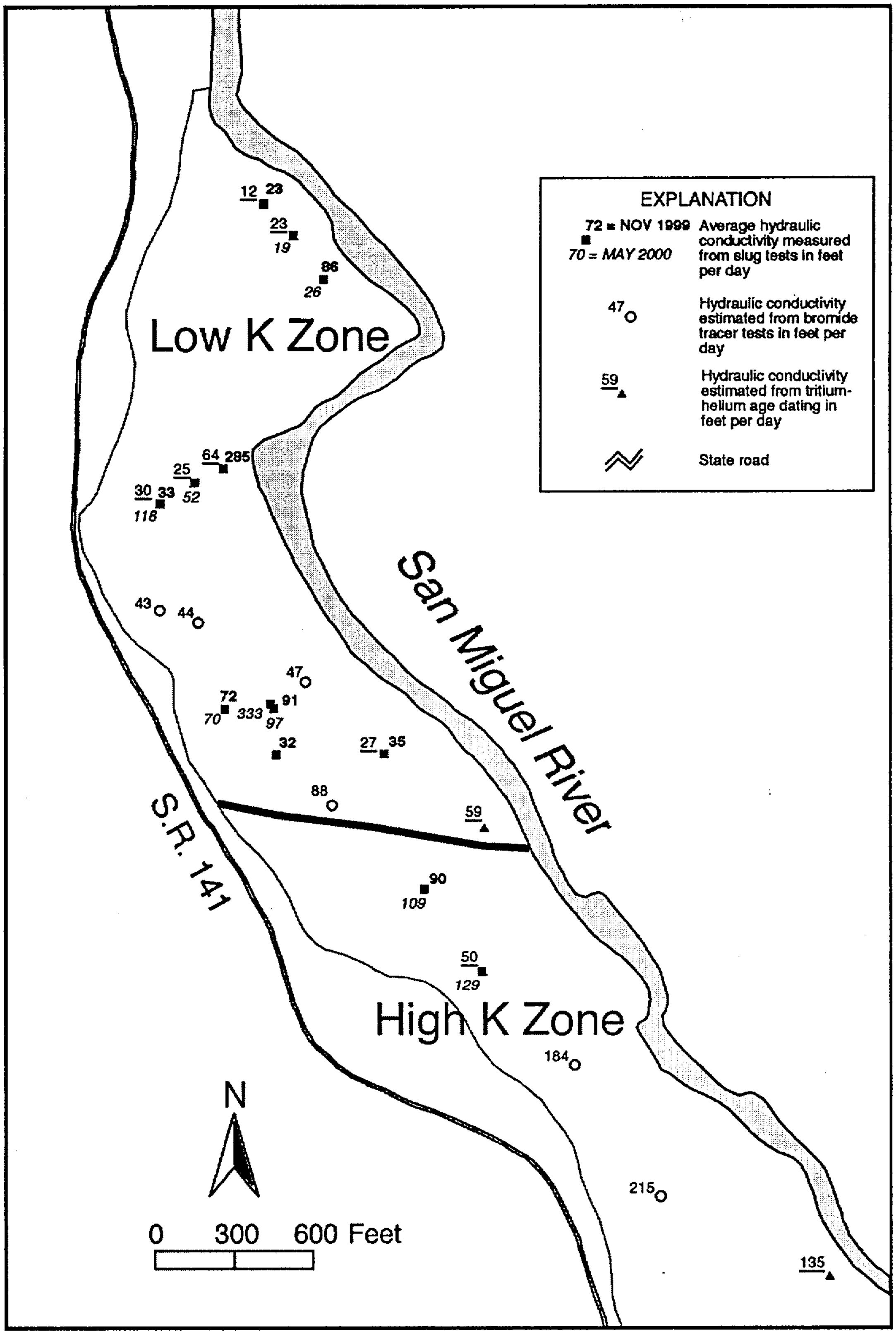


Figure 4–18. Hydraulic Conductivity Values Calculated from Slug Tests and Estimated from Bromide Tracer Tests and Tritium-Helium Age Dating

4.9 Surface Flow Measurements

The Naturita site is bordered on the east side by the San Miguel River. It is believed that ground water in the alluvial aquifer is recharged mainly by inflow from the river upstream of the UMTRA site. The aquifer also discharges back to the river downstream of the site. The San Miguel River drains an area of approximately 1,500 square miles, beginning in the San Juan Mountains and discharging into the Dolores River, about 25 miles downstream from the Naturita site. Surface flow of the San Miguel River has been historically recorded at two USGS gaging stations: Brooks Bridge, located 4.5 miles upstream of the Naturita site, and at Uravan, located 15 miles downstream from the site. In addition, stream elevations were surveyed at nine sites along the San Miguel River at the Naturita site. These measuring points are shown in Figure 4–19.

River stage was also recorded at location Stage 1 (Figure 4–19) near well NAT29 for comparison to changes in ground water levels. The stage was recorded during the period November 1999 to March 2001 using an Omnidata Data Logger pressure transducer. No attempt was made to quantify flow of surface water. The paired stage–water table data were collected to quantify the effects and lag times of river stage on the alluivial aquifer. Figure 4–19 shows two ephemeral streams that cross the site from the slope on the western side of the site. These streams have been observed to flow during large storm events and are believed to a source of intermittent areal recharge. Also, after heavy rainfall, the soil in these areas will often remain saturated for several days.

4.9.1 San Miguel River at Brooks Bridge near Nucla, Colorado

USGS maintains a gaging station on the San Miguel River at the Brooks Bridge near Nucla. The gage is located approximately 4.5 miles upstream from the Naturita site. Figure 4–20 shows a hydrograph for the period March 31, 1995, to September 30, 1999. Stream discharge ranges from a base flow of approximately 3 cubic ft per second (cfs) to 100 cfs. Peak flows range from 1,000 to 4,000 cfs. However, these ranges are only based on four years of data, recorded from 1996 to 1999. The peak flows result from snow melt in the San Juan mountains at the head of the watershed and generally start in the first week of April and continue until early summer. Low-flow conditions are generally constant and occur between roughly the first week of August to the end of March, although rainfall can cause short-term increases in stream flow.

4.9.2 San Miguel River at Uravan, Colorado

USGS maintains another gaging station on the San Miguel River at Uravan. The gage is located approximately 15 miles downstream from the Naturita site. Figure 4–20 shows a hydrograph for the period August 30, 1996, to September 30, 1999. Base flow ranges from 20 to 100 cfs, and peak flows typically range from 2,000 cfs to a historical high of 8,910 cfs on September 6, 1970 (not shown on hydrograph). These ranges are based on records dating back to 1954. As shown in Figure 4–20, the San Miguel River exhibits the same pattern of flow at Uravan as at Brooks Bridge, with peaks and base flows occurring at the same time of year. Dry Creek is a perennial stream that enters the San Miguel River about a mile upsteam from the site. This stream and numerous ephemeral streams are the main sources of discharge to the river between the Brooks Bridge and Uravan gaging stations.

