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Rev. 1

Final Site Observational Work Plan for the UMTRA Project Old Rifle Site

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Prepared by
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Grand Junction Office
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Appendices - **Will be provided upon request. Email lm.records@gjo.doe.gov to request**

Acronyms and Abbreviations

ACL	alternate concentration limit
AEC	Atomic Energy Commission
ASTM	American Society of Testing Materials
BLRA	baseline risk assessment
cfs	cubic feet per second
COC	contaminants of concern
COPC	contaminants of potential concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ET	evapotranspiration
ft	foot (feet)
ft/day	foot (feet) per day
ft^2/day	square feet per day
gal	gallon(s)
GCAP	Ground-Water Compliance Action Plan
GJO	Grand Junction Office
gpm	gallons per minute
HEW	U.S. Department of Health, Education, and Welfare
HI	hazard index
HQ	hazard quotient
i.d.	inside diameter
K_d	distribution coefficient
kg	kilogram
L	liter(s)
L/s	liter(s) per second
MAP	management action process
MCL	maximum contaminant level
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliters
mL/g	milliliters per gram
µg/L	micrograms per liter
mm	millimeters
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
o.d.	outside diameter
pCi/L	picocuries per liter
pCi/g	picocuries per gram
PEIS	Programmatic Environmental Impact Statement
PVC	polyvinyl chloride
RAP	remedial action plan
RBC	risk based concentration
rpm	revolutions per minute
RRM	residual radioactive material
SDWA	Safe Drinking Water Act

SOWP	site observational work plan
TAGR	*Technical Approach to Ground Water Restoration*
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U. S. Geological Survey

Executive Summary

Ground water beneath the Old Rifle, Colorado, site was contaminated by former vanadium and uranium ore-processing operations that were ongoing from 1924 through 1958. Mill tailings and other associated radioactive contaminated surface materials were removed from the site by 1996 in accordance with criteria established in 40 CFR Part 192 Subpart A as part of the Uranium Mill Tailings Remedial Action (UMTRA) Surface Project. However, the potential for infiltration of ground water contaminants remained until that time. It is also possible that residual contamination, particularly from nonradiological constituents, is a potential continuing source of ground water contamination.

Site-specific field investigations reveal the alluvial ground water is the only aquifer affected by the former milling operations. Contaminants of concern (COCs) in the alluvial aquifer are identified as arsenic, selenium, uranium, and vanadium. Uranium is the most prevalent site-related contaminant occurring in the alluvial ground water. Concentrations up to 0.27 milligrams per liter (mg/L) present beneath the site exceed the UMTRA maximum concentration limit of 0.044 mg/L, but steadily decrease to background levels near the downgradient edge of the site. Similarly, selenium concentrations exceeding the 0.01 mg/L UMTRA standard are present up to 0.09 mg/L near the center of the former tailings footprint and also decrease to background levels near the downgradient edge of the site. No ground water standards have been established for vanadium. However, concentrations up to 0.77 mg/L are present near the former tailings footprint which exceed the 0.33 mg/L human health risk-based concentration. Arsenic concentrations in ground water exceed maximum acceptable levels for human health risk at a single location near the center of the former tailings pile footprint, however these concentrations are less than the UMTRA maximum concentration limit of 0.05 mg/L.

DOE’s goal is to implement a cost-effective strategy to remediate the ground water at the former Old Rifle mill site that complies with the U.S. Environmental Protection Agency (EPA) ground water standards and protects human health and the environment. The requirements for ground water compliance for UMTRA Project sites, including the Old Rifle site, are found in the Uranium Mill Tailings Radiation Control Act (42 USC §7901 *et seq.*) and EPA’s Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40 CFR Part 192; 60 FR 2854). The compliance framework was developed in the UMTRA Ground Water programmatic environmental impact statement (DOE 1996c).

The proposed compliance strategy to cleanup the alluvial ground water at the Old Rifle Site is no ground water remediation of constituents that do not pose a potential risk and do not exceed EPA standards. For constituents that pose a potential risk or exceed EPA standards or both, the strategy is to perform natural flushing ground water remediation in combination with the establishment of alternate concentration limits (ACLs) and institutional controls.

Numerical modeling of ground water flow and transport indicates that concentrations of uranium will decrease to UMTRA standards or background concentrations during the 100-year natural flushing period. ACLs proposed for selenium and vanadium are 0.05 mg/L and 0.33 mg/L, respectively. The selenium ACL is the maximum contaminant level established in the Safe Drinking Water Act. The vanadium ACL is the risk-based level for human health that is protective for residential use of drinking water. The proposed ACLs will be met within the

100-year natural flushing period as demonstrated by ground water flow and transport modeling. The ACLs are protective of human health and the environment. Institutional controls in the form of a deed restriction will prohibit ground water use during the period of natural flushing and ground water monitoring will be conducted to observe the progress of remediation. Information presented in this final site observational work plan supports the proposed compliance strategy in a manner that is consistent with the regulatory compliance framework.

1.0 Introduction

1.1 Purpose and Scope

The Old Rifle Uranium Mill Tailings Remedial Action (UMTRA) Project site is a former ore-processing facility located approximately 0.3 mile east of the city of Rifle in Garfield County, Colorado (Figure 1–1). The site is situated on a relatively low-lying alluvial terrace created by a flood-plain meander of the Colorado River. The terrace is bounded on the south side by a steep slope that abruptly descends to the river and on the other sides by steeply ascending slopes of the more resistant sedimentary rocks of the Wasatch Formation.

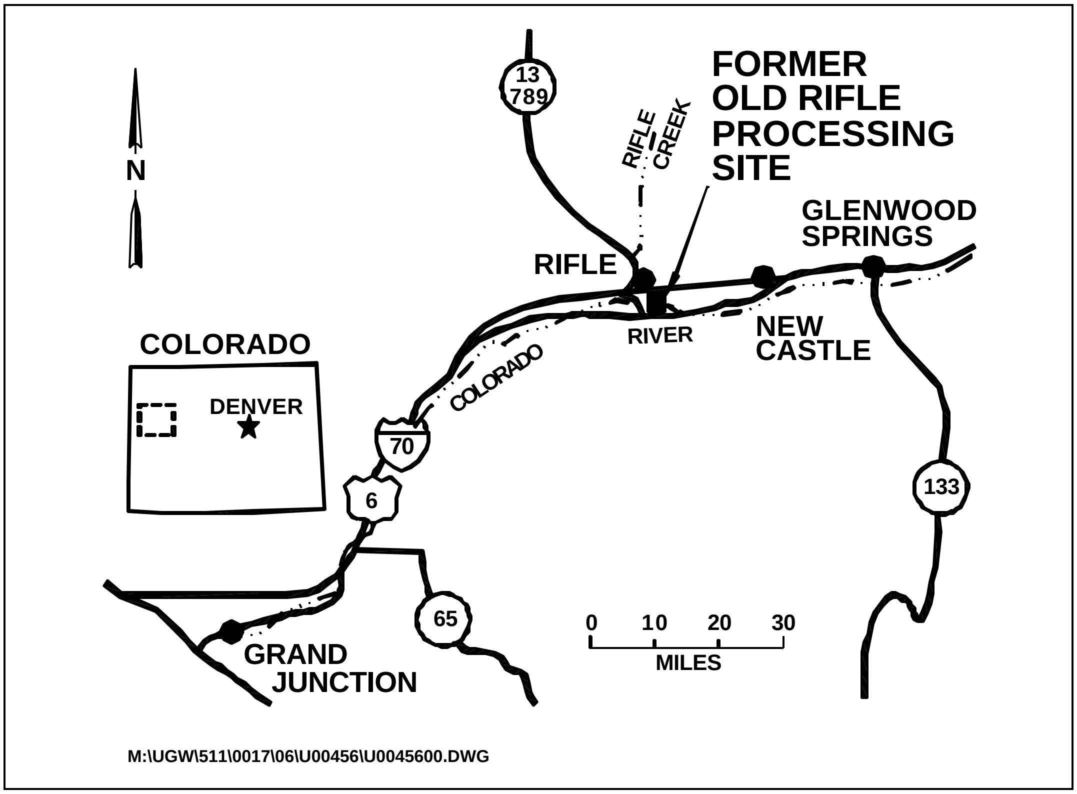

Figure 1–1. Location of the Old Rifle Site

The U.S. Department of Energy (DOE) completed surface remediation of abandoned uranium mill tailings and other contaminated surface radioactive material associated with the former milling operation at the site by relocating the contaminated materials to the Estes Gulch disposal cell approximately 9 miles north of Rifle. Surface remedial action began in 1992 and was completed in 1996. The former processing site is currently covered and regraded with clean fill material and reseeded with range grasses.

DOE's goal is to implement a cost-effective compliance strategy that is protective of human health and the environment by remediating contaminated ground water at the Old Rifle site. The proposed compliance strategy to cleanup the alluvial ground water at the Old Rifle site is no ground water remediation of constituents that do not pose a potential risk and do not exceed U.S. Environmental Protection Agency (EPA) standards. For constituents that pose a potential risk or exceed EPA standards or both, the strategy is to perform natural flushing ground water remediation in combination with the establishment of alternate concentration limits (ACLs) for selected constituents (selenium and vanadium). Institutional controls will prohibit ground water use during the natural flushing period and ground water monitoring will be conducted to observe progress of remediation.

This final site observational work plan (SOWP) documents the site-specific strategy that will allow DOE to comply with EPA ground water standards at the Old Rifle UMTRA Project site and provides a mechanism for stakeholder participation, review, and acceptance of the recommended remedial alternative. Site-specific data are presented that support the proposed strategy.

Compliance requirements for meeting the regulatory standards at the Old Rifle site are present 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 1998 field investigations conducted at the site 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. 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 is presented in Section 7.0.

1.2 UMTRA Project Programmatic Documents

Programmatic document that guide the SOWP include the *UMTRA Groundwater Management Action Process* (MAP) (DOE 1998a), the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996c), and the *Technical Approach to Groundwater Restoration* (TAGR) (DOE1993b). 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 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 1992) provides early site characterization information. This information was updated in developing the SOWP to strengthen the site conceptual model. After a ground water compliance strategy is selected for this site, a draft and final Ground Water Compliance Action Plan (GCAP) will be prepared to document the remediation decision.

In 1996, a baseline risk assessment (BLRA) was prepared (DOE 1996a) 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 assessment) will be prepared, if required by the NEPA process, to determine the potential effects, if any, of implementing the proposed compliance strategy.

1.4 SOWP Revisions

The SOWP is a multi-year process of sequenced document preparation and field data-collection activities consisting of two versions: Revision 0 (draft) and Revision 1 (final).

The draft SOWP was prepared in 1996 and included all previous information about the site, presented a proposed compliance strategy, and defined additional data needs that were required to support the most likely compliance strategy. Following stakeholder review and resolution of comments, field work was conducted in 1998 to address the data gaps identified in the draft SOWP.

This final SOWP presents the additional data collected in 1998, correlates the data to previous information, updates the site conceptual model and risk assessment, and recommends a final compliance strategy based on the most current information.

2.0 Regulatory Framework

This section identifies the regulatory framework to be applied to the selected ground water compliance strategy at the former Old Rifle millsite to achieve compliance with Subpart B of EPA health and environmental protection standards for uranium and thorium mill tailings (40 CFR Part 192) and the final rule to the standards published in 60 FR 2854.

2.1 Uranium Mill Tailings Radiation Control 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.

Three UMTRCA titles apply to uranium ore-processing sites. Title I designates 24 inactive processing sites for remediation. It directs EPA to promulgate standards, mandates remedial action in accordance with these standards, stipulates that remedial action be selected and performed with the concurrence of the U.S. Nuclear Regulatory Commission (NRC) and in consultation with the states and Indian tribes, directs NRC to license the disposal sites for long-term care, and directs DOE to enter into cooperative agreements with the affected states and Indian tribes. Title II applies to active uranium mills. Title III applies only to certain uranium mills in New Mexico. The UMTRA Project is responsible 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.

2.1.1 EPA Ground Water Protection Standards

UMTRCA requires EPA to promulgate standards for protecting public health, safety, 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).

The standards (60 FR 2854) address two ground water contamination scenarios: (1) future ground water contamination that might occur from tailings material after disposal cell construction, and (2) the cleanup of residual contamination from the milling process at the processing sites that occurred before disposal of the tailings material. The UMTRA Surface Project is designed to control and stabilize tailings and contaminated soil. The UMTRA Ground Water Project addresses ground water contamination at the processing sites and is regulated by Subparts B and C of 40 CFR Part 192.

2.1.1.1 Subpart B: Standards for Cleanup of Land and Buildings

Subpart B, "Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites," requires documentation that action at the former ore-processing sites ensures that ground water contamination meets any of the following three criteria:

- Background levels, which are concentrations of constituents in nearby ground water not contaminated by ore-processing activities.
- UMTRA maximum concentration limits, which are limits set by EPA for certain hazardous constituents in ground water and are specific to the UMTRA Project (Table 2–1). Note that maximum contaminant levels (MCLs) have also been established for some of these constituents by EPA under the Safe Drinking Water Act (SDWA) (also provided in Table 2–1). Most of the UMTRA standards are the same as the MCLs for corresponding contaminants, but some differences do exist.
- ACLs which are concentration limits for hazardous constituents that do not pose a substantial hazard (present or potential) to human health or the environment as long as the limit is not exceeded.

Table 2–1. Standard for Inorganic Constituents in Ground Water at UMTRA Project Sites[a]

Constituent	**UMTRA**[b]	**SDWA**[c]
Arsenic	0.05	0.05
Barium	1.0	2.0
Cadmium	0.01	0.005
Chromium	0.05	0.1
Lead	0.05	N/A
Mercury	0.002	0.002
Molybdenum	0.1	N/A
Nitrate (as N)	10.0[d]	10.0[d]
Selenium	0.01	0.05
Silver	0.05	N/A
Combined radium-226 and radium-228	5 pCi/L	5 pCi/L
Combined uranium-234 and uranium-238	30 pCi/L[e]	N/A
Gross alpha-particle activity (excluding radon and uranium)	15 pCi/L	15 pCi/L

[a] Concentrations reported in milligrams per liter (mg/L) unless otherwise noted.
[b] Maximum Concentration of Constituents for Groundwater Protection, UMTRA Standard (40 CFR Part 192, Table 1, Subpart A).
[c] Maximum Contaminant Levels, Safe Drinking Water Standard (40 CFR 141.23 and 141.62).
[d] Equivalent to 44 mg/L nitrate as NO_3.
[e] Equivalent to 0.044 mg/L, assuming secular equilibrium of uranium-234 and uranium-238.