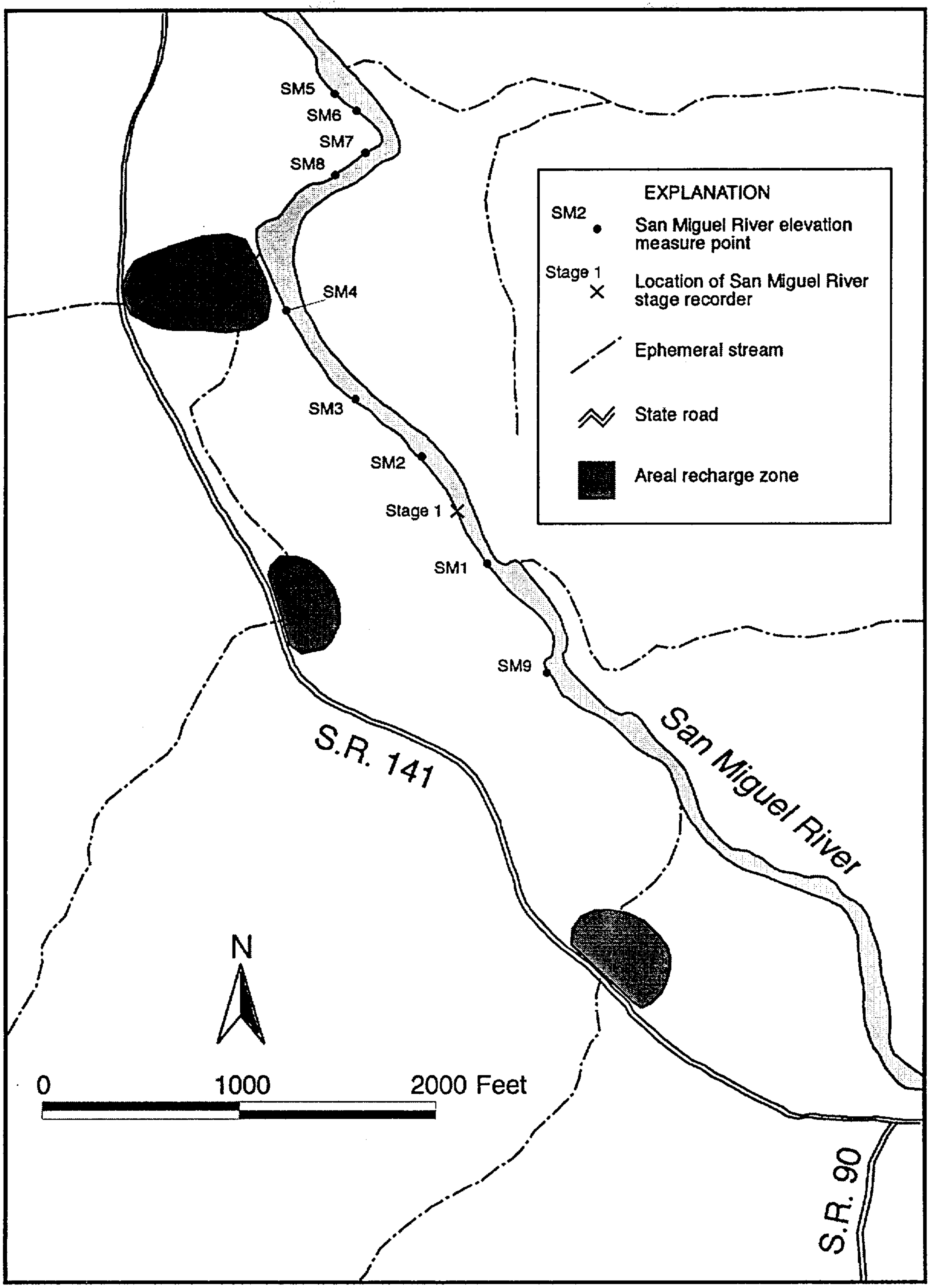


Figure 4–19. Locations of San Miguel River Elevation Measuring Points, Stage Recorder, and Zones of Areal Recharge at the Naturita UMTRA Site

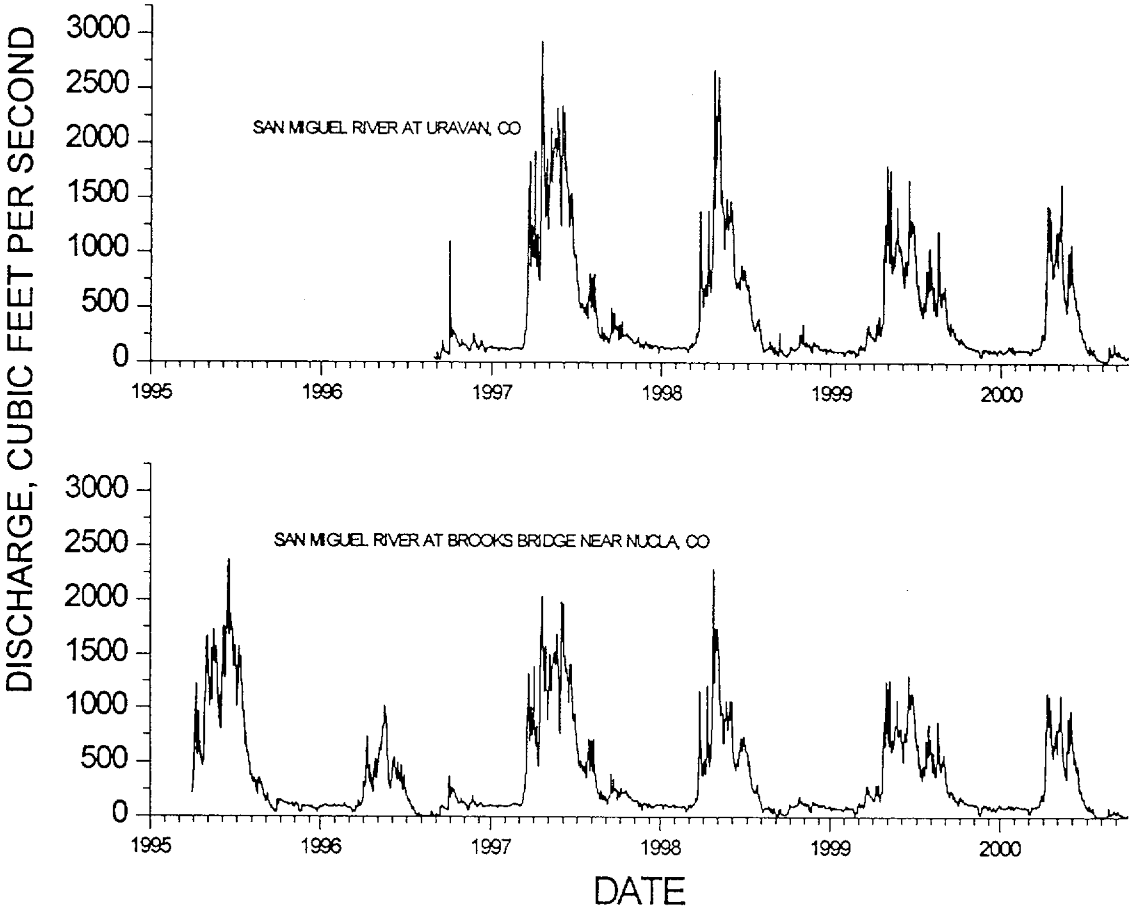
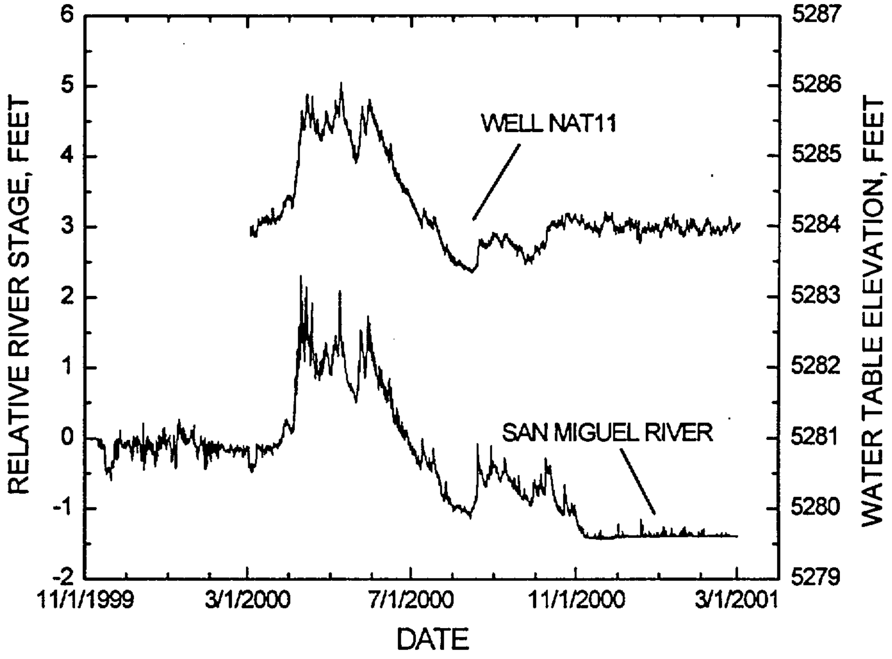


Figure 4–20. Hydrographs from USGS Gaging Stations on the San Miguel River near the Naturita UMTRA Site

4.9.3 Stage Recorder and Surface Water Elevation Measurements

Flow from the San Miguel River is believed to be the most important source of recharge to the alluvial aquifer. This is supported by the close coupling between the stage in the San Miguel River and the observed heads in several of the wells in the aquifer. Figure 4–19 shows the location of the stage recorder. No gage was installed at the site to relate stream stage changes to a set datum. Figure 4–21 shows the changes seen in the river stage in well NAT29, which is 138 ft from the river, and in well NAT11, which is 445 ft from the river. Figure 4–22 illustrates the correlation between temporal variations in the river stage and the head in NAT08 (380 ft from the river). Figure 4–23 shows the same correlation in wells NAT25 (380 ft from the river) and NAT23 (100 ft from the river). The head changes more slowly at NAT23 and NAT25 relative to NAT29, NAT11, and NAT08. This is probably because NAT23 and NAT25 are located farther down the ground water flow path and are more hydraulically removed from the river than the other wells. This effect would tend to dampen out small changes seen in the river stage.



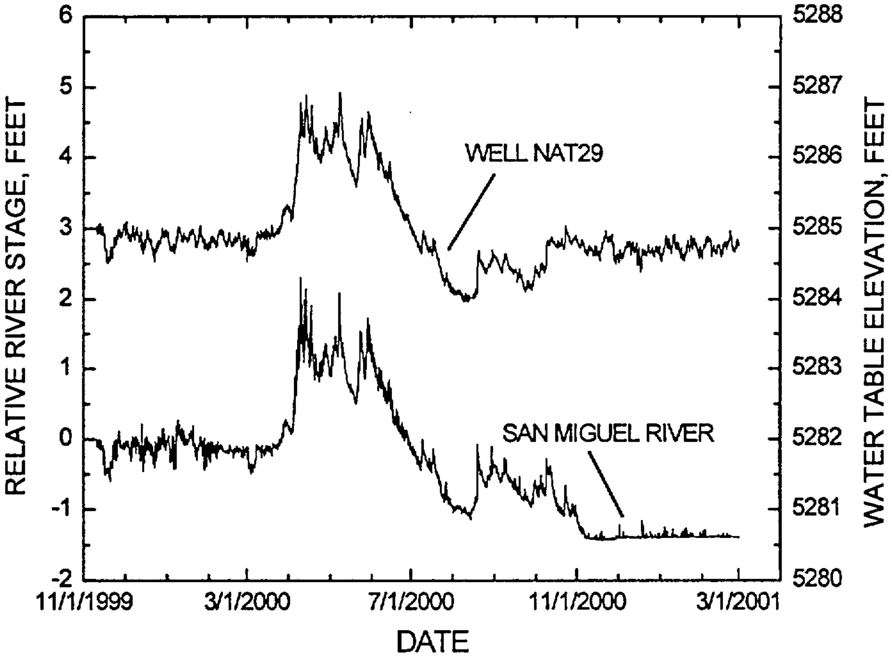


Figure 4–21. Correlation Between Water Table Elevation in Wells NAT11 and NAT29 and Relative Stage of the San Miguel River Measured at Location Stage 1

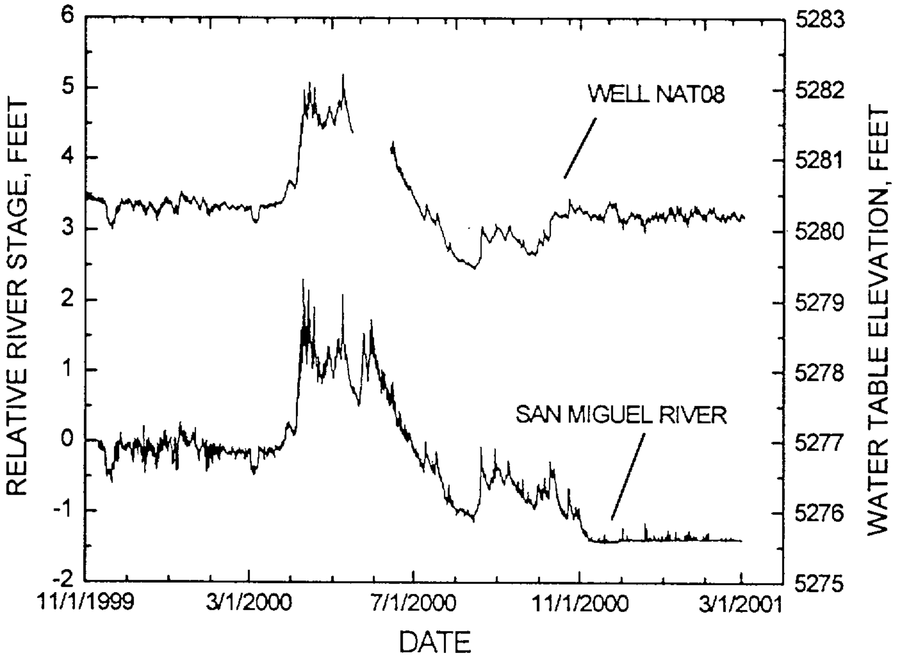
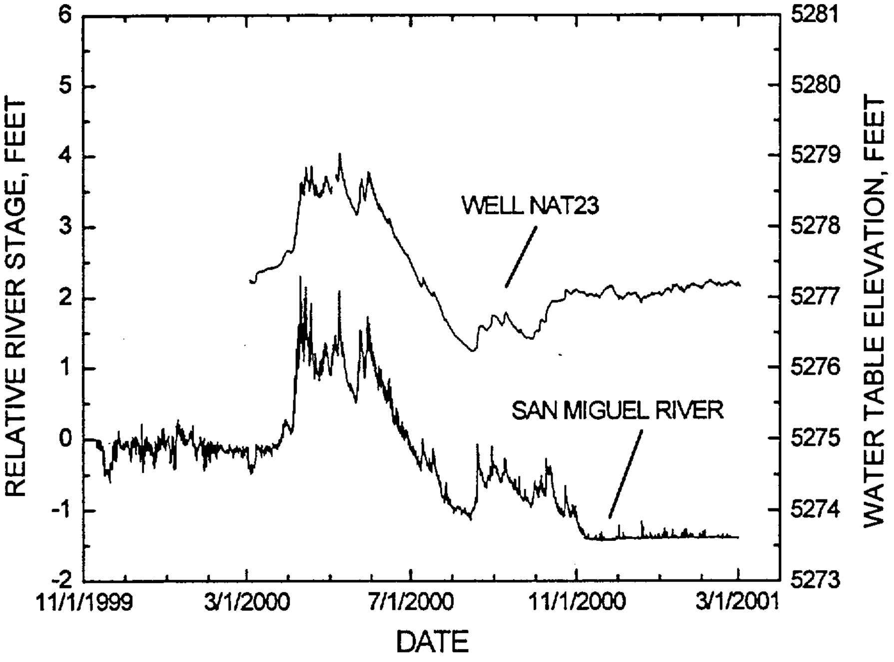