N/A = not applicable
pCi/L = picocuries per liter.

Natural Flushing to Achieve Standards

Subpart B also allows 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, UMTRA 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 and the environment 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 for a public water system subject to provisions of the SDWA during the period of natural flushing.

2.1.1.2 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 will be stated in a site-specific GCAP. The plan must contain a compliance strategy and a monitoring program, if necessary.

Supplemental Standards

Under certain conditions, DOE may apply supplemental standards to contaminated ground water in lieu of background levels, UMTRA maximum concentration limits, 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 environmental harm that is clearly excessive, compared to the health benefits of remediation, to persons living on or near the sites, 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 impractical from an engineering standpoint.
- The ground water is classified as limited-use ground water. Subpart B of 40 CFR Part 192 defines limited-use ground water as ground water that is not a current or potential source of drinking water because total dissolved solids (TDS) exceed 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 supply systems; or the quantity of water available to a well is less than 150 gallons (gal) (570 liters [L]) 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.

2.1.2 Cooperative Agreements

UMTRCA requires that remedial action include full participation of the states and Indian tribes that own land containing uranium mill tailings. UMTRCA also directs DOE to enter into cooperative agreements with the states and Indian tribes.

2.2 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 contained 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 1993a).

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 NEPA document 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 must comply with the Record of Decision.

3.0 Site Background

The Old Rifle UMTRA Project site is located in western Colorado, approximately 0.3 miles east of the city of Rifle (Figure 1–1). The 22-acre site, which is accessible by U.S. Highway 6, is the location of a former vanadium and uranium mill that operated from 1924 through 1958. An overview of the site's physical setting and climate, a history of the former milling operation, a summary of previous investigations, and the city of Rifle's current land and water use plan is presented in the following sections.

3.1 Physical Setting and Climate

The former millsite is located near the northeastern edge of the Colorado Plateau Physiographic Province. The area is characterized by mature, stream-eroded upland pediment surfaces, large structural upwarps and intervening basins, and flat-topped basalt mesas. Major features include the Roan Cliffs to the northwest, the Grand Hogback monocline to the north and northeast, and the Colorado River and Taughenbaugh Mesa along the northern flank of the Battlement Mesa to the south. Topographic elevations range from approximately 5,300 feet (ft) above mean sea level at the site to 8,000 ft along the Grand Hogback to the north and to more than 10,000 ft on top of the Battlement Mesa to the south. The region has an arid to semiarid climate with high evaporation, low precipitation, low humidity, and large temperature variations.

The weather station closest to the Rifle site is operated by the National Weather Service (station number 57031) which is located a few miles to the southeast of the city. Climatological data collected from the weather station for the period 1910 through 1997 is presented in Table 3–1 and indicates the site receives on average approximately 11.0 inches of total precipitation per year. Rainfall occurs during the summer in high-intensity, short-duration, late afternoon thunderstorms that are conducive to runoff. Precipitation occurs in the winter as snowfall.

Table 3–1. Meteorological Data for Rifle, Colorado

Month	Air Temperature (°F)			Precipitation (inches)	Potential Evaporation (inches)
	Mean Low	Mean	Mean High		
January	8.9	22.6	36.3	0.83	0.0
February	16.2	29.9	43.6	0.71	0.0
March	24.0	38.6	53.5	0.88	0.62
April	31.3	47.6	64	0.94	1.67
May	38.7	56.2	73.7	0.95	2.98
June	45.1	64.6	84.0	0.70	4.13
July	51.8	70.8	89.9	1.00	5.33
August	50.2	68.9	87.5	1.08	4.6
September	41.3	60.4	79.4	1.05	3.12
October	31.0	49.1	67.2	1.13	1.73
November	21.3	36.3	51.3	0.83	0.25
December	12.4	25.8	39.2	0.91	0.0
Annual	31.0	47.6	64.1	11.0	

Temperatures show considerable diurnal and seasonal variations. Winters are cold, with average low temperatures typically below freezing from December through February. Summers are hot, with average high temperatures up to 90 F in July.

Potential evaporation (inches) for the Rifle area was estimated based on the Thornthwaite equation (Thornthwaite and Mather 1957) using the site air temperature data presented in Table 3–1 (Calculation Set U0044700). The data indicates potential evaporation exceeds precipitation from April through October. The highest potential evaporation occurs in July when evaporation exceeds 5 inches.

3.2 Site History

The U.S. Vanadium Company constructed the original Old Rifle processing plant in 1924 for the production of vanadium (Merritt 1971) (Figure 3–1, June 1987). In 1926 the assets of the U.S. Vanadium Company were purchased by Union Carbide and Carbon Corporation (Union Carbide), and the U.S. Vanadium Corporation was established as a subsidiary (Chenoweth 1982). The plant closed in 1932 as a result of a shortage of vanadium ore. In 1942 Union Carbide reactivated the plant for vanadium production as a result of an increase in demand due to World War II. The plant continued to operate until 1946 when it was modified to include the recovery of uranium as well as vanadium. Uranium and vanadium production continued until 1958 when the plant was replaced with a new mill located approximately 3 miles west of the Old Rifle site.

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Figure 3–1. Former Tailings Pile, Ore Storage Area, and Associated Buildings at the Old Rifle Site

Millfeed consisted of raw ore mined from deposits located primarily in Garfield (Garfield and Rifle Mines), Mesa, Montrose, Moffat (Meeker Mine), and San Miguel Counties in Colorado (Chenoweth 1982). Atomic Energy Commission (AEC) records from 1947 to 1958 indicate that 761,000 tons of ore were processed at the site. Over 2,000 tons of uranium concentrate (U_3O_8) were sold to the AEC (Chenoweth 1982).

Approximately 13 acres of tailings remained at the Old Rifle site before the surface remedial action. No structures remained at the millsite. The relatively flat tailings pile was stabilized by Union Carbide in 1967 in accordance with the State of Colorado regulations. The edge of the pile was moved away from the railroad tracks and the entire pile was covered with 6 inches of soil, fertilized, and seeded with native grasses. Water from the Colorado River was used for irrigation. Surface water draining from an upgradient seep across U.S. Highway 6 flowed through the site. The seep water collected in a lined pond after it passed the tailings pile. Overflow from the pond was released into the Colorado River. The pond and tailings were removed during surface remedial action completed in 1996.

3.2.1 Previous Investigations

The U.S. Department of Health, Education, and Welfare (1962) and Merritt (1971) provide detailed descriptions of the uranium concentration process, mill by-products, and process waste streams. Albrethsen and McGinley (1982) summarizes the history of the domestic uranium procurement policies and practices under the AEC.

Fischer (1960) and Chenoweth (1982) document the vanadium and uranium deposits located along East Rifle Creek approximately 15 miles north of the site. Geologic studies conducted in the area of the site are reported by the U.S. Geological Survey (Donnell 1969; Shroba and others 1995) and the Colorado Geological Survey (Stover 1993).

Site-specific hydrogeologic and geochemical investigations are described in an Environmental Impact Statement (DOE 1990), a RAP (DOE 1992), a BLRA (DOE 1996a), and the draft SOWP (DOE 1996d).

3.3 Land and Water Use

The population of the city of Rifle is approximately 6,000. The town contains businesses, industrial areas, and residential neighborhoods. There are no residences adjacent to the site. The nearest residence is located approximately 500 ft northwest of the site fence line across U.S. Highway 6. Ranching and farming are the main land uses on Graham Mesa north and northeast of the Old Rifle site. Several sand and gravel mining operations occur along the floodplain east of the site. Figure 3–2 presents a land use map for the Old Rifle Site and surrounding areas, with information derived from city of Rifle, and Garfield county sources during 1998.

The site is located just outside the Rifle city limits and is under the jurisdiction of Garfield County (Figure 3–2). The site is located within the 100-year floodplain and is currently zoned by Garfield County for agricultural/industrial use.

The City of Rifle’s Comprehensive Plan identifies the land within the Old Rifle Site boundaries as being in a zone called “Environmental Education/Open Space Preserve.” This designation would allow for open space/agriculture, wildlife habitat enhancement, environmental education, passive recreation, agriculture, and mine reclamation land use at a future date if the property is annexed by the City of Rifle.

The site is currently deeded to the State of Colorado. Plans to transfer the land to the community are in progress.

3.3.1 Potable Water Use

Residents in the city of Rifle obtain potable water from the municipal water system, which receives surface water from the Colorado River and Beaver Creek. Water from the Colorado River is collected at an inlet approximately 0.5 mile upstream of the site. Water in Beaver Creek originates from Beaver Mountain snowmelt and precipitation across the river approximately 5 miles southwest of the city and is transported into the municipal water supply via a pipeline. Beaver Creek supplies approximately 10 percent of the city's municipal water.

The city provides potable water to some users outside the city limits, though most residents living outside the municipal boundaries obtain water from private wells or springs (DOE 1996a). Natural ground water quality in the Colorado River alluvium and weathered bedrock is poor tasting and considered unpalatable because of high sulfate and TDS levels. Consequently, the ground water from these private wells and springs generally is not used for drinking water unless treated. Ground water is known to be used for other domestic purposes such as bathing, watering domestic livestock, and watering gardens. The nearest residential well (location 436) is located approximately 1.5 miles upgradient (east) of the site and north of U.S. Highway 6.

3.3.2 Irrigation Water Use

Agriculture has been the Rifle region's primary industry since the late 1920s. Since the Rifle region has been heavily irrigated for decades, both regional and local water quality has been impacted. Springs and other shallow water sources have been created due to irrigation. As irrigation use in the region increased, it became apparent that the Grass Valley Reservoir south of Rifle could not supply all the demand. Initial investigations to expand the irrigation potential for the area were conducted by the Bureau of Reclamation in 1936. Funding for what is referred to as the Silt Project was authorized in 1956. The project was awarded in 1964 and completed in 1967.

Primary achievements of the Silt project were the construction of the Rifle Gap Dam and Reservoir and the Silt Pumping Plant. The Rifle Gap Reservoir is located on Rifle Creek about 5.5 miles north of Rifle at a point where Rifle Creek cuts through the Grand Hogback. Surface runoff from north of Rifle Gap are stored in the reservoir and releases are made to meet downstream irrigation demands. Harvey Gap Reservoir, which previously ran low every year, is now used only after water storage in the Rifle Gap Reservoir has been depleted, thus providing a longer irrigation season. Graham and Prefontaine Mesas, north of the Old Rifle site, are some of the most heavily irrigated areas in the Rifle area (Lemon 1995).

The Silt Pumping Plant is located approximately 5 miles east of Rifle on the Colorado River. The 7.6 mile pump canal, that extends northwest from the pumping plant discharge line, carries

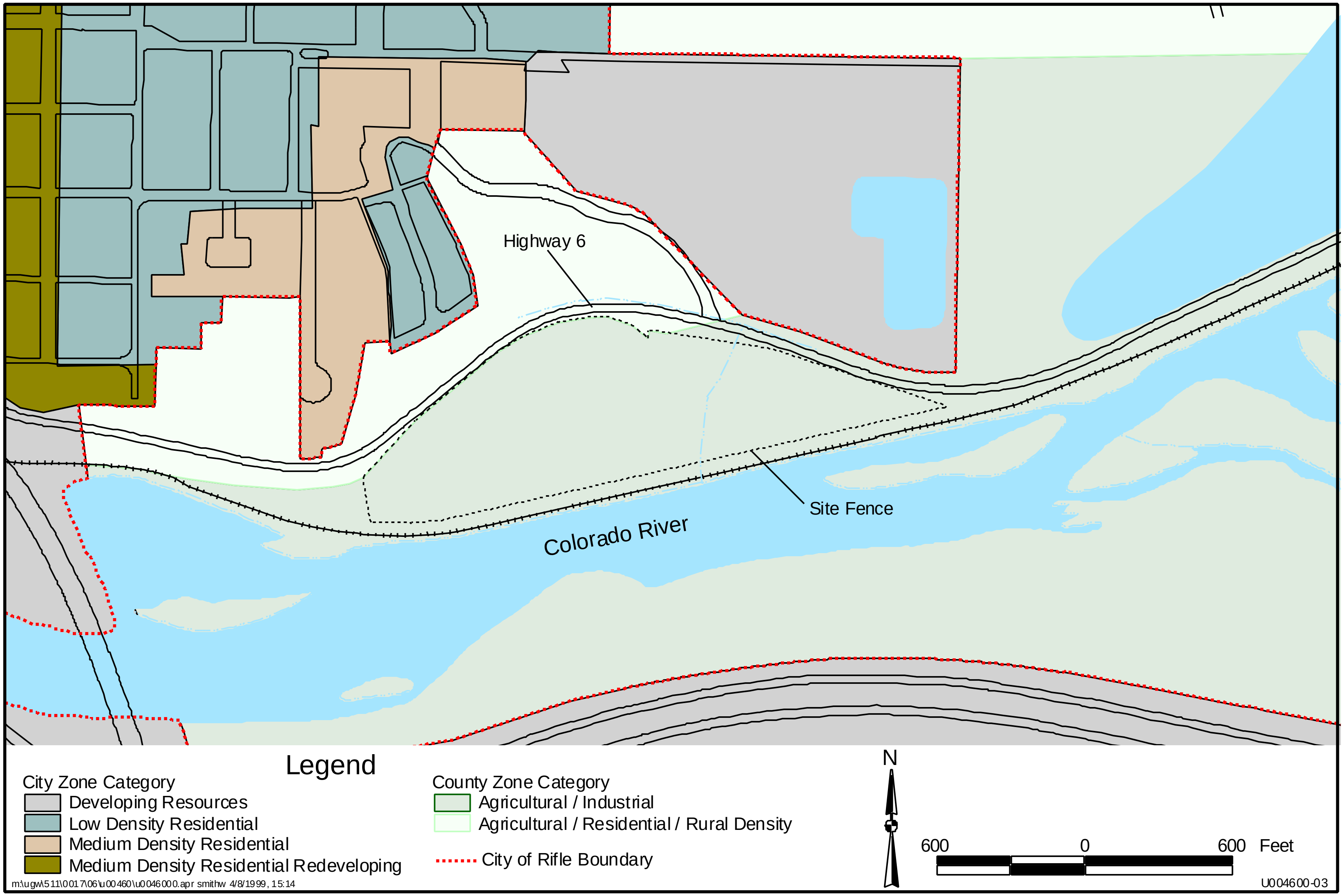


Figure 3–2. Land Use Map for the Old Rifle Site and Surrounding Areas

irrigation water via the Lower Cactus Valley Ditch from the river to low lying mesas between Silt and Rifle. The Lower Cactus Valley Ditch discharges to the One Mile Pond area just east of the Old Rifle site during spring and summer. Irrigation in the Rifle area generally lasts from April through November each year. The quantities of surface runoff collected annually in the Rifle Gap Reservoir and pumpage from the Colorado River at Silt, both influence the amount of water which is released from storage at the Harvey Gap Reservoir. Since the various irrigation sources each have different water quality, and relative regional contributions change on an annual basis as a result of changes in annual precipitation and demand, irrigation in the Rifle area has a significant and variable influence on local ground water flow and water quality in the vicinity of the Old Rifle site.