Figure 4–22. Correlation Between Water Table Elevation in Well NAT08 and Relative Stage of the San Miguel River Measured at Location Stage 1

Reference elevation points were installed and surveyed at nine points along the San Miguel River adjacent to the Naturita site. The points are shown as SM1 through SM9 in Figure 4–19. Table 4–12 shows the elevations measured for each reference point. Figure 4–24 shows a hydrograph comparing the relative change in river stage as recorded by the river pressure transducer to the elevation of the San Miguel River measured at location SM1.



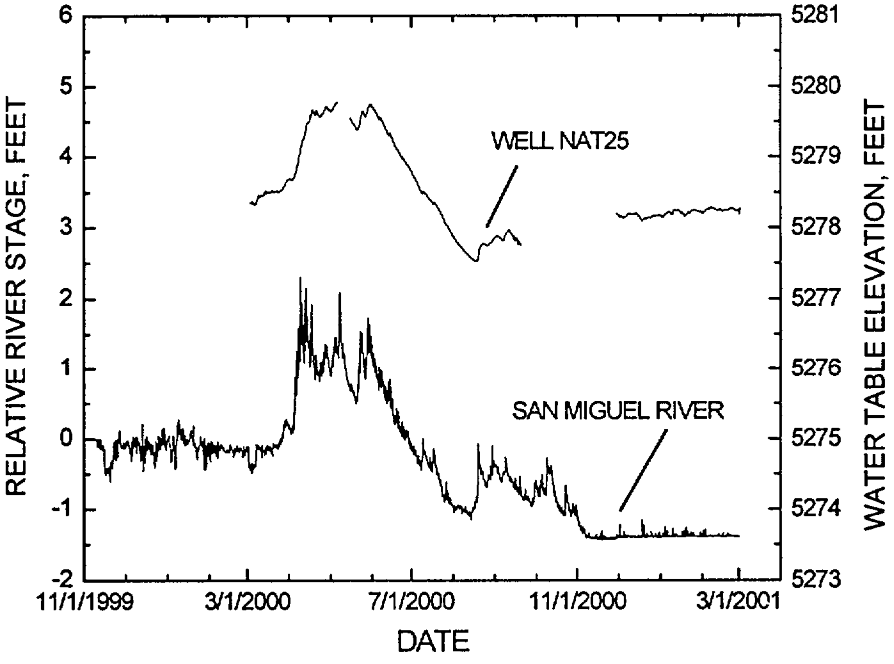


Figure 4–23. Correlation Between Water Table Elevation in Wells NAT23 and NAT25 and Relative Stage of the San Miguel River Measured at Location Stage 1

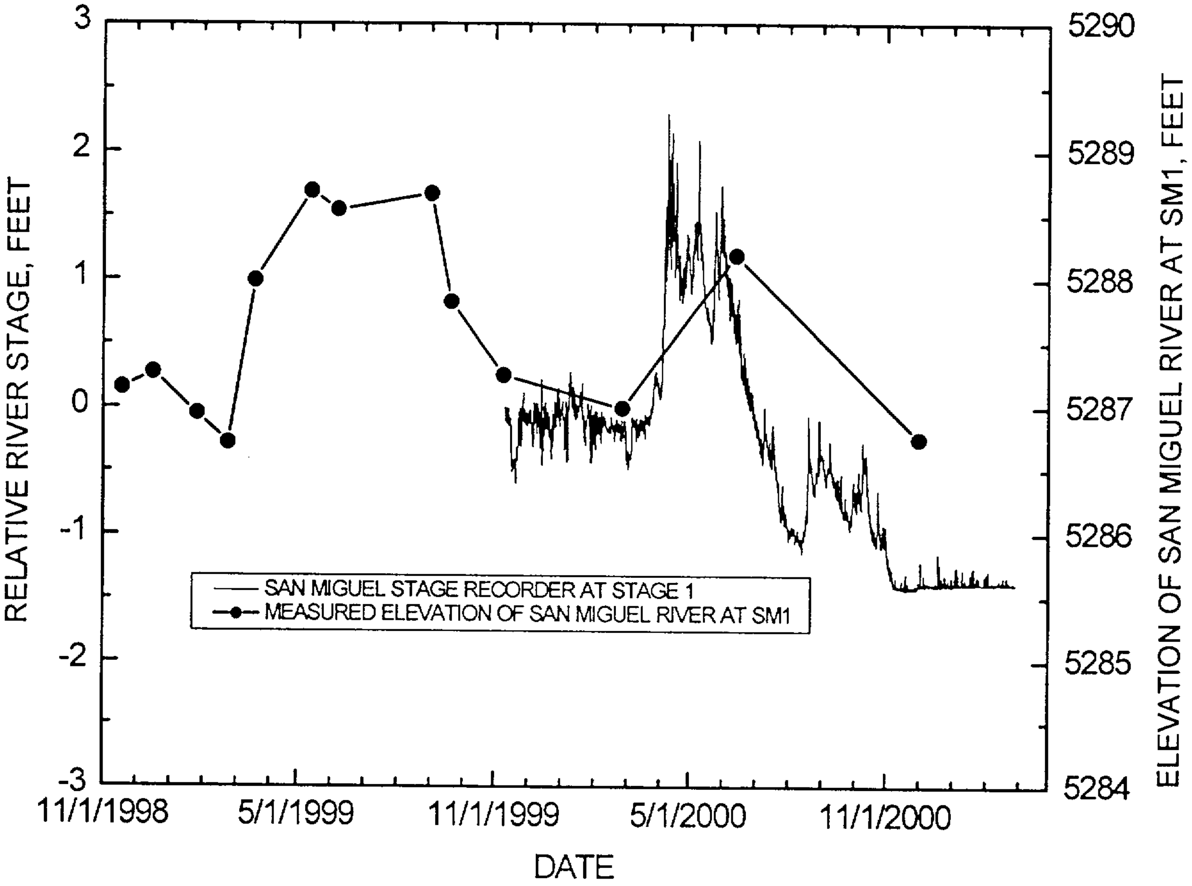


Figure 4–24. Relative Stage of the San Miguel River Recorded at Location Stage 1 and Measured Elevation of the San Miguel River at Location SM1

Table 4–12. Elevation of the San Miguel River at Locations SM1 through SM9

Date	SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM8	SM9
11/18/98	5287.15	5284.25	5281.86	5278.93	5271.16	nd	nd	nd	nd
12/17/98	5287.27	5284.45	5281.88	5279.11	5271.19	nd	nd	nd	nd
01/27/99	5286.95	5284.17	5281.75	5278.92	5271.05	5271.36	5273.73	5273.97	5291.34
02/25/99	5286.72	5283.98	5281.65	5278.67	5270.89	5271.12	5273.60	5273.83	5291.00
03/22/99	5287.99	5284.82	5282.36	5279.64	5271.61	5272.06	5274.31	5274.76	5292.17
05/13/99	5288.69	5286.67	5284.40	5281.32	nd	5272.78	5274.89	5275.41	5292.72
06/07/99	5288.55	5285.39	5282.95	5280.24	5272.13	5272.62	5274.75	5275.33	5292.60
09/02/99	5288.67	5285.46	5283.00	5280.31	5272.14	5272.70	nd	5275.41	5292.82
09/21/99	5287.82	5284.83	5282.29	5279.50	5271.56	5271.99	5274.33	5274.79	5292.06
11/09/99	5287.25	5284.25	5281.93	5279.16	5271.31	5271.55	5273.87	5274.39	5292.54
02/28/00	5286.99	5284.21	5281.83	5279.00	5271.11	5271.40	5273.87	5274.23	5291.32
06/13/00	5288.19	5285.19	nd	5281.58	5271.94	5272.44	5274.79	5275.25	5292.36
12/01/00	5286.75	nd	5281.75	5279.02	5270.95	5271.34	5273.87	5274.17	5291.18
02/26/01	5286.66	nd	5281.72	5278.85	5270.95	5271.33	5273.62	5274.03	5291.04

nd = no data

4.10 Ecological Field Investigations

In general, the goal of ecological field investigations under the UMTRA Project is to acquire data to determine if site-related contamination may adversely affect ecological receptors (flora and fauna). The ecology of the former millsite and surrounding areas has been characterized to support the assessment of potential ecological risks associated with site-related contaminated ground water and to update the *Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Site Near Naturita, Colorado* (BLRA, DOE 1995). Data needed to evaluate potential risks include faunal and floral species composition, ecological interactions, contaminated media, contaminant concentrations within specific media, and exposure pathways. This section summarizes the data collected and identifies any additional data needs. Section 6.2 of this SOWP evaluates the data and draws conclusions as to the level of risk presented by site-related contamination to ecological receptors.

Because UMTRCA does not specify an ecological risk assessment protocol, the UMTRA Ground Water Project adopted EPA's 1992 risk assessment guidance (EPA 1992) as a best management practice. The BLRA preceded EPA's 1998 risk assessment guidelines (EPA 1998). The data and subsequent evaluation (Section 6.2) have been developed to support a risk-based compliance strategy that is protective of the environment. It includes a discussion of the ecological contaminants of potential concern, potential receptors, and potential adverse effects. A defensible ecological risk assessment (ERA) will provide a sound basis for development of a risk-based compliance strategy. The following sections provide descriptions of ecological field activities conducted to date.

4.10.1 Site Ecological Setting

The Naturita site lies in the Canyonlands section of the Colorado Plateau physiographic province and borders the San Miguel River to the northeast. The USGS reports that average low flow of the San Miguel River is about 60 cfs. The San Miguel River joins the Dolores River approximately 20 miles downstream from the site. Site-related ground water contamination moves in a generally northeast direction toward the river. Ground water flow from the site terminates in the San Miguel River along a stretch approximately 500 ft long. Seeps are evident along the northeastern boundary of the site, directly adjacent to the river. The most prominent seep at sampling location 0538 forms a small pond within the river channel during low flow, which empties into the river. This area presents the greatest potential for receptors to access contaminated media.

4.10.1.1 Site Flora and Fauna

The flora and fauna of the Naturita millsite and surrounding areas were investigated between 1986 and 1994. Section 7.2 of the BLRA describes the potential ecological receptors in detail. Additional information is provided in the *Environmental Assessment of Remedial Action at the Naturita Uranium Processing Site Near Naturita, Colorado* (DOE 1994), which documents the results of the investigations and lists the potential ecological receptors, including threatened or endangered species. Ecological characterization and surveys targeted terrestrial ecological receptors, with an emphasis on riparian plant communities and associated wildlife along the San Miguel River.

The BLRA also identifies and discusses six federally listed threatened or endangered species, one federally proposed species, and nine federal candidate species that may occur in the vicinity of the site. Of the species listed, the area may provide suitable habitat for only the southwestern willow flycatcher (*Empidonax traillii extimus*).

Plant Ecology Characterization

The San Miguel River valley includes the riparian community along the river surrounded by moderate to steep hillsides. Surrounding areas include two other major community types: piñon-juniper woodland and sagebrush-grass communities. Figure 7.1 of the BLRA shows the plant communities in the vicinity of the site at the time of remediation. In October 2000, vegetation of the former millsite was assessed using a semiquantitative relevé technique. With this method, representative stands of each vegetation type are subjectively chosen and traversed. The vegetation types are differentiated on the basis of the two dominant species present in each one. A list of all the plant species in the stand is made, and the percent cover of each species is estimated. A value for one of six cover class percentages is assigned to each species, and the percent cover is not measured precisely.

The goal of the investigation was to identify potential exposure pathways and ecological receptors. Field characterization activities focused on the identification of phreatophytic species that may be rooted into areas of site-contaminated ground water, in both riparian and upland communities.

Results

The Naturita site is dominated by upland plants that are mostly grasses and annual weeds. However, several areas have phreatophytes, or plants that can root into ground water. Phreatophytic species include willows (*Salix* spp.), cottonwoods (*Populus* spp.), tamarisk (*Tamarix* spp.), and greasewood (*Sarcobatus vermiculatus*). A strip of riparian and wetland vegetation growing along the San Miguel River includes willows and cottonwoods. Tamarisk and willows grow along a ditch through the site at the north end. An island of shrubby vegetation around a group of power poles in the field includes greasewood. Altogether, there are four riparian/wetland vegetation types and three upland vegetation types, as shown in Figure 4–25.

A willow-dominated riparian area is at the north end of the site along the river. Sandbar willow (*Salix exigua*) up to 8 ft tall is the main species; the understory is smooth brome (*Bromus inermis*), thistle (*Cirsium* sp.), common reed (*Phragmites australis*), Woods rose (*Rosa woodsii*), and aster species.