4.0 1998 Field Investigations

The draft SOWP (DOE 1996d) included all previous information collected about the site, presented a proposed compliance strategy, and defined additional data needs that were required to support the most likely compliance strategy. Following stakeholder review and resolution of comments, a field investigation was conducted in 1998 to address the data gaps identified in the draft SOWP. Specifically, data was collected to: (1) evaluate if ground water contaminants in the alluvial aquifer will flush naturally in 100 years or less, (2) determine if the alluvial aquifer qualifies for supplemental standards on the basis of widespread ambient contamination, and (3) estimate the incremental risk imposed by mill-related contamination in the alluvial aquifer.

All fieldwork and data quality objectives applied to the data collection activities were performed in accordance with the *Work Plan for Characterization Activities at the UMTRA Project New and Old Rifle Sites* (DOE 1998b). Sequencing the activities to achieve a more logical data collection strategy optimized field investigations. The field activities were sequenced as follows: (1) installation of temporary alluvial wells, (2) coring, soil sampling, and installation of permanent alluvial and bedrock monitor wells, (3) surveying elevation and location coordinates of wells, (4) ecological and ground water sampling and analyses, (5) abandonment of temporary alluvial wells, and (6) performing continuous aquifer tests.

Information obtained from each of the above activities was integrated with existing data to revise the site conceptual model and to refine the data collection needs. This integration was performed either concurrently with or before proceeding to the next characterization activity. Data collection results for the 1998 field investigation and the laboratory analyses are presented in this section. Discussion, interpretation, and integration of the 1998 results with historical information are presented in the subsequent Site Conceptual Model (Section 5.0).

4.1 Temporary and Permanent Ground Water Monitor Well Installation

Temporary and permanent monitor wells were installed to collect water samples for the characterization of the ground water quality and to provide a means to determine hydraulic properties of the alluvial and bedrock aquifers. Installation procedures, construction details, and locations for the wells are described in this section.

Ten temporary wells were installed at the Old Rifle site to provide water quality samples and ground water elevation data to assist in optimizing the location for the permanent monitor wells. A casing-advance air drilling method was used to advance the temporary borehole to the base of the alluvial aquifer. A 2-inch diameter polyvinyl chloride (PVC) well casing was then installed through the inside of the drill casing. The well was constructed with a 5-ft section of machine slotted PVC screen (0.02 inch slot size) at the bottom of the well casing and completed with a natural sand pack. A 3-ft bentonite seal was placed above the natural sand pack to stabilize and secure the well casing so accurate water level measurements could be performed and to seal the borehole from infiltration of surface water. The temporary wells are identified by the 300 series locations (RFO–301 through –310) shown in Figure 4–1.

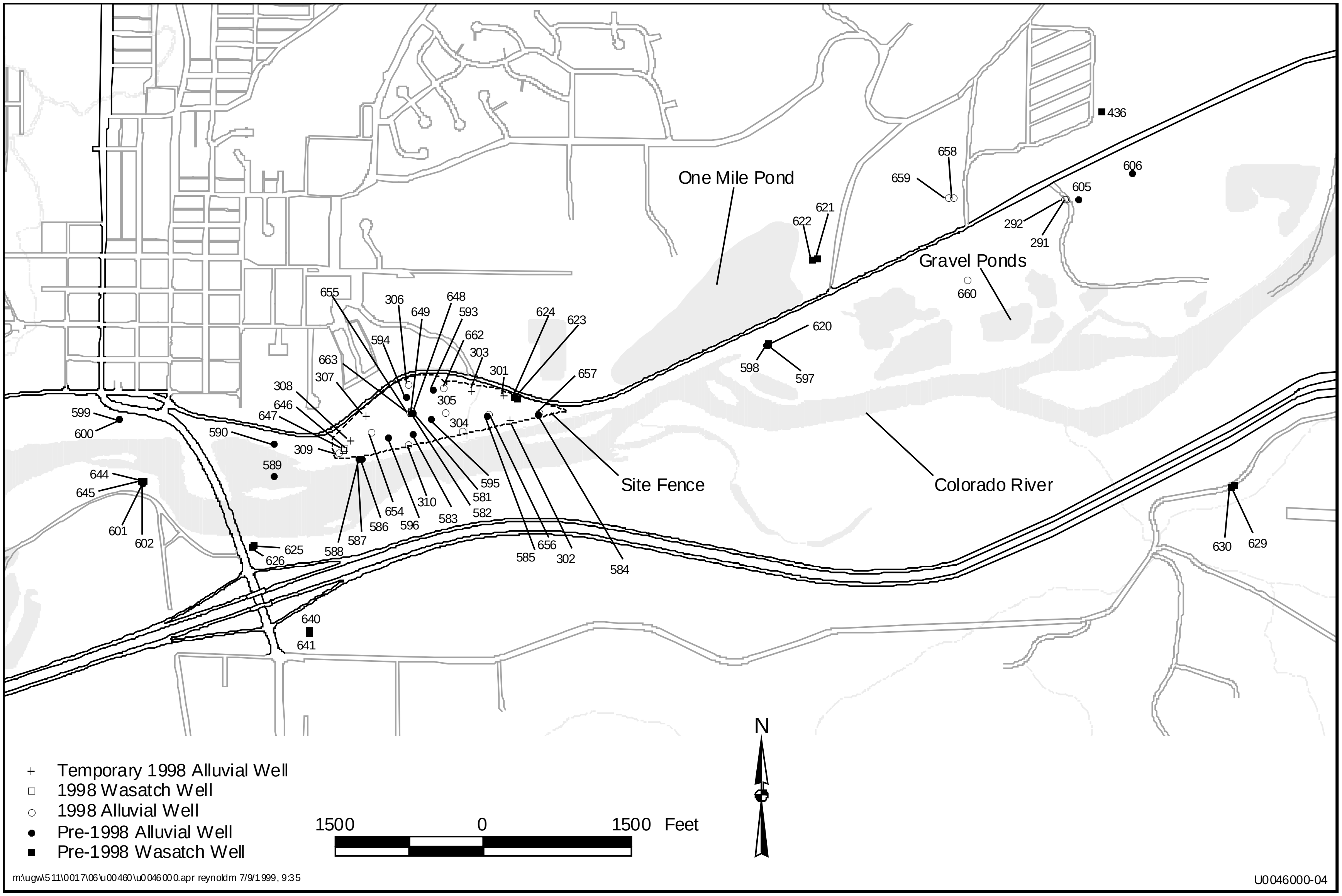


Figure 4–1. Ground Water Monitor Well Locations at the Old Rifle Site

Upon installation of the temporary monitor wells the top of each casing was surveyed for elevation and location coordinates, the depth to water was measured, and water samples collected for chemical analyses. After evaluation of the water level measurements and the chemical analysis results, it was decided to retain five of the temporary wells (RFO–304, –305, –306, –309, and –310) as permanent wells for future ground water monitoring. Therefore for these wells, the annular space above the bentonite seal was filled with concrete to the ground surface and a 3-ft diameter well pad with a locking steel protective cover was installed. The five remaining temporary well casings (RFO–301, –302, –303, –307, and –308) were removed and the holes properly abandoned in accord with the State of Colorado Water Well Construction Rules (2 CCR 402–2).

A total of 15 additional permanent monitor wells were installed during the course of the field investigation. Five of the wells (RFO–291, –292, –658, –659, and –660) were installed in background areas east of the site to characterize the upgradient alluvial ground water that is unaffected by the former vanadium and uranium processing operations. Ten wells were installed on-site for the purpose of characterizing the nature and extent of ground water contamination and to determine the hydrologic properties of the aquifers; six were installed in the alluvial aquifer (RFO–654, –655, –656, –657, –662, and –663) and four in the bedrock aquifer (RFO–646, –647, –648, and –649). These permanent monitor well locations are shown in Figure 4–1.

All permanent alluvial and bedrock wells were completed with 4-inch or 2-inch i.d., flush-joint, threaded, PVC casing and wire-wrapped screen (0.02 in slot size). Two of the 11 alluvial monitor wells and all four of the bedrock wells were completed with 4-inch casings so that aquifer testing could be performed. The remaining nine alluvial wells were all completed with 2-inch casings. With the exception of four background wells located upgradient (east), all the alluvial monitoring wells were screened over the entire saturated thickness in which most cases was 20 ft or less. The saturated thickness was greater than 20 ft in several background areas. For this reason, four background alluvial wells were installed as pairs (RFO–291/–292 and –658/–659) with a shallow well completed with a 10- or 15-ft screened interval, the top of which is located at the water table, and a deep well completed with a 15-ft screened interval, the bottom of which is at the bottom of the alluvial aquifer. The alluvial well pairs with screens at different depths allows vertical characterization of the aquifer’s water quality that may be influenced by lithology changes due to deposits of silt, sand, and gravel transported by the Colorado River from source areas east of the site that are interbedded with colluvial Wasatch material eroded from outcrops to the north.

The four permanent bedrock monitor wells installed on-site consist of two paired completions (RFO–646/–647 and –648/–649). At each paired location, a shallow well was completed with a 10-ft screen beginning 10 ft below the contact between the alluvium and Wasatch Formation. The other bedrock well was completed deeper with a 10-ft screen beginning 30 ft below the contact. The bedrock well pairs with screens at different depths provide information to evaluate the potential impact from the overlaying alluvial plume and the vertical hydraulic gradients in the shallow Wasatch Formation. Drilling and completion techniques to avoid cross-contamination of the Wasatch Formation when drilling the bedrock wells included using an ODEX casing-advance type drilling rig and setting surface casing down into competent bedrock and then drilling through the cement plug into the deeper formation.

The permanent wells were constructed with a medium-grained sand pack (10–20 sieve size) placed in the annular space from the bottom of the borehole to 2 ft above the top of the well screen. A fine-grained sand pack (20–40 size) was placed to fill 2 ft of the annular space above the medium-grained sand. Both sand packs consist of clean quartz sand. A 3-ft bentonite seal

was placed above the fine-grained sand pack. Enviroplug grout was used to fill the annular space above the bentonite seal to within 3 ft of ground surface. Concrete was used to fill the remaining annular space to the ground surface and to install a 3-ft diameter well pad with a locking steel protective cover. Completion diagrams for the alluvial monitor well installations and the Wasatch well pairs are presented in Figure 4–2 and Figure 4–3, respectively.

The following procedures from the *Environmental Procedures Catalog* (GJO 1998) were used for monitoring well installation.

- LQ–14(P), "Technical Comments on ASTM D 5092—Standard Practice for Design and Installation of Ground Water Monitor Wells in Aquifers."
- GN–13 (P), "Standard Practice for Equipment Decontamination."

Construction details for new water wells installed during the 1998 field investigation and for existing wells are provided in Appendix A and summarized in Table 4–1.

4.2 Soil, Sediment, and Rock Sampling

Soil, sediment, and rock samples were collected during the installation of the temporary and permanent monitor wells (Section 4.1) for lithologic logging (Section 4.3) and chemical analysis (Sections 4.4 and 4.5). Lithologic logs were prepared for all monitor well boreholes to support development of the site hydrogeologic model. Sediment, soils, and rock samples were collected for chemical analysis to determine distribution coefficients (K_d) and mobile fractions of site-related constituents in the subpile soils to aid in characterizing subsurface contaminant transport.

A truck-mounted Mobile B–80 drilling rig equipped with a downhole air hammer was used to advance casing through the alluvial aquifer to bedrock. During the drilling the air was continuously returned to the surface inside the casing where it was diverted to a cyclone sampler. Samples of the drill cutting entrained in the return air were collected at the cyclone's discharge every 5 ft of depth drilled.

Split-barrel sampling was conducted with the truck-mounted casing-advance drilling rig centered over the sample location. After advancing the casing to the desired sampling depth a 3-inch o.d. by 24-inch-long split-barrel sampler was lowered inside the casing to the top of the sample interval. A 140-pound drop hammer was then used to drive the split-barrel sampler the required 2 ft or until penetration was less than 6 inches per 50 blows. The barrel was then removed from the borehole, separated from the drive-rod assembly, and laid flat on an uncontaminated surface, where the head and drive shoe were removed. One-half of the split barrel was removed to expose the sample. The uppermost portion of sample in the split barrel was inspected for slough and the slough discarded, if present. The site geologist logged the remaining representative sample.

Continuous core samples of the Wasatch Formation were collected using a nominal 5-ft long, double tube, swivel-type, NX diamond core barrel and wireline system. Clean water was used as the circulation medium. State-of-the industry coring practices were used to effect the highest

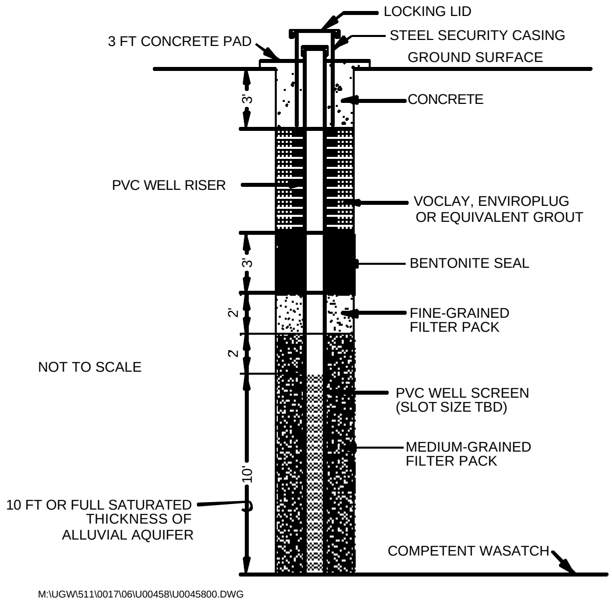


Figure 4–2. Completion Diagram for Water Wells Installed in the Alluvial Aquifer

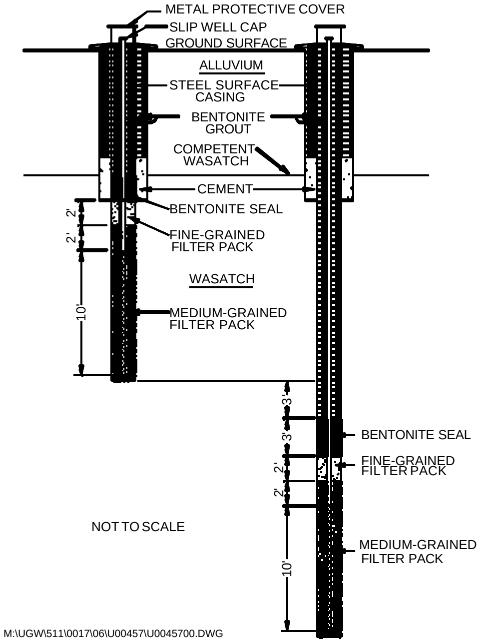


Figure 4–3. Completion Diagram for Well Pairs Installed in the Wasatch Formation

Table 4–1. Construction Details for Water Wells at the Old Rifle Site

Location Code	North Coord. (State Plane)	East Coord. (State Plane)	Ground Elev. (ft)	Borehole Depth (bls)[a]	Borehole Diameter (in.)	Top of Casing Elev. (ft)	Casing Length (ft)	Casing Diameter (in)	Screen Depth (bls)[a]	Screen Length (ft)	Flow Code[b]	Zone of Completion[c]	Status
New Wells Installed in 1998													
291	627851.33	1365963.27	5327.35	33.00	7.00	5329.27	33.46	2.00	15.96	15.00	U	AL	Active
292	627847.72	1365945.24	5327.94	18.50	7.00	5329.49	18.91	2.00	6.78	10.00	U	AL	Active
301	625857.86	1360276.18	5313.68	22.00	7.00	5314.16	19.68	2.00	14.00	5.00	O	AL	Abandoned
302	625608.83	1360347.60	5310.12	21.00	7.00	5310.80	20.29	2.00	14.39	5.00	O	AL	Abandoned
303	625900.53	1359952.12	5313.05	29.00	7.00	5313.65	29.32	2.00	23.50	5.00	O	AL	Abandoned
304	625510.24	1359853.47	5307.90	19.00	7.00	5310.63	21.15	2.00	13.20	5.00	O	AL	Active
305	625698.55	1359685.19	5309.91	21.20	7.00	5312.08	21.15	2.00	13.76	5.00	O	AL	Active
306	625972.48	1359311.09	5313.20	27.20	7.00	5316.24	30.23	2.00	21.61	5.00	O	AL	Active
307	625657.75	1358893.67	5313.85	33.20	7.00	5314.62	33.40	2.00	27.05	5.00	O	AL	Abandoned
308	625404.60	1358732.16	5311.56	28.20	7.00	5312.36	28.55	2.00	17.17	5.00	O	AL	Abandoned
309	625285.61	1358611.24	5310.36	23.20	7.00	5313.37	25.52	2.00	16.93	5.00	O	AL	Active
310	625369.79	1359312.38	5309.11	23.80	7.00	5311.64	26.04	2.00	17.93	5.00	O	AL	Active
646	625331.46	1358662.17	5311.84	59.50	9.34	5312.57	60.05	4.00	49.00	10.00	O	WS	Active
647	625323.98	1358655.40	5311.72	42.00	9.34	5313.03	43.23	4.00	31.60	10.00	O	WS	Active
648	625696.30	1359345.21	5311.78	60.00	9.34	5313.28	61.38	4.00	49.55	10.00	O	WS	Active
649	625701.28	1359336.52	5311.71	42.00	9.34	5313.16	42.77	4.00	31.00	10.00	O	WS	Active
654	625483.88	1358927.12	5312.31	33.70	7.00	5313.65	35.08	2.00	8.16	25.00	O	AL	Active
655	625706.33	1359344.17	5311.82	24.00	9.34	5312.87	24.98	4.00	13.60	10.00	O	AL	Active
656	625677.35	1360119.30	5310.92	22.20	7.00	5313.28	24.29	2.00	6.35	15.00	O	AL	Active
657	625698.19	1360632.12	5312.38	18.25	7.00	5314.50	20.02	2.00	7.32	10.00	O	AL	Active
658	627860.16	1364822.37	5320.23	19.00	7.00	5323.07	20.39	2.00	2.30	15.00	U	AL	Active
659	627861.39	1364771.88	5320.13	39.10	7.00	5322.77	38.72	2.00	20.83	15.00	U	AL	Active
660	627036.78	1364958.36	5321.84	28.20	7.00	5323.38	28.92	2.00	11.80	15.00	U	AL	Active
662	625947.00	1359670.37	5313.26	27.20	7.00	5315.19	29.00	2.00	6.49	20.00	O	AL	Active
663	625690.28	1359320.31	5311.67	23.50	7.00	5313.28	24.97	2.00	7.78	15.00	O	AL	Active
Wells Installed Before 1998													
436	628742.00	1366330.00	—	—	—	—	—	—	—	—	U	WS	Private
581	625681.70	1359343.40	5321.30	34.00	6.63	5323.05	35.75	4.00	30.00	2.50	O	AL	Abandoned
582	625687.70	1359354.00	5321.21	22.50	6.63	5323.41	23.70	4.00	19.00	2.50	O	AL	Abandoned
583	625475.60	1359353.50	5321.58	28.30	6.63	5323.08	27.50	4.00	17.50	6.00	O	AL	Abandoned
584	625678.60	1360620.50	5311.61	19.20	6.63	5312.91	20.50	4.00	13.20	6.00	O	AL	Abandoned
585	625658.20	1360113.70	5312.11	21.50	6.63	5313.71	21.60	4.00	12.50	5.00	O	AL	Abandoned
586	625222.00	1358838.30	5306.84	22.50	6.63	5308.35	24.01	4.00	20.00	2.50	O	AL	Abandoned
587	625222.90	1358826.00	5306.83	17.30	6.63	5308.13	18.60	4.00	5.00	9.50	O	AL	Abandoned
588	625222.90	1358814.10	5307.01	11.50	6.63	5308.41	12.90	4.00	8.50	3.00	O	AL	Abandoned
589	625041.20	1357955.80	5306.00	18.00	6.63	5307.16	19.16	4.00	7.50	10.50	D	AL	Abandoned
590	625377.98	1357952.33	5306.32	20.60	6.63	5308.34	21.52	4.00	12.50	7.00	D	AL	Active
593	625929.20	1359556.20	5320.20	21.00	6.00	5322.50	23.30	2.00	16.00	5.00	O	AL	Abandoned
594	625850.00	1359290.50	5323.30	25.50	6.00	5325.10	21.80	2.00	15.00	5.00	O	AL	Abandoned
595	625620.80	1359553.20	5315.00	18.70	6.00	5323.22	26.92	2.00	9.30	5.00	O	AL	Abandoned
596	625435.70	1359111.00	5315.00	25.60	6.00	5324.26	34.86	2.00	13.10	5.00	O	AL	Abandoned
597	626379.80	1362950.15	5313.78	12.00	6.00	5316.46	14.68	2.00	5.00	5.00	U	AL	Active
598	626370.97	1362945.20	5313.79	20.00	6.00	5316.18	22.39	2.00	15.00	4.00	U	AL	Active
599	625620.88	1356384.08	5301.04	12.00	6.00	5303.73	14.69	2.00	5.00	5.00	D	AL	Active
600	625618.02	1356394.25	5301.39	21.00	6.00	5303.06	21.67	2.00	13.00	5.00	D	AL	Active
601	624978.40	1356613.00	5296.10	12.00	4.00	5297.21	13.11	2.00	5.00	5.00	D	AL	Active
602	624973.50	1356622.60	5295.80	19.00	6.00	5297.84	21.04	2.00	13.00	5.00	D	AL	Active
605	627852.85	1366097.20	5331.42	16.75	2.00	5334.17	19.50	2.00	9.25	4.00	U	AL	Abandoned
606	628113.92	1366645.79	5332.95	16.70	2.00	5336.15	19.90	2.00	8.05	4.00	U	AL	Active
620	626390.93	1362956.74	5314.34	69.00	6.00	5316.35	71.01	2.00	30.00	35.00	U	WS	Active
621	627249.59	1363447.73	5316.28	101.00	8.00	5317.51	102.23	4.00	78.00	20.00	U	WS	Active
622	627234.77	1363413.98	5316.25	59.75	6.00	5317.75	60.50	2.00	47.00	10.00	U	WS	Active
623	625826.99	1360414.61	5324.36	112.36	8.00	5325.78	113.78	4.00	100.36	10.00	O	WS	Active
624	625839.67	1360388.89	5324.64	86.04	6.00	5325.38	86.78	2.00	74.04	10.00	O	WS	Active
625	624342.60	1357754.00	5303.29	100.00	8.00	5304.95	101.66	4.00	75.00	20.00	D	WS	Active
626	624335.70	1357729.70	5304.64	60.00	6.00	5306.39	61.75	2.00	48.00	10.00	D	WS	Active
629	624952.90	1367671.30	5361.00	200.00	8.00	5362.26	186.26	4.00	160.00	20.00	C	WS	Active
630	624940.20	1367640.10	5360.90	142.00	6.00	5362.39	143.49	2.00	130.00	10.00	C	WS	Active
640	623486.80	1358317.90	5303.70	98.00	8.00	5302.66	96.96	4.00	86.00	10.00	C	WS	Active
641	623455.20	1358316.90	5300.20	69.00	6.00	5302.08	70.88	2.00	57.00	10.00	C	WS	Active
644	624996.00	1356630.40	5297.27	155.00	8.00	5298.64	156.37	4.00	125.00	20.00	D	WS	Active
645	624992.80	1356609.00	5297.08	115.00	6.00	5298.50	116.42	2.00	93.00	20.00	D	WS	Active

[a] bls = below land surface

[b] C = crossgradient D = downgradient O = on-site U = upgradient

[c]: AL = alluvium WS = Wasatch formation-undifferentiated

core recovery possible. Recovered core was washed and then placed in boxes within the longitudinal separators, from left to right, as a book would be read; that is, core was placed starting with the shallowest portion of the hole in the lower right corner. Spacer blocks were inserted between the cored sections within the longitudinal separators where no recovery was noted. All core boxes, including the lids, were permanently marked showing top and bottom and the beginning and ending depths for the core. The site geologist described all cores.

All sediment, soil, and rock sampling was performed in accordance with the following procedures from the *Environmental Procedures Catalog* (GJO 1998):

- SL–6(P), "Technical Comments on ASTM D 1452–80(90)—Standard Practice for Soil Investigation and Sampling by Auger Borings."
- SL–7(P), "Technical Comments on ASTM D 1586–84(92)—Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils."
- SL–9(P), "Technical Comments on ASTM D 2113–83(93)—Standard Practice for Diamond Core Drilling for Site Investigation."
- GN–8(P), "Standard Practice for Sample Labeling."
- GN–9(P), "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples."
- GN–13(P), "Standard Practice for Equipment Decontamination."

4.3 Lithologic Logging

Lithologic logging of the alluvial aquifer matrix was performed primarily on drill cutting samples that were collected from the cyclone every 5 ft of drilled depth (Section 4.2) during the course of the monitor well installations. Split-barrel sampling for lithologic purposes was attempted once every 5 ft of drilled depth. However, in most cases a large amount of undisturbed sample could not be recovered due to the difficulty in collecting unconsolidated silt, sand, and cobble gravel with a spoon type sampling device.

Lithologic logging of the Wasatch Formation was based primarily on continuous diamond core (Section 4.2) collected during the installation of the bedrock water wells. Approximately 37 ft of competent core was collected at each of the lower Wasatch completions (RFO–646 and –648) and logged for lithology. Split-barrel sampling was also attempted at the bottom of each temporary and permanent alluvial well boring to verify the bedrock contact. In most cases, an adequate amount of Wasatch material was recovered to confirm that bedrock was reached.

Lithologic descriptions of the drill cuttings, split-barrel samples, and rock core recorded by the site geologist are presented in the borehole summaries in Appendix A. All lithologic logging was performed in accordance with the following procedures from *the Environmental Procedures Catalog* (GJO 1998).

- SL–19(P), "Technical Comments on ASTM D 2488–93—Standard Practice for Description and Identification of Soils."
- SL–24(P), "Technical Comments on ASTM D 2487–93—Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)."

4.4 Distribution Coefficient (K_d) Analysis

The K_d is a bulk parameter that has been used with some success to describe the retardation of contamination in an aquifer system. Laboratory measurements to determine the K_d for selected analytes were performed on alluvial and Wasatch material to support computer-modeling efforts in characterizing subsurface contaminant transport at the Old Rifle site. Details regarding the laboratory procedure used to determine the K_d values are presented in the Calculation Sets U0041000 and U0049800. A summary of the results is provided in the following sections.

4.4.1 Method of Solution

Laboratory analyses of the K_d were performed according to American Society for Testing and Materials (ASTM) procedure D 4646–87 (ASTM 1987) for selected regulated and commonly retarded site-related contaminants of potential concern (COPCs); arsenic (As), molybdenum (Mo), selenium (Se), uranium (U), and vanadium (V). Essentially, the ASTM procedure involves placing a sample representative of a site (e.g., soil, sediments, cuttings, core samples) into a solution containing simulated contaminated ground water with which the material is likely to come in contact. The simulated ground water solution is agitated for 24 hours and then filtered. The filtered 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

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

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 a contaminant in ground water.

The ASTM 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 used and all contaminant loss in the final solution is attributed to sample adsorption. Use of contaminated samples could potentially underestimate the K_d for contaminants with higher adsorptive properties, as the adsorptive ability of the sample would be reduced by contaminants already present.

4.4.1.1 Sample Selection

Alluvial and Wasatch samples collected during the installation of monitor wells (Section 4.1) were selected for K_d testing. Sample collection procedures are described in Section 4.2. Sample locations are shown in Figure 4–1.

Some of the alluvial samples had very limited recovery and sample size was not adequate to perform the analyses because they consisted mainly of very coarse cobbles and other materials for which K_d testing is not appropriate. However, alluvial samples collected at two upgradient locations, monitor well RFO–292 and well pair RFO–658/–659, were adequate in volume for K_d testing. A shallow and a deep sample were selected at each of these locations: one at the water table (RFO–292–1–1 and RFO–658–1–1) and one near the base of the saturated alluvium (RFO–292–2–1 and RFO–659–1–1). A duplicate shallow sample was also selected at each of the upgradient locations for K_d analysis (RFO–292–1–2 and RFO–658–1–2).