The south end of the riparian area has two distinct vegetation types. One has an abundance of mature lanceleaf cottonwoods (*Populus accuminata*), with an herbaceous understory of scratchgrass muhly (*Muhlenbergia asperifolia*) and sweet clover (*Melilotus officinalis*). The other is a mixture of willows and cottonwoods, both juvenile and mature, with a variety of grasses and forbs underneath.

The final wetland vegetation type is a 10-ft-wide strip along a ditch toward the north end of the site. The vegetation is mostly 6–8-ft-tall sandbar willow (*Salix exigua*) with some Canada thistle (*Cirsium arvense*), tamarisk, and common reed (*Phragmites australis*).

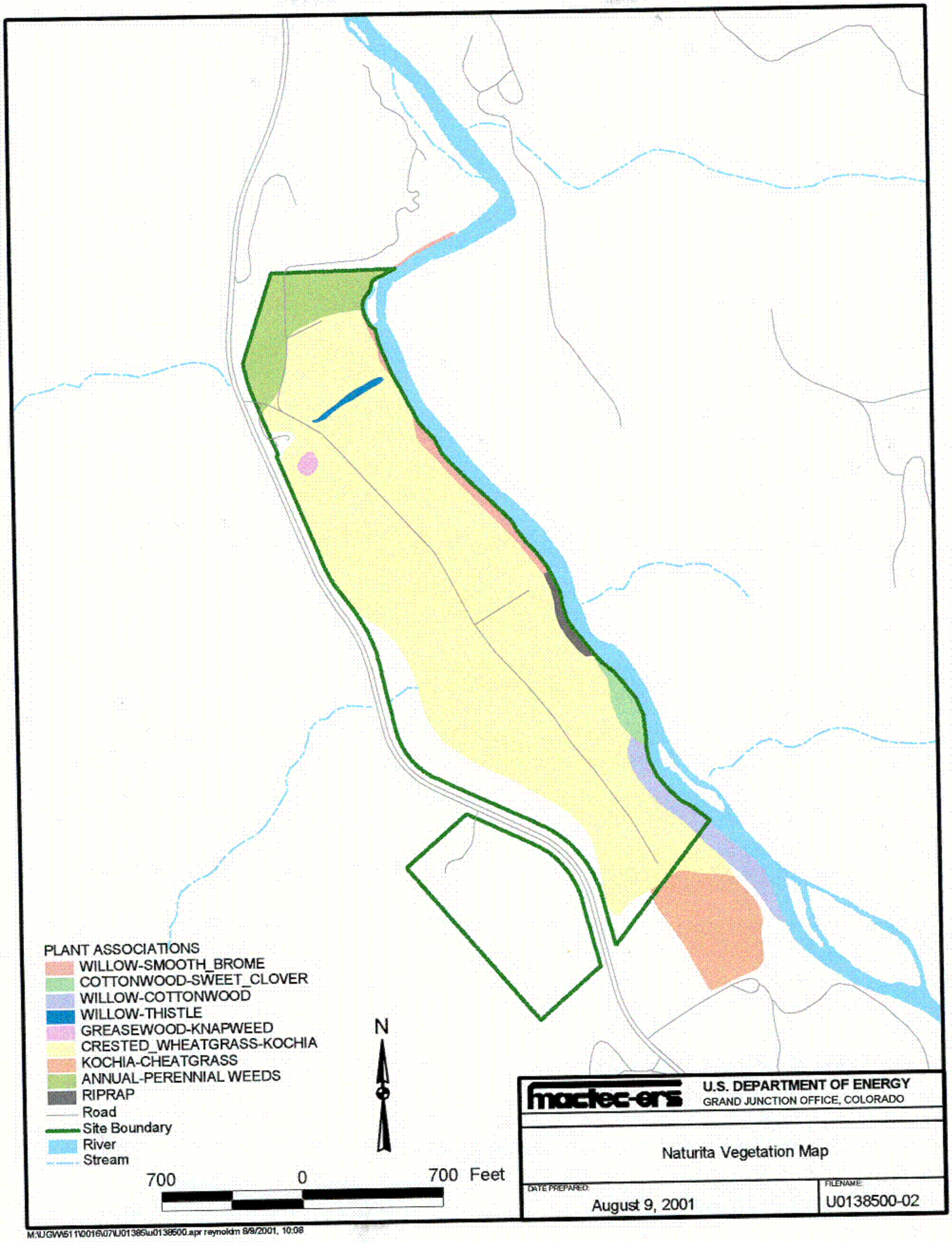


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Figure 4–25. Vegetation Map of the Naturita Millsite

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The major upland type is the reseeded portion of the field. It is approximately 50 percent bare, and the main vegetation consists of crested wheatgrass (*Agropyron cristatum*) and kochia (*Kochia scoparia*), both under 6 inches tall. The far north end of the field is dominated by annual and perennial weeds, including Russian thistle (*Salsola iberica*), Russian knapweed (*Centaurea repens*), and cheatgrass (*Anisantha tectorum)*. The knapweed will be treated and this portion of the site will be reseeded in September 2001. Small islands around the power poles in the field contain mostly greasewood and Russian knapweed. The south end of the upland area is a weedy field with kochia and cheatgrass. Grazing restrictions will be implemented by installing fencing to improve the condition of the upland vegetation at the site.

4.10.2 Sampling and Analysis

4.10.2.1 BLRA Results

Ground water was sampled and analyzed to determine if concentrations of site-related contaminants exceeded background or maximum concentration limits established in 40 CFR 192. If ground water concentrations exceeded background, the contaminant was evaluated for potential ecological risks. Table 3.1 of the BLRA summarizes the ground water characterization results for key contaminants. Section 3.4 and Table 3.3 of the BLRA identified 27 E-COPCs that, based on the median concentrations, exceeded background ground water concentrations. Table 4–13 lists the 23 inorganic and 4 radionuclides identified in the BLRA as E-COPCs. No explanation is provided as to why three constituents (tin, zinc, and radium-226), which had concentrations that exceeded background in Table 3.1 of the BLRA, were not identified as exceeding background. It is assumed that tin and zinc were excluded because they only slightly exceeded background. It is assumed that radium-226 was excluded because the median concentration (4.9 pCi/L) within the contaminated area is just under the maximum concentration limit of 5 pCi/L (40 CFR 192). However, Table 3.3 of the BLRA, which lists E-COPCs, included radium-226 but excluded thorium-230. Tin and zinc were also excluded as E-COPCs in Table 3.3.

Because soil was remediated to standards in 40 CFR 192 under the surface remediation program, both soil and air are eliminated as media of concern for ecological receptors. However, ground water presents a possible secondary source and exposure medium. The primary concern is the possibility that contaminated ground water may be hydrologically connected to surface water, thereby creating the potential to contaminate the adjacent river or ponds. Because the San Miguel River is close to the ground water contamination, it is included for evaluation. Therefore, ground water, surface water, and associated sediments are the media of interest for ecological risk assessment. These media were selected because both direct and indirect pathways to ecological receptors are possible.

4.10.2.2 Abiotic Sampling and Analysis

Ground water data were used to determine E-COPCs for terrestrial receptors. Surface water and sediment sampling was conducted to determine E-COPCs for both terrestrial and aquatic receptors, but primarily for aquatic receptors. This section summarizes the data reported in Sections 3.0 and 7.0 of the 1995 BLRA.