Two Wasatch samples were selected from one on-site uncontaminated core hole (RFO–648) for K_d analysis. One sample was collected from a shallow depth and one from a deeper depth. The shallow sample (648–1–1) obtained 14 ft below the top of the Wasatch Formation is typical of the highly altered claystone found in the upper weathered bedrock at the Old Rifle site. The deeper-depth sample (648–2–1) was obtained 36 ft below the top of the Wasatch Formation and is representative of the claystones below the weathered zone.

4.4.1.2 Sample Preparation

All the samples were air dried at room temperature and sieved to less than 10 mesh (2 millimeters [mm]). A riffle splitter is used to separate a sample for oven drying at 105 C to determine moisture content. The difference between the air-dried and oven-dried weights was always less than 2 percent and usually less than 1 percent so no correction was made for the water contents of the air-dried samples.

For analysis of As, Mo, U, and V, a synthetic solution was prepared that simulated ground water at the Old Rifle site, based on ground water analysis for well 583 from a previous sampling round (November 5, 1992; SEE_UMTRA data base). The composition of the synthetic ground water is as follows (in mg/L): Na = 171.23, K = 6.73, Ca = 315.68, Mg = 94.71, SO_4 = 993.32, Cl = 107.42, NO_3 = 26.83, and C (inorganic) = 89.29. Contaminants were added to obtain the following target concentrations (mg/L): As = 0.2, Mo = 0.2, U = 0.5, V = 0.8. The pH was adjusted to about 7 and the measured alkalinity was about 250 mg/L as $CaCO_3$.

Selenium K_d testing was performed separately because of a laboratory omission. The synthetic solution for Se analysis was based on results of well 654 from a more recent round of sampling (May 19, 1998; SEE_UMTRA data base). The composition of the synthetic ground water is as follows (in mg/L): Na = 177.98, K = 5.66, Ca = 142.71, Mg = 100.63, SO_4 = 648.61, Cl = 67.14, NO_3 = 4.84, and C (inorganic) = 93.73. Selenium with a target concentration of 0.1 mg/L was added. The pH was adjusted to about 7 and the measured alkalinity was about 250 mg/L as $CaCO_3$.

4.4.1.3 Sample Analysis

An analysis of the synthetic ground water solution (Syn–1) was performed to verify the target concentrations were achieved for As, Mo, U, and V. Syn1–S was analyzed for Se. These results are reported in Table 4–2. Arsenic, U, and Se are consistent with the target concentrations of 0.2, 0.5, and 0.1 mg/L, respectively. Actual V and Mo concentrations are slightly higher than the target values of 0.8 and 0.2 mg/L, respectively.

Table 4–2. Laboratory Analytical Results for Synthetic Ground Water Solution, Sample Leachate, and Method Blanks

Sample ID	Sample Description	Solution Volume (mL)	Sample Volume (g)	Concentration (mg/L)				
				As	V	Mo	U	Se
Syn–1	Synthetic ground water	N/A	N/A	0.202	1.18	0.28	0.52	—
Syn1–S	Synthetic ground water	N/A	N/A	—	—	—	—	0.998
292–1–1	Alluvium leachate	100	5.0	0.025	0.097	0.279	0.517	0.0154
292–1–2	Duplicate	100	5.0	0.022	0.081	0.289	0.509	0.0144
292–2–1	Alluvium leachate	100	4.7	0.048	0.213	0.286	0.524	—
658–1–1	Alluvium leachate	100	5.0	0.065	0.464	0.298	0.526	0.0367
658–1–2	Duplicate	100	5.0	0.044	0.291	0.293	0.517	0.0356
659–1–1	Alluvium leachate	100	5.0	0.129	0.796	0.290	0.534	0.0535
659–1–2	Duplicate	100	5.0	—	—	—	—	0.0552
648–1–1	Wasatch leachate	100	5.0	0.032	0.157	0.297	0.493	—
648–2–1	Wasatch leachate	100	5.0	0.040	0.194	0.288	0.503	—
B1–KB	Method blank	100	None	0.204	1.16	0.282	0.529	—
B2–KB	Method blank	100	None	0.203	1.18	0.278	0.531	—
B3–KB	Method blank	100	None	0.202	1.17	0.283	0.535	—

Approximately 5 grams of each sample were measured and placed in 125-milliliters (mL) Nalgene bottles with 100 mL of the synthetic ground water. Samples were rotated end-over-end at 8 revolutions per minute (rpm) for 24 hours. They were then centrifuged at 3,000 rpm and filtered through a 0.45 micrometer (Fm) filter. The resulting leachate samples were preserved with 1 percent nitric acid and submitted to the Grand Junction Office (GJO) Analytical Chemistry Laboratory for analysis of As, V, Mo, and U. Analytical results are reported in Table 4–2.

Laboratory blanks, consisting only of the spiked synthetic ground water solution, were processed through the same procedure (but without sediment) to determine effects of the method on solution concentration. Results of the laboratory method blanks are presented in Table 4–2. As evidenced by the data in Table 4–2, the concentrations for each contaminant are consistent with the synthetic ground water analysis (Syn–1) indicating that there is no procedure affect. However, the average concentrations obtained for the three laboratory method blanks were used as the initial concentrations in subsequent calculations (for As, Mo, U, and V), rather than the synthetic ground water analysis (Syn–1), as specified in the ASTM procedure. (Note that blanks were not run for Se analysis and the results of the synthetic ground water, Syn1–S, were used in the calculations.)

4.4.1.4 K_d Calculation:

K_ds are calculated using the analytical data summarized in Table 4–2 and the following equation:

$$K_d = \frac{(A-B)V}{(M_s)B} \qquad \text{where}$$

A = initial concentration of the COPCs in the synthetic ground water, defined as the mean concentration obtained for the laboratory method blanks (mg/L) (results of synthetic ground water, Syn1–S, were used in Se calculations)
B = final concentration of the COPC in the leachate, after 24 hours in contact with the sediment sample (mg/L)
V = volume of solution (mL)
M_s = mass of sediment sample (grams)
K_d = distribution coefficient (milliliters per gram [mL/g])

Results of the calculations are presented in Table 4–3. Note that the K_d in Table 4–3 is the same as the Rd in the ASTM procedure; this value only represents a true K_d if equilibrium conditions were attained during the test period.

Table 4–3. Measured K_d Values for Alluvium and Wasatch Samples at the Old Rifle Site

Sample ID	Monitor Well	Sample Depth (ft below surface)	Sample Description	K_d (mL/g)				
				As	V	Mo	U	Se
292–1–1	292	8–9.5	Alluvium at water table	142	221	0.1	0.6	110
292–1–2	292		Duplicate sample	168	269	–0.6	0.9	119
292–2–1	292	17–8.5	Alluvium at base of saturated zone	69	96	–0.4	0.3	—
658–1–1	658	3–9	Alluvium at water table	43	30	–1.1	0.2	34
658–1–2	658		Duplicate sample	73	60	–0.8	0.5	36
659–1–1	659	23–24	Alluvium at base of saturated zone	11	9	–0.6	–0.1	17
659–1–2	659		Duplicate	—	—	—	—	16
648–1–1	648	35.5	Weathered Wasatch claystone	106	129	–1.1	1.5	—
648–2–1	648	58	Wasatch claystone below weathered zone	83	101	–.05	1.1	—

Measured K_d values obtained for the alluvial aquifer samples were adjusted based on aquifer grain size analysis. As part of an adsorption study performed by Jacobs Engineering Group Inc. (Jacobs 1993), over 400 pounds of material from each of seven test pits excavated in the alluvial aquifer (totaling over a ton of material) was sorted and analyzed for grain size distribution. The study found that on average, only 38 percent of the aquifer material was contained in the <2 mm size fraction and that the majority was gravel size. Therefore, the measured K_d values for the alluvial aquifer, which were performed on the <2 mm size fraction, were adjusted by multiplying by 0.38. This assumes that the gravel-sized materials are insignificant in terms of contaminant adsorption. The adjusted values are reported in Table 4–4.

Table 4–4. Results of Alluvial K_d Values Adjusted for Grain Size Distribution

Sample ID	Monitor Well	Sample Depth (ft below surface)	Sample Description	K_d (mL/g)				
				As	V	Mo	U	Se
292–1–1	292	8–9.5	Alluvium at water table	54	84	0.1	0.2	42
292–1–2	292		Duplicate	64	102	–0.2	0.3	45
			Mean 292–1	59	93	–0.1	0.2	43.5
292–2–1	292	17–18.5	Alluvium at base of saturated zone	26	37	–0.1	0.1	—
658–1–1	658	3–9	Alluvium at water table	16	12	–0.4	0.1	13
658–1–2	658		Duplicate	28	23	–0.3	0.2	14
			Mean 658–1	22	18	–0.4	0.1	13.5
659–1–1	659	23–24	Alluvium at base of saturated zone	4.4	3.6	–0.2	–0.04	7
659–1–1	659		Duplicate	—	—	—	—	6
			Mean 659–1	—	—	—	—	6.5

4.5 Subpile Soil Analysis

All radioactive tailings and material were removed from the Old Rifle site in 1996 as part of the surface remediation program. No radioactive materials exceeding 15 picocuries per gram (pCi/g) radium-226 were left. However, the potential exists for nonradionuclide contaminants to have seeped into the soils below the limit of remediation. Contaminated soils could contaminate infiltrating water as it passes through them and prolong the ground water cleanup effort. This section presents the analytical procedures used to evaluate the distribution of selected site-related constituents in the soils underlying the former tailings pile and in background soils.

4.5.1 Subpile Soil Sample Selection

Six samples from six boreholes were collected as described in Section 4.2. Four sample locations are in the former footprint of the Old Rifle tailings pile and former ore stockage area. Two sample locations are in background areas upgradient of the site. Figure 4–1 shows the locations of the six boreholes. Details are provided in Calculation Set U0045300.

The soil sample obtained from location RFO–656 was collected above the saturated zone. Soil samples obtained from locations RFO–292 and –658 were collected near the top of the saturated zone. Samples from locations RFO–309, –654, and –663 were collected near the base of the saturated zone. Many of the alluvial samples from the Old Rifle site were composed of large cobbles that were unsuitable for subpile soil testing.

4.5.2 Subpile Soil Sample Preparation and Extraction

Chemical extractions were used to determine the potential mobility of contaminants. Each sample was extracted by using two separate lixiviants; a synthetic ground water solution and a 5 percent nitric acid solution. Extractions were performed sequentially on the same starting material to avoid variation due to sample heterogeneity. Each extraction was harsher than the preceding one.

Each chemical extraction was related to a scenario that could cause contaminant release at the site. Synthetic ground water was used first to simulate the water-table rise that could cause ground water to contact contaminated soils. The synthetic solution was prepared based on ground water analysis for well RFO–583 (November 5, 1992, SEE_UMTRA data base). The composition of the synthetic ground water is as follows (in mg/L): Na = 171.23, K = 6.73, Ca = 315.68, Mg = 94.71, SO_4 = 1,028.7, Cl = 107.42, NO_3 = 113.96, and C (inorganic) = 89.29. The pH was adjusted to about 7 and the measured alkalinity was approximately 330 mg/L as $CaCO_3$. Additional bicarbonate present in the site ground water should release additional uranium that may be sorbed to oxides or silicates.

Five percent nitric acid was then used to remove most amorphous oxides that are likely to contain adsorbed contaminants as well as any more resistant water-soluble constituents. As desired, 5 percent nitric acid 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 sorbed cations. Although oxyhydroxides are stable in most soils, irrigation practices or other land use could cause reducing conditions in the soils and lead to dissolution of the oxyhydroxides with release of their sorbed constituents.

The specific steps in the extraction procedure are as follows:

- Samples were air-dried (no oven heat) and sieved to less than 2 mm.
- Two grams of soil (accurately weighed) was divided between two 50-mL centrifuge tubes; each tube was filled to a 50-mL volume with synthetic ground water solution.
- Tubes were placed in an end-over-end rotary shaker for 4 hours.
- Tubes were removed from the shaker and centrifuged for 30 seconds at 3,000 rpm to remove particles less than 2 microns. Supernatant from both tubes was decanted to a 100 mL volumetric flask and filled to volume with synthetic ground water solution.
- Centrifuge tubes were refilled to 50 mL volume with synthetic ground water solution and placed in an end over end rotary shaker for 30 minutes.
- Tubes were removed from shaker and centrifuged for 30 seconds at 3,000 rpm. Supernatant from both tubes was decanted to a 100-mL volumetric flask and filled to volume with synthetic ground water solution.
- Contents of the two 100-mL volumetric flasks were combined and filtered through a 0.45 micron filter and the filtered sediment residue was retained. Samples were refrigerated for storage prior to submitting for laboratory analysis.
- The same procedure was repeated using the retained sediment samples and a 5 percent nitric acid solution in place of the synthetic ground water.
- All extracted samples were analyzed for As, Mo, Se, U, and V.
- From these data, the amount of each constituent removed during each step was calculated.

4.5.3 Subpile Soil Concentration Results

Two grams of soil sample were extracted with a total of 200 mL of lixiviant. The resulting concentrations in micrograms per liter (µg/L) of As, Mo, Se, U, and V measured in each leachate sample were then converted to units of milligrams per kilograms (mg/Kg) in order to estimate the amount of extractable contaminant per mass of subpile soil by the following equation:

$$\frac{200\ \text{mL lixiviant}}{2\ \text{g soil}} \times \frac{\mu\text{g contaminant}}{\text{L extract}} \times \frac{\text{L}}{1{,}000\ \text{mL}} \times \frac{\text{mg}}{1{,}000\ \mu\text{g}} \times \frac{1{,}000\ \text{g}}{\text{Kg}} = \text{mg/Kg}$$

For example, a concentration of 2.0 µg/L As was measured in the synthetic ground water extract for soil sample 309. Converting this value to mg/Kg using the above equation results in 0.20 mg of As per Kg of subpile soil that is extractable using synthetic ground water. Using the same equation, concentrations were calculated for the amount of contaminant that is extractable using the nitric acid lixiviant. Contaminant concentrations extractable by the synthetic ground water and nitric acid leach are summarized in Tables 4–5 and 4–6, respectively.

Table 4–5. Amount of Contaminant Extractable by Synthetic Ground Water per Mass of Subpile Soil

Sample ID	Monitor Well	Sample Depth (ft below surface)	Location	Contaminant (mg/Kg)				
				As	Mo	Se	U	V
Upgradient samples								
292–1	292	8–9.5	Background	0.31	0.12	<0.2	0.38	0.5
658–1	658	3–9	Background	0.26	0.10	<0.2	0.10	0.5
Average background				0.29	0.11	<0.2	0.24	0.5
Onsite samples								
309–1	309	18–18.3	Former Tailings Area	0.20	0.10	<0.2	0.35	0.5
654–1	654	18–18.2	Former Tailings Area	0.27	0.10	<0.2	0.17	3.7
656–1	656	8–9.5	Former Stockpile Area	0.20	0.18	<0.2	12.6	0.5
663–1	663	13–13.6	Former Tailings Area	0.28	0.12	<0.2	0.72	1.9
Average onsite				0.24	0.13	<0.2	3.46	1.7

Table 4–6. Amount of Contaminant Extractable by 5 Percent Nitric Acid Solution per Mass of Subpile Soil

Sample ID	Monitor Well	Sample Depth (ft below surface)	Location	Contaminant (mg/Kg)				
				As	Mo	Se	U	V
Upgradient samples								
292–1	292	8–9.5	Background	1.4	0.27	<0.2	0.67	4.3
658–1	658	3–9	Background	0.99	0.41	<0.2	0.27	1.7
Average background				1.2	0.34	<0.2	0.47	3
Onsite samples								
309–1	309	18–18.3	Former Tailings Area	0.92	0.31	<0.2	1.1	2.2
654–1	654	18–18.2	Former Tailings Area	1.1	0.13	<0.2	0.28	25.5
656–1	656	8–9.5	Former Stockpile Area	1.4	0.25	<0.2	8.4	12.8
663–1	663	13–13.6	Former Tailings Area	2.9	0.32	<0.2	1.3	29.2
Average onsite				1.58	0.25	<0.2	2.77	17

4.6 Water Sampling and Analysis

Each new monitor well was allowed to sit undisturbed for at least 40 hours after final completion before it was developed. Development was performed according to the Drilling Statement of Work. After the wells were properly developed, a total of 39 permanent and temporary monitor wells and 7 surface water locations were sampled from May 18 to May 27, 1998, during a period of high river flow conditions. Additional sampling of 27 permanent monitor wells and 8 surface water locations was performed from November 23 to December 1, 1998, during low river flow conditions. All samples collected during the May and November 1998 sampling events were submitted to the GJO Analytical Laboratory for analyses. The following sections describe the sampling and analysis procedures.

4.6.1 Water Sampling Procedures

Ground water and surface water sampling was performed in accordance with the *Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1997) and the *Environmental Procedures Catalog* (GJO 1998). The following specific procedures from the *Environmental Procedures Catalog* were used for water sampling:

- GN–8(P), “Standard Practice for Sample Labeling.”
- GN–9(P), “Standard Practice for Chain-of-Sample-Custody and Physical Security of Samples.”
- GN–13(P), "Standard Practice for Equipment Decontamination.”
- LQ–2(T), “Standard Test Method for the Measurement of Water Levels in Ground Water Monitor Wells.”
- LQ–3(P), “Standard Practice for Purging Monitor Wells.”
- LQ–4(T), “Standard Test Method for the Field Measurement of pH.”
- LQ–5(T), “Standard Test Method for the Field Measurement of Specific Conductance.”
- LQ–6(T), “Standard Test Method for the Field Measurement of the Oxidation-Reduction Potential (Eh).”
- LQ–7(T), “Standard Test Method for the Field Measurement of Alkalinity.”
- LQ–8(T), “Standard Test Method for the Field Measurement of Temperature.”
- LQ–9(T), “Standard Test Method for the Field Measurement of Dissolved Oxygen.”
- LQ–10(T), “Standard Test Method for Turbidity in Water.”
- LQ–11(P), “Standard Practice for Sampling Liquids.”

- LQ–12(P), "Standard Practice for the Collection, Filtration, and Preservation of Liquid Samples."

4.6.2 GJO Analytical Laboratory Sample Analyses

Ground and surface water samples were submitted to the GJO Analytical Laboratory. A minimum of 10 percent of the samples collected and analyzed were field quality-control samples. Field quality-control samples included equipment blanks, trip blanks, check samples, and duplicates. These samples were submitted for the same analyses as the other field samples.

Analyses of water samples submitted to the GJO Analytical Laboratory were also checked for accuracy through internal laboratory quality-control checks, such as blind duplicates, splits, and known standards as specified in relevant EPA guidelines or the Contractor's *Handbook of Analytical and Sample-Preparation Procedures Volumes I, II, and III* (WASTREN–GJ undated).

Analytical methods used for analysis of ground and surface water samples are listed in Table 4–7. Sample preservation consisted of storing the samples in an ice chest with Blue Ice (or equivalent) to cool samples during field sampling, packaging, and shipping. Water samples were analyzed for TDS, major ion constituents, and previously identified COPCs. In addition, U-234 and U-238 activity concentrations (picocuries per liter [pCi/L]) were included for the May 1998 round of sampling. Sample handling, preparation, and analyses are described in the references shown in Table 4–7.

Table 4–7. GJO Analytical Laboratory Sample Requirements

Measurement Parameter	Analyte	Sample Container	Analytical Instrument/Method	Detection Limit
Ground and Surface Water	Total uranium	2 each 120 mL	ICP/MS EPA 6020	1.0 µg/L
	Other Inorganics	See *Supplemental Water Sampling and Analysis Plan for all UMTRA Sites* (DOE 1996b) and *Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1997).		

Final analytical results were entered into the SEE_UMTRA database and an independent data validation assessment was performed on the May and November–December 1998 sampling events (DOE 1998c and 1998d, respectively). Results of the surface water and ground water analyses are presented in Appendices B and C, respectively.

4.7 Alluvial Aquifer Test

Estimates of the aquifer parameters for the alluvial aquifer are required to develop a better understanding of the hydrogeologic characteristics of the site that could influence migration of contaminants in the ground water and as input parameters in a ground water flow and transport model. Specific details regarding the aquifer test procedures and data analyses are contained in the Old Rifle Aquifer Test calculation set (Calculation Set U0042700). The calculation set also includes copies of the data logger files and curve-matching graphs generated during the analyses of the drawdown and recovery data. A summary of the aquifer test results is provided in Table 4–8.

Table 4–8. Results of Drawdown and Recovery Test Data Analysis

Analytical Method	Observation Well 663 Transmissivity (ft^2/day)	Observation Well 663 Hydraulic Cond. (ft/day)	Pumping Well 655 Transmissivity (ft^2/day)	Pumping Well 655 Hydraulic Cond. (ft/day)
Drawdown Data				
Theis	1,498	125	NA	NA
Jacob-Cooper	1,398	117	NA	NA
Recovery Data				
Theis & Jacob Recirculation	1,362	114	1,381	115
Neuman Recirculation	1,314	110	1,150	96

NA = data not analyzed to determine hydraulic parameter.

Several slug tests and a continuous aquifer test were conducted as part of the 1998 field investigation. The slug tests were attempted on several of the newly installed Old Rifle alluvial wells; however, the wells recovered too quickly to provide data that could be properly analyzed. The aquifer test provided data that was analyzed to estimate the alluvial aquifer transmissivity and hydraulic conductivity.

A step test at 15, 30, and 40 gallons per minute (gpm) was first completed at newly installed alluvial aquifer well 655 to determine the optimal pumping rate for the aquifer test. During the aquifer test, well 655 was pumped for 44 hours at an average rate of 39.1 gpm. In addition to monitoring the drawdown in this pumping well, the drawdown was also monitored in observation wells 663 (screened in the alluvial aquifer), 649 (screened in the weathered Wasatch zone), and 648 (screened in the Wasatch) during the test. Water level data were also collected during the recovery phase of the test.

The drawdown data collected from observation well 663 were analyzed using Theis and Jacob-Cooper equations to determine the transmissivity and hydraulic conductivity of the alluvial aquifer. In addition, recovery data collected from observation well 663 and pumping well 655 were also analyzed (Table 4–8).

As shown in Table 4–8, analyses of the data using the methods listed in Table 4–8 indicate that the transmissivity for the alluvial aquifer in the vicinity of well 655 is between 1,150 and 1,498 square feet per day (ft^2/day). The hydraulic conductivity (calculated by dividing the transmissivity by a saturated thickness of 12 ft) ranges between 96 and 125 feet per day (ft/day).

Water elevation data collected from the newly installed wells suggest the average horizontal hydraulic gradient during high and low river stage ranges from 0.0033 to 0.0047 ft/ft. Using this gradient with an assumed effective porosity of 0.27, the linear ground water flow velocity ranges from 1.4 to 2.0 ft/day.

4.8 Surface Water Flow Measurements

The alluvial aquifer underlying the Old Rifle site is partially recharged by surface water seepage. Surface water is contained by the collection system located adjacent to U.S. Highway 6. Surface runoff and irrigation return flow from the hillside above the site is diverted through an underground culvert that discharges onto the site. This culvert, which discharges to the site continuously, is routed to the Colorado River across the Old Rifle site via a north-south trending unlined ditch located between wells 304 and 656 (Figure 4–1).

Flow measurements were performed in September 1998 during the field investigation and again in February 1999 to determine the volume of surface water entering and leaving the site. Surface water flow rates of approximately 86 gpm and 39.6 gpm, respectively, were measured at the point where the underground culvert discharges into the unlined ditch on the site. At the Colorado River discharge point located just south of the railroad tracks, a flow rate of approximately 60 gpm was measured in September 1998 and 32.1 gpm in February 1999. The respective 26 gpm and 7.5 gpm difference between the two measuring points represents the amount lost to evapotranspiration (ET) and infiltration into the alluvial aquifer from the unlined ditch.

4.9 Ecological Investigation

The main objective of the ecological investigation conducted in 1998 was to identify potential pathways by which ecological receptors could be potentially exposed to site-related contamination. Based on the initial screening-level ecological risk assessment (DOE 1996a) the most probable pathways identified were (1) uptake of contaminated ground water by deep-rooted plants with subsequent indirect exposure by foraging wildlife and (2) exposure of aquatic organisms to contaminated sediments in the Old Rifle Pond.

Since the time the initial screening-level ecological risk assessment was conducted, the Old Rifle Pond was destroyed by flood waters of the Colorado River and no longer presents a potential exposure pathway. Therefore, the current 1998 ecological investigation focused primarily on the plant ecology of the site.

4.9.1 Methods and Results

The vegetation of the former millsite and tailings area was characterized using a semi-quantitative relevé technique (Barbour et. al. 1987). The site was traversed on May 4, 1998. This walk-through, ocular survey revealed two vegetation types. Most of the site is comprised of the seeded vegetation that is dominated by tall wheatgrass (*Elymus elongatum*) and western wheatgrass (*Pascopyrum smithii*).

Irrigation and surface runoff water, not associated with the site, is collected in an unlined ditch north of U.S. Highway 6 above the site. A metal culvert is used to divert the irrigation water underneath the highway to an open ditch near the center of site. The second plant type grows along this ditch and is dominated by wintercress (*Barbarea orthoceras*) and Canada thistle (*Cirsium arvense*). One tamarisk shrub (*Tamarix ramosissima*) was observed growing along the ditch. Classes of species found in each vegetation type are presented in Table 4–9.

Table 4–9. Relevé Data Showing Species Cover of Plant Types at Old Rifle Site

Latin Name	Common Name	Wheatgrass Type	Ditch Type
Agropyron cristatum	crested wheatgrass	1	
Atriplex confertifolia	shadscale	+	
Barbarea orthoceras	wintercress		2
Bromus inermis	smooth brome	+	
Cirsium arvense	Canada thistle		2
Chrysothamnus viscidiflorus	green rabbitbrush	+	
Descurania pinnata	tansy mustard	+	
Elymus elongata	tall wheatgrass	4	
Juncus ensifolius	daggerleaf rush		2
Pascopyrum smithii	western wheatgrass	2	
Rumex crispus	curly dock		1
Salsola kali	Russian thistle	1	
Tamarix ramosissima	tamarisk		+

COVER Classes: (+) <1%, (1) 1–5%, (2) 5–25%, (3) 25–50%, (4) 50–75%, (5) 75–100%

All types of vegetation identified at the site are shallow-rooted and not considered to be phreatophytes (plants that root in ground water). No surface water, other than the open irrigation ditch, was present at the site. The site is not currently used for livestock grazing and is fenced which prevents larger wildlife entry. No further ecological investigation or sampling was necessary because no pathways were present that permit exposure of ecological receptors to contaminated ground water.

5.0 Site Conceptual Model

This section presents an interpretation of the site characterization data collected in 1998, integrates the most recent data with previous information, and provides the most current understanding of the extent and magnitude of contamination and exposure pathways to the public health and environment. The conceptual model provides the basis for the subsequent risk assessment (Section 6.0) and the proposed ground water compliance strategy (Section 7.0).

5.1 Geology

Principal geologic rock types in the area include Quaternary floodplain deposits and Tertiary age sedimentary beds of the Wasatch Formation. The floodplain deposits consist of alluvial silt, sand, and cobble gravels in stream channels and beneath flood plains and in terraces along the Colorado River Valley and its major tributaries. The Wasatch Formation consists mostly of variegated claystone, siltstone, and sandstone of fluvial origin. Carbonaceous shale and lignite occur near the base of the formation. The former Old Rifle milling site is situated on an alluvial terrace that directly overlies several thousand feet of Wasatch Formation.

Ground water in the surficial alluvial aquifer and the shallow Wasatch Formation directly beneath the site are the hydrostratigraphic units of primary interest. Therefore, the geologic field investigations concentrated on characterizing the nature and extent of the alluvial material and the relationship between the alluvium and the shallow Wasatch rocks that are most susceptible to vertical contaminant invasion from the site. Presented in this section is a brief overview of the regional geologic setting followed by site-specific geologic information. These data form the basis for the site conceptual hydrostratigraphic model that supports the ground water flow and transport computer models used to simulate natural flushing.

5.1.1 Regional Geologic Setting

Structurally, the site is located near the southeastern edge of the Piceance Creek basin and along the southwestern edge of the Grand Hogback monocline that was formed in response to the adjacent White River uplift. Numerous faults expose Cambrian- to Tertiary-age bedrock on the steeply dipping rock surfaces as shown in the regional geologic map presented in Figure 5–1. A north to south geologic cross-section of the Rifle region is presented in Figure 5–2. Brief overviews of the principal rock units, from oldest to youngest, that are present in the region are described below.