Table 4–13. E-COPCs that Exceeded Background Ground Water Concentrations

Inorganics	Radionuclides
Aluminum Ammonium Antimony Arsenic Barium Boron Calcium Chloride Fluoride Magnesium Manganese Molybdenum Nitrate Phosphate Potassium Selenium Silica Silver Sodium Strontium Sulfate Uranium Vanadium	Lead-210 Polonium-210 Radium-226 Radium-228

Ground Water

Ground water sampling at the site was conducted between 1986 and 2001. However, BLRA data and interpretation addressed only the period from 1986 through 1994. Data gathered after 1995 are addressed in Section 6.2, the BLRA update. Table 4–14 lists the ground water sampling locations that were sampled from 1986 through 1994. Ground water locations 0547 and 0548 are the only locations of the 12 historical sampling locations that continue to be monitored.

Table 4–14. Ground Water Sampling Locations from 1986 through 1994

Location Number	Description	Dates Sampled	References/Comments
0505	Mill Yard/On site	1986–94	BLRA Table 3.2
0506	Tailings Pile/On site	1986–94	BLRA Table 3.2
0546[a]	Upgradient/Off site	1986–92	BLRA Table 3.2
0547[a]	Upgradient/Off site	1986–94	BLRA Table 3.2
0548	Downgradient/Off site	1986–94	BLRA Table 3.2
0549[a]	Upgradient/Off site	1987–92	BLRA Table 3.2
0616	Tailings Pile/On site	1989–92	BLRA Table 3.2
0619	Tailings Pile/On site	1989–92	BLRA Table 3.2
0630	Tailings Pile/On site	1989–92	BLRA Table 3.2
0632	Tailings Pile/On site	1989–92	BLRA Table 3.2
0637	Tailings Pile/On site	1989–92	BLRA Table 3.2
0656	Tailings Pile/On site	1990–92	BLRA Table 3.2

[a] Background Location
BLRA = Baseline Risk Assessment

Surface Water

On the basis of the E-COPCs, surface water sampling locations 0531, 0532, and 0533 were initially established in the San Miguel River channel to determine if ground water was affecting the quality of surface water. Both filtered and unfiltered samples were collected. Location 0531 was used to establish background concentrations. Four additional locations 0534, 0535, p536, and 0538) were added in 1994 (Table 4–15). Location 0538, which is referred to as a spring in the BLRA, is actually a seep that feeds into a small pond in the river floodplain. The pond eventually discharges to the river approximately 200 ft downstream. Because the seep was believed to be ground water discharging to the surface, location 0538 was discussed in the ground water section of the BLRA. The BLRA also refers to other ponds that no longer exist due to fluctuations and changes in the river's channel. All four 1994 locations were only sampled once.

Table 4–15. Surface Water Locations from 1986 to 1994.

Location Number	Description	Dates Sampled	References/Comments
0531	S.M. River/upstream	1986–94	BLRA Fig. 3.5/Table 3.5
0532	S.M. River/middle of site	1986–94	BLRA Fig. 3.5/Table 3.5
0533	S.M. River/downstream	1986–94	BLRA Fig. 3.5/Table 3.5
0534	S.M. River/south end of site	1994	BLRA Fig. 3.5/Table 3.5
0535	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.5
0536	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.5
0538	Floodplain/north end of site	1994	BLRA Fig. 3.5/Table 3.1

BLRA = Baseline Risk Assessment

Although data showed the potential for a slight increase over background for three site-related constituents (sodium, sulfate, and uranium), initial sampling and statistical evaluations indicated that the San Miguel River was not being affected. Therefore, no E-COPCs were identified for surface water at that time. However, additional sampling and analysis was recommended. Section 3.6 of the BLRA details the results of sampling.

Sediments

Sediment samples were collected at all seven surface water locations (Table 4–16) in one round of sampling in 1994. Sediment benchmarks were found for nine of the E-COPCs. The benchmarks are updated in the current ecological risk assessment in Section 6.2 of this SOWP. A qualitative assessment showed that concentrations of uranium, sulfate, and zinc appeared to be higher in downstream sediments than in upstream. Zinc was the only constituent that showed a noticeable increase over background at location 0538. The BLRA recommended that additional data be collected to confirm the results. However, it was also noted that it may not be possible to distinguish between the site-related contribution of elevated concentrations (e.g., uranium) and naturally occurring contributions.

Table 4–16. Sediment Samples Collected in 1994

Location Number	Description	Dates Sampled	References/Comments
0531[a]	S.M. River/upstream	1994	BLRA Fig. 3.5/Table 3.6
0532	S.M. River/middle of site	1994	BLRA Fig. 3.5/Table 3.6
0533	S.M. River/downstream	1994	BLRA Fig. 3.5/Table 3.6
0534	S.M. River/south end of site	1994	BLRA Fig. 3.5/Table 3.6
0535	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.6
0536	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.6
0538	Floodplain/north end of site	1994	BLRA Fig. 3.5/Table 3.6

[a] Background location
BLRA = Baseline Risk Assessment

4.10.2.3 Biotic Sampling

With the exception of wetland plants, no sampling of benthic, terrestrial, or aquatic organisms was conducted at the site before 1995. Therefore, there is no information in the BLRA or site documents addressing the analysis of these organisms.

Wetland plants were sampled once at six locations (0531–0536) in 1994. Samples were collected in areas influenced by the site-related contaminated ground water, the millsite floodplain, and in reference areas. Reference areas, or background areas, resemble the site ecologically—landform, soil, and vegetation are similar—but lack the influence of millsite-related ground water contamination. Reference areas were used for baseline chemical data for the ERA and to help project possible successional pathways. The reference areas used to evaluate risk for the millsite vegetation were locations 0531 and 0534. Spikerusk (*Eleocharis* spp.) was sampled in saturated substrate at each location. On the basis of the limited data, no consistent difference between background reference sites and site sample concentrations was noted. Table 7.2 of the BLRA lists the results for 10 selected constituents. No explanation is provided as to why these constituents were selected. It is assumed that they were selected due to the higher concentrations in on-site ground water. In addition, ground water concentrations in the alluvial aquifer were compared to screening benchmarks for terrestrial plants (BLRA, Table 7.5). Additional sampling was recommended.

4.10.3 Update

No sampling of any media was conducted between 1995 and 1997. In 1998, sampling and analysis resumed. Several additional locations were added and some of the historical locations were no longer used. Changes in sampling locations and target analytes were made on the basis of pre-1995 sampling. Details of the changes are provided in the following sections.

4.10.3.1 Abiotic Sampling and Analysis

Ground Water

Thirty-nine sampling locations were added between 1998 and 2000. Only two locations, 0547 and 0548, were retained from the original 12 (Figure 4–1), bringing the total number of ground water locations to 41. The 2001 Statement of Work reduced the list of wells to be monitored to 28. Table 4–17 summarizes monitor well locations retained for monitoring.