The oldest rock units in the region are present north of Rifle, between the Grand Hogback and the White River uplift, where a 6-mile section of near-vertical sedimentary beds of Paleozoic and Mesozoic age are exposed. Located in this area is one of the largest vanadium-uranium deposits on the Colorado Plateau that occurs in host rocks of the Triassic Chinle Formation, Triassic-Jurassic Glen Canyon Sandstone, and Jurassic Entrada Sandstone (Chenoweth 1982, Fischer 1960). The deposits produced approximately 47 million pounds of V_2O_5 and about one million pounds of U_3O_8 from the Garfield and Rifle Mines from 1925 through 1977. A few miles east of the Rifle mine several smaller vanadium-uranium deposits were mined from the Salt Wash Member of the Morrison Formation.

Sediments containing uranium, vanadium, and other metals from these mineralized Triassic-Jurassic host rocks were eroded and transported south and deposited in the Wasatch Formation prior to the later part of the Laramide deformation when intensive folding of the Grand Hogback monocline occurred in response to the White River uplift. As a result of the uplift the sedimentary beds of the Wasatch Formation are now at a near-vertical orientation along the face of the Grand Hogback monocline. To the southwest of the monocline the dip declines rapidly to 30 to 40 degrees just north of Rifle and then gently flattens to a dip of 5 degrees or less in the vicinity of the site. Shallow bedrock between the Colorado River and the Grand Hogback consists of variegated shale, siltstone, and fine-grained sandstone of the Wasatch Formation. Although the Wasatch Formation contains some resistant beds that form cliffs, most of the formation weathers easily and has formed lowland mesas, including the Prefontaine and Graham Mesas directly northwest and northeast of the city of Rifle.

Younger sedimentary rocks overlying the Wasatch Formation are the Tertiary sandstone, oil shale, and marlstone beds of the Green River Formation which crop out almost continuously around the southeastern margin of the Piceance Creek Basin forming the prominent Roan Cliffs. These cliffs are visible to the northwest from the town of Rifle.

The youngest geologic units include a diverse assemblage of Quaternary alluvium, colluvium, landslides, debris-flow, and loess that has been mapped in and adjacent to the Colorado River valley near Rifle (Shroba et al. 1995, Stover 1993). Several thousand feet of Tertiary-age Wasatch Formation underlie these surficial unconsolidated units.

5.1.2 Local Geology

The Old Rifle site is located along a flat, low-lying alluvial terrace where a former channel of the Colorado River has left a crescent-shaped meander scar in the more resistant cliff-forming beds of the Wasatch Formation. Along the north side of the alluvial terrace the steep slopes of the more resistant sedimentary rocks of the Wasatch Formation ascend abruptly 40 to 60 ft above the site to U. S. Highway 6. A steep slope that abruptly descends approximately 10 ft to the river bound the south side of the terrace. Lateral accretion by the meander channel resulted in a uniform deposition of approximately 20 to 25 ft of floodplain alluvium on the site. This Quaternary floodplain deposit consists mostly of red, well-rounded clasts that range in size from cobbles to clay. A generalized surface geologic map and a geologic cross-section extending northeast and southwest through the Old Rifle site is presented in Figures 5–3 and 5–4, respectively.

Shroba and others (1995) and Stover (1993) mapped an older alluvial terrace unit resting on the Wasatch Formation that crops out to the north just above the site along U. S. Highway 6. The lower part of the unit was deposited by the ancestral Colorado River and generally consists of poorly to moderately well-sorted, clast-supported, cobbly pebble gravel with a sand matrix. The unit contains subrounded to well-rounded igneous, metamorphic, and sandstone clasts. Seeps and springs flow along the contact between the older alluvial terrace gravels and the underlying, relatively impermeable Wasatch bedrock formation.

The upper part of the older alluvial terrace gravels exposed further north of the site on Graham Mesa was deposited by a former course of Rifle Creek and consists of slightly silty to silty sand with occasional thin, well-sorted, pebble and sand lenses. The upper fine-grained alluvium on Graham Mesa is mantled by loess.

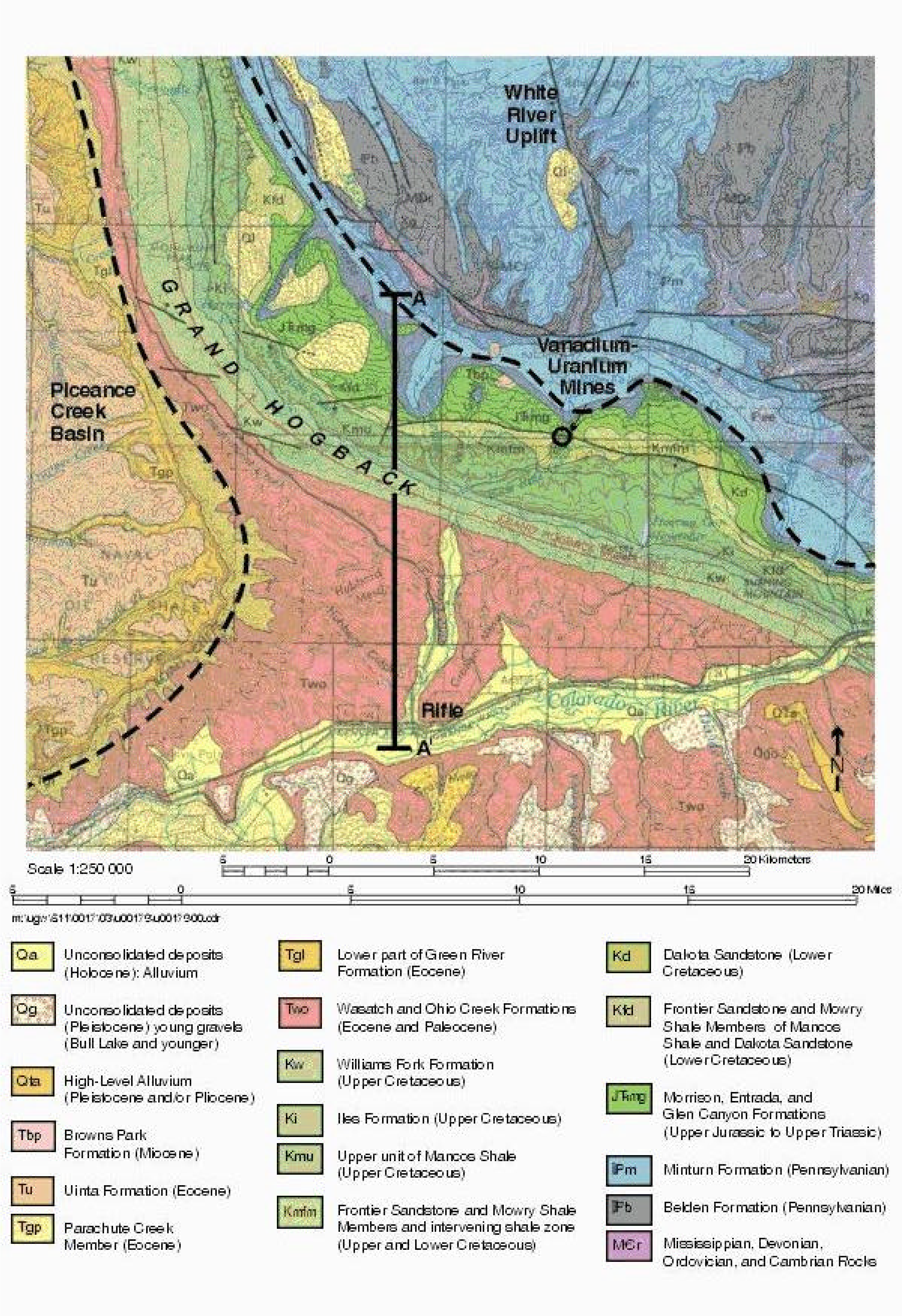
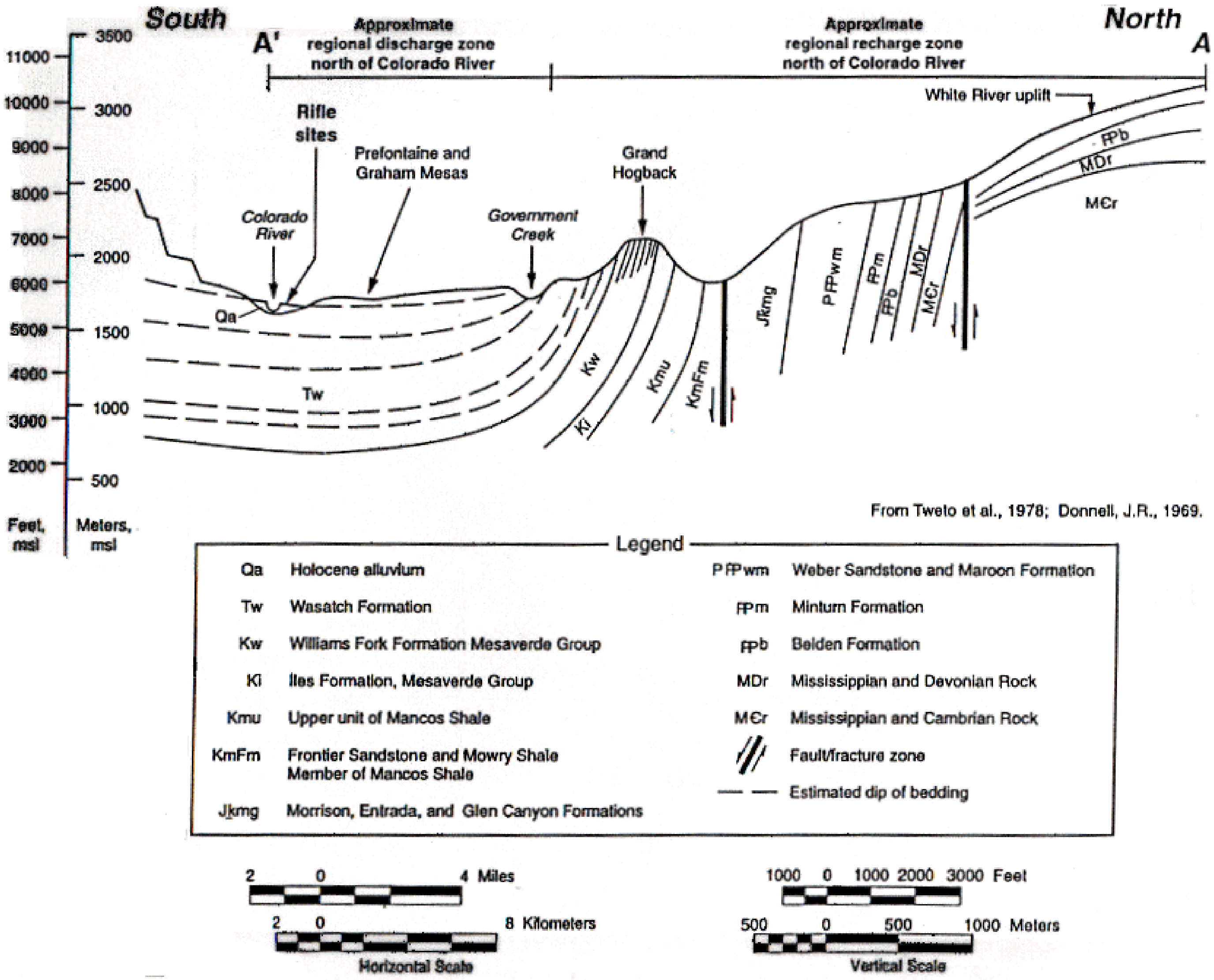


Figure 5–1. Regional Geologic Map Showing Principal Physiographic Features (modified from Tweto et al., 1978)



From Tweto et al., 1978; Donnell, J.R., 1969.

Figure 5–2. Regional Geologic Cross-Section of the Rifle Area

5.1.3 Stratigraphy

The primary rock types affecting the ground water at the site are the Quaternary alluvium and the Tertiary Wasatch Formation. Observable characteristics of the alluvium and older sedimentary rocks of the Wasatch Formation that are exposed or penetrated by boreholes at the site are described below.

5.1.3.1 Tertiary Wasatch Formation

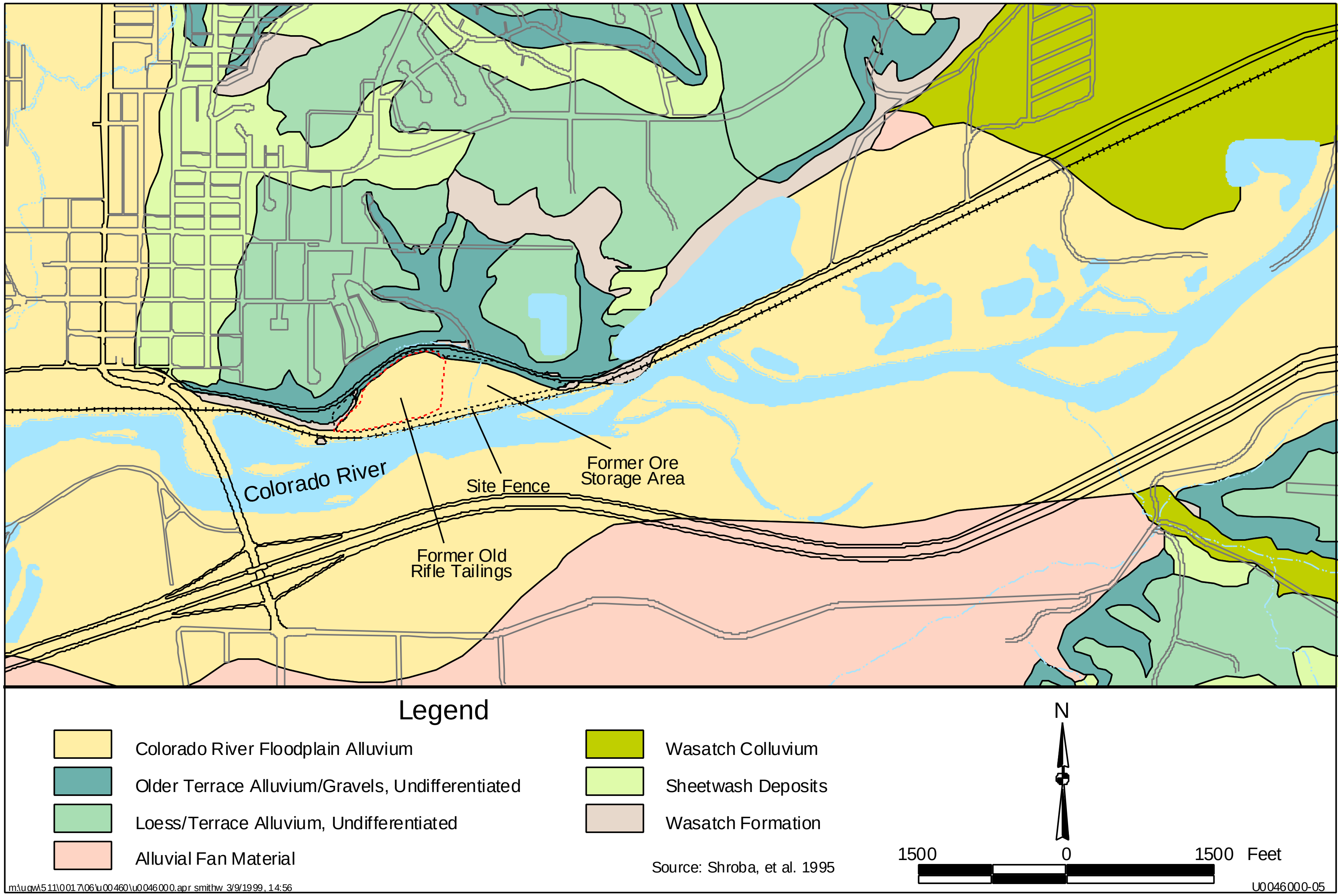
Sediments in the Wasatch Formation were deposited in a braided stream, flood-plain lacustrine, and a lacustrine environment during the Paleocene and early Eocene. Donnell (1969) describes the Formation as a single stratigraphic unit that is divided into three members. The upper and lower members, the Shire and Atwell Gulch, respectively, consist mostly of variegated claystones. The intervening Molina Member consists predominantly of thick brown ledge-forming massive sandstones with thin interbeds of variegated claystone.