Table 4–17. Monitor Well Locations Retained for Monitoring

Location Number	Description	Dates Sampled	References/Comments
0547[a]	Upgradient/off site	1986–94, 1999–2001	BLRA Table 3.2/USGS data
0548	Downgradient/off site	1986–94, 1999–2001	BLRA Table 3.2/USGS data
DM1[a]	Upgradient/off site	2000–01	USGS Data
MAU03	Downgradient/off site	1998–01	USGS Data
MAU04	Downgradient/off site	1998–01	USGS Data
MAU05	Downgradient/off site	1998–01	USGS Data
MAU06	Downgradient/off site	1999–01	USGS Data
MAU07	Downgradient/off site	1999–01	USGS Data
MAU08	Downgradient/off site	1999–01	USGS Data
NAT01	Off site/downgradient	1998–01	USGS Data
NAT02	On site	1998–01	USGS Data
NAT03	On site	1998–01	USGS Data
NAT04	On site	1998–01	USGS Data
NAT06	On site	1998–01	USGS Data
NAT08	On site	1999–01	USGS Data
NAT10	On site	1998–01	USGS Data
NAT11	On site	1998–01	USGS Data
NAT15	On site	1999–01	USGS Data
NAT16	On site	1999–01	USGS Data
NAT19	On site	1999–01	USGS Data
NAT20	Upgradient/off site	1999–01	USGS Data
NAT23	Downgradient/off site	1999–01	USGS Data
NAT24	Downgradient/off site	1999–01	USGS Data
NAT25	Downgradient/off site	1999–01	USGS Data
NAT26	Downgradient/off site	1999–01	USGS Data
NAT27	On site	1999–01	USGS Data
NAT29	On site	1999–01	USGS Data
NAT30	On site	1999–01	USGS Data

[a] Background Location

On the basis of the BLRA and subsequent evaluation, DOE determined that only 19 of the original 27 E-COPCs would be sampled for in 1998 through 2000 sampling events (Table 4–18). Ammonium, antimony, fluoride, and silver were the nonradionuclides excluded. No explanation is provided in previous documentation as to why these and the four radionuclides identified in the BLRA were not retained for further sampling. Iron and zinc were added to the list for risk assessment purposes, bringing the total number of constituents to 21 (Table 4–18). For the eight constituents excluded from current sampling, the analysis of ecological risk is completed on the basis of historical (pre-1998) data.

Table 4–18. E-COPCs Selected for Analysis in the 1998–2000 Ground Water Samples

Inorganics	Radionuclides
Aluminum Arsenic Barium Boron Calcium Chloride Iron Magnesium Manganese Molybdenum Nitrate Phosphate Potassium Selenium Silica Sodium Strontium Sulfate Uranium Vanadium Zinc	None

In the *Statement of Work for Ground Water Characterization at the Naturita, Colorado UMTRA Site* for work conducted by USGS for DOE, 11 constituents were identified for future sampling (Table 4–19). Those denoted with an asterisk in the table were sampled for ecological risk assessment.

Table 4–19. Summary of 11 E-COPCs Retained for Sampling in the 2001 Statement of Work

E-COPCs Retained	E-COPCs Not Retained
Arsenic	Aluminum
Barium*	Ammonium
Boron*	Antimony
Manganese	Calcium
Molybdenum	Chloride
Nitrate	Fluoride
Selenium	Iron
Sulfate	Lead-210
Uranium	Magnesium
Vanadium	Phosphate
Zinc	Polonium-210
	Radium-226 and 228
	Silica
	Silver
	Sodium
	Strontium
	Thorium-230

The 17 E-COPCs excluded are evaluated for risk in Section 6.2 on the basis of historical data. Those retained will be evaluated based on data collected from 2000 through 2001.

Surface Water

Nine sampling locations (0558–0561, SM1–SM4, and SM9) were added from 1998 through 2001 (Figure 4–6). Four locations (0531, 0533, 0536, 0538) of the original seven were also retained, bringing the total number of surface water sampling locations to 13 through 2001. Table 4–20 summarizes surface water locations from 1998 through 2001. The 11 analytes listed in Table 4–19 for ground water were also identified for surface water analysis. Therefore, the evaluation of potential ecological risks associated with surface water for these constituents is based on 1998–2001 sampling data. E-COPCs that are not currently being analyzed are evaluated in Section 6.2 based on historical data.

Table 4–20. Surface Water Locations Sampled Between 1998 and 2001

Location Number	Description	DOE	USGS	Dates Sampled	References/ Comments
0531	S.M. River/upstream	X		1986–94, 2000–2001	BLRA Fig. 3.5/Table 3.5
0533	S.M. River/downstream	X		1986–94, 2001	BLRA Fig. 3.5/Table 3.5
0535	S.M. River/north end of site	X		1994, 2001	BLRA Fig. 3.5/Table 3.5
0536	S.M. River/north end of site	X		1994, 2001	BLRA Fig. 3.5/Table 3.5
0538	Floodplain/north end of site	X		1994, 2000–2001	BLRA Fig. 3.5/Table 3.1
0558	S.M. River/middle of site	X		2000–2001	2001 SOW
0559	S.M. River/north end of site	X		2000–2001	2001 SOW
0560	S.M. River/north end of site	X		2000–2001	2001 SOW
0561	S.M. River/middle of site	X		2000–2001	2001 SOW
SM1	S.M. River/middle of site		X	1998–2001	2001 SOW
SM2	S.M. River/middle of site		X	2000–2001	2001 SOW
SM3	S.M. River/middle of site		X	2000–2001	2001 SOW
SM4	S.M. River/middle of site		X	2000–2001	2001 SOW
SM9	S.M. River/middle of site		X	2000–2001	2001 SOW

BLRA = Baseline Risk Assessment
SOW = Statement of Work
S.M. = San Miguel

Filtered surface water samples were collected. The filtered sample represents the soluble component for aquatic receptors. Each sample bottle was first rinsed with the surface water; the rinse water was then discarded prior to sample collection. A sample was collected by immersing the bottle just below the water surface and filling to just below the mouth of the bottle. Samples were then filtered using a 0.45-µm filter and acidified for preservation.

Sample labels showing the date, time, location, laboratory bar code, sampler, analyses requested, preservatives, and comments were applied to each container and secured with clear plastic tape. All sample containers were placed in coolers containing ice for transport to the GJO Analytical Chemistry Laboratory. All samples were maintained under strict chain of custody.

Sediments

Nine sediment sampling locations (0558–0561, SM1–SM4, and SM9) were co-located with surface-water samples from 1998 through 2001 (Figure 4–6). Four locations (0531, 0533, 0536, and 0538) of the original seven were also retained, bringing the total number of sediment locations sampled through 2001 to 13.

The area for sample collection was typically a circle with a radius less than 5 ft. Excess organic matter and larger rocks and pebbles were removed from the sample prior to compositing. The contents of one stainless-steel auger (i.e., one subsample) was collected at each composite location and placed in a large stainless steel mixing pan. The material in the mixing pan was mixed thoroughly with a stainless steel spoon, and about 4 ounces (114 g) of material was removed for metals analysis.

Sample labels were applied to each container and secured with clear plastic tape. All sample containers were placed in coolers containing ice for transport to the GJO Analytical Chemistry Laboratory. All samples were maintained under strict chain of custody. The preparation method for the sediment samples included a complete acid digestion rather than an acid leach as was used for some previous sediment analyses.

4.10.3.2 Biotic Sampling and Analysis

No biotic sampling was conducted between 1998 and 2001, no further sampling of vegetation or other biota is currently planned. If future ecological risks are suspected, DOE will consider further sampling at that time.