The stratigraphic equivalents of the three members crop out in entirety along the Grand Hogback approximately 6 miles north of the town of Rifle. The stratigraphic equivalent of the Shire Member exposed along the Grand Hogback is in excess of 4,000 ft thick. Locally, the upper Shire Member consists of variegated colored claystones and siltstones with minor units of brown lenticular sandstones. The thickness of the Shire Member near Rifle is probably about 1,600 ft although some of it may have been removed by erosion.

Donnell (1969) mapped a possible equivalent bed of the middle Molina Member that is approximately 400 ft thick at Rifle Gap. Another possible stratigraphic equivalent unit of the middle Molina Member attains a thickness of 600 ft in the Carter 1 E.C. Hunter gas well (T6S, R94W) approximately 5 miles southwest of Rifle. The sandstone beds in this well are thin and separated by thick units of siltstone and variegated claystone. The Molina Member near the site is probably about 500 ft thick.

At Rifle Gap a possible stratigraphic equivalent unit of the lower Atwell Gulch Member is approximately 700 ft thick (Donnell 1969). The lower member is probably about 600 ft thick in the area of the site. Locally, the lower member consists of a series of brown and gray shales and sandstones with several thin, discontinuous interbeds of lignite and carbonaceous shale near the base.

Wasatch sediments beneath the site are probably correlative to the lower Shire Member and consist predominantly of alternating beds of variegated claystone and siltstone interbedded with minor lenticular and laterally discontinuous sandstone. A geologic cross-section of the strata prepared from core obtained at bedrock borings RFO–623, –646, and –648 is presented in Figure 5–5. Detailed lithologic descriptions of the core indicate that most of the bedrock contact immediately beneath the alluvium consists of highly weathered claystone (Appendix A). The thickness of the weathered claystone bed varies from 13 ft near the center of the site at boring RFO–646 to 8 ft at boring RFO–648 near the downgradient edge of the site. The base of the weathered claystone bed grades down into a moderately-hard siltstone and fine-grained sandstone interbedded with alternating claystone layers.



Source: Shroba, et al. 1995

Figure 5–3. Local Surface Geology at the Old Rifle Site

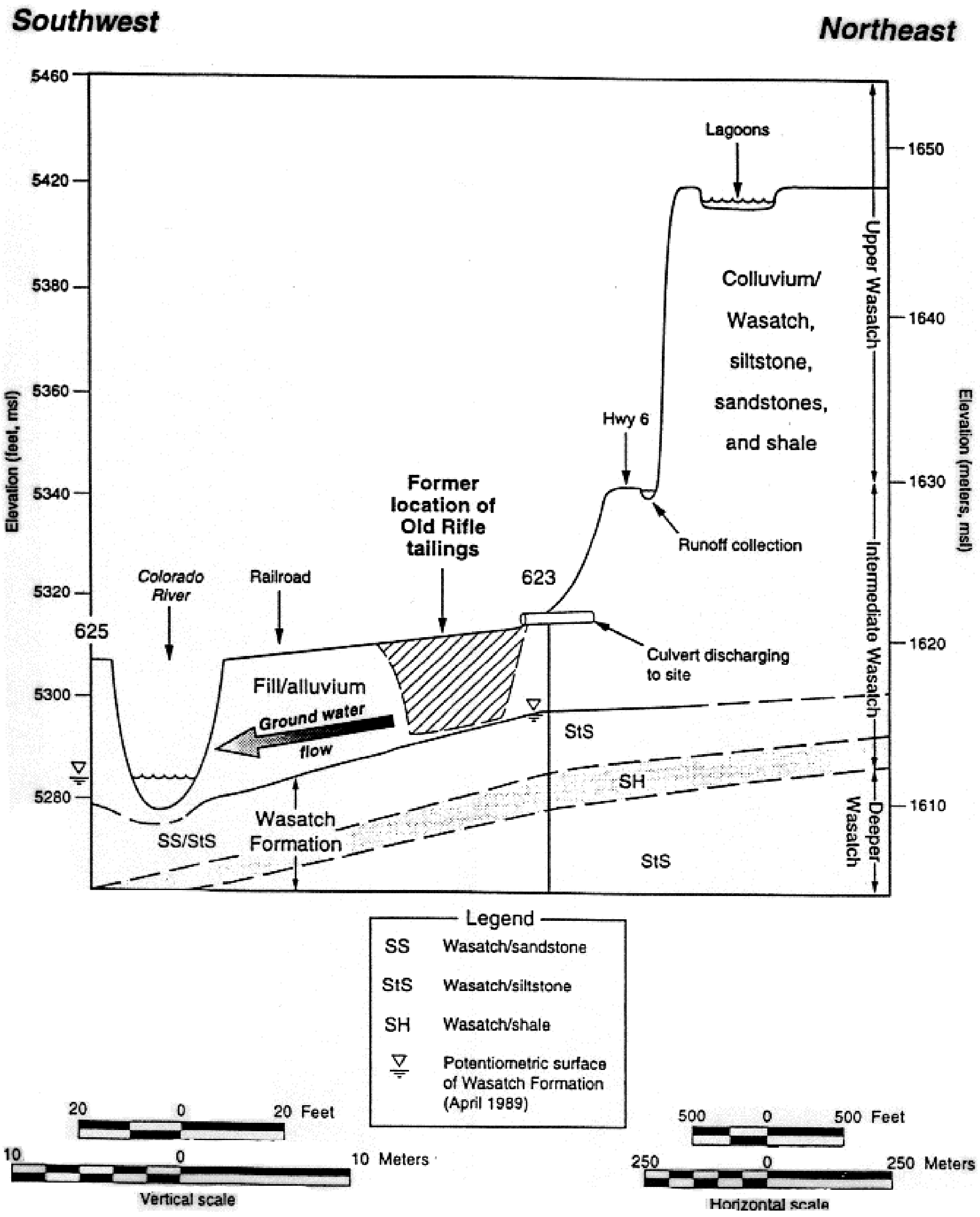


Figure 5–4. Local Geologic Cross-Section Extending Northeast and Southwest Through the Old Rifle Site
(from Tweto et al., 1978; Donnell, J.R., 1969.)

Bedrock Topography

The general topography of the bedrock surface in the vicinity of the site is illustrated in Figure 5–6 by the structure contours drawn at 10-ft intervals on top of the Wasatch Formation. The structure contour map was prepared from borehole information and field mapping conducted during the site investigation (Section 4.0). In general, the Wasatch Formation beneath the site reflects a fairly flat topographic surface that gently slopes to the south. Contour elevations abruptly steepen at the west, north, and east boundaries of the site reflecting the erosional flood-plain scarp scoured in the Wasatch by a former meandering channel of the Colorado River. Structure contours near the west boundary of the site define a narrow man-made gap in the Wasatch outcrop that is approximately 50 ft wide. The gap is believed to have been constructed for passage of the railroad track rather than representing a natural erosional feature created by the Colorado River.

5.1.3.2 Quaternary Alluvium

A uniformly thick deposit of unconsolidated Quaternary material consisting mostly of alluvial sand and cobble gravel covers the relatively flat-lying scoured bedrock surface beneath the site. The lateral surface extent of the Quaternary floodplain deposit is bounded by the Wasatch outcrops shown on the alluvial isopach map presented in Figure 5–7. The thickness of the Quaternary material at the site is typically around 20 to 25 ft as indicated by the isopach contours. Slightly over 30 ft of alluvium is present near the downgradient edge of the site where it fills a slight depression eroded in the bedrock subsurface. Approximately 5 ft of fill material, used to provide a base for the railroad tracks, is believed to be present in the man-made gap between the Wasatch outcrop at the west boundary of the site.

The lithologic character and variability of the Quaternary material was determined by examination of split barrel samples and drill cuttings obtained from the boreholes installed during the 1998 field investigation (Section 4.0). Most commonly, the alluvial material consists of sandy gravels (60 percent gravel, 35 percent sand, 5 percent silt) and gravelly sands (60 percent sand, 35 percent gravel, 5 percent silt) deposited by the Colorado River. Grain size for the gravels vary from pebbles to cobbles (Wentworth scale). Colors are typically brown, dark brown, and dark yellowish brown (10YR Munsell notation). The borehole lithologic logs in Appendix A provide descriptions of the unconsolidated material.

5.2 Hydrologic System

Major features of the regional hydrologic system are the result of the White River uplift and the Grand Hogback located north of the site (Figure 5–1). In addition to being in the regional zone of recharge (Figure 5–2), the steeply dipping Grand Hogback monocline redirects surface drainage from the steep-walled canyon and the mountain region of the White River Plateau to the broad flat valleys of the Colorado River Basin. Many different flow systems discharge south to the Colorado River Basin. Rifle Creek drains the majority of the regional hydrologic catchment north of Rifle and is used extensively as a source of surface irrigation water in the Rifle area (Section 3.3). Other tributaries to the Colorado River that provide regional drainages north of Rifle include Government and Elk Creek. The Colorado River to the south is in the zone of regional discharge and acts as the regional ground water flow divide. Regional ground water flow is complicated by the structural, topographical, and geological variations in the Rifle area.

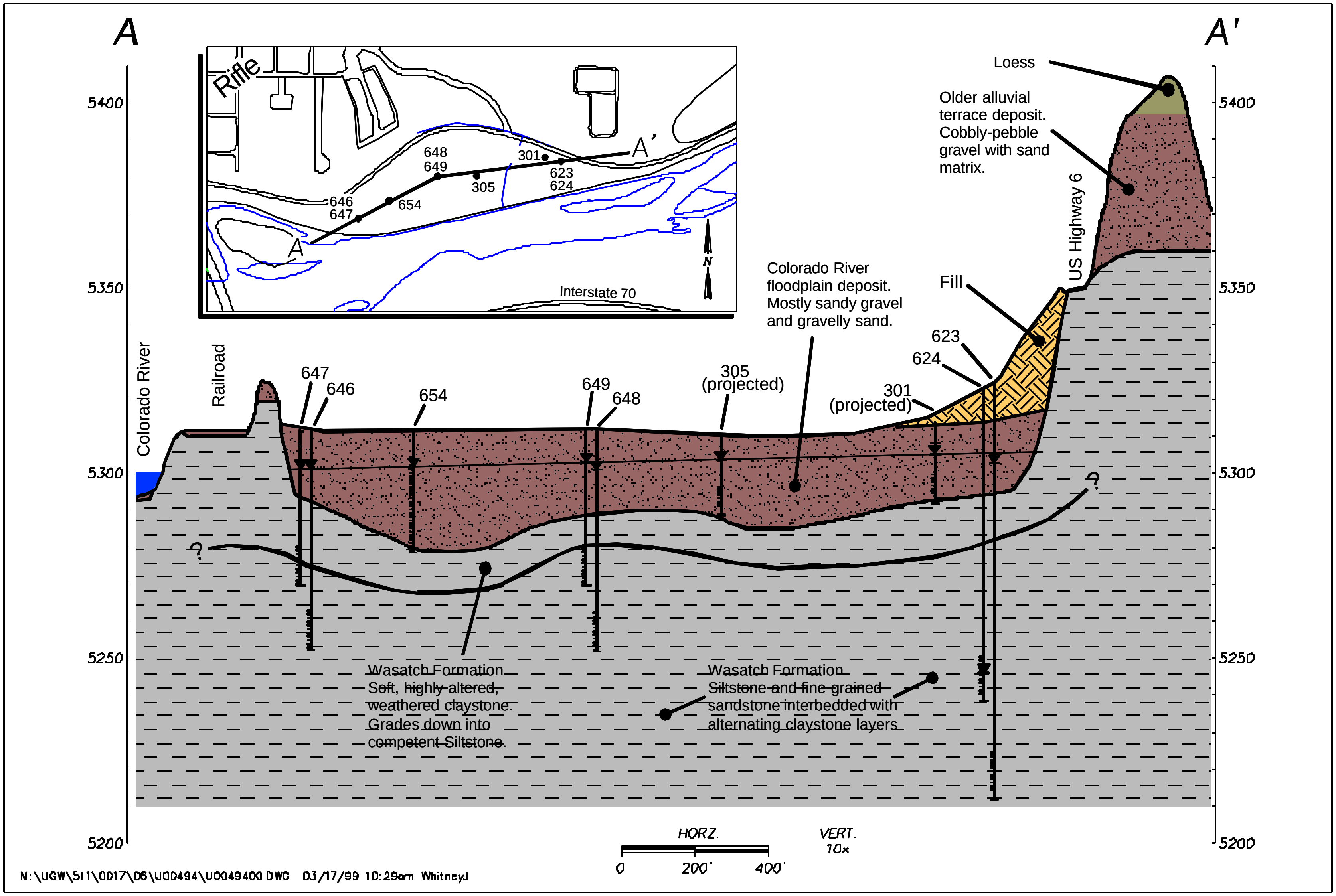


Figure 5–5. Geologic Cross-Section West to East Across Old Rifle Site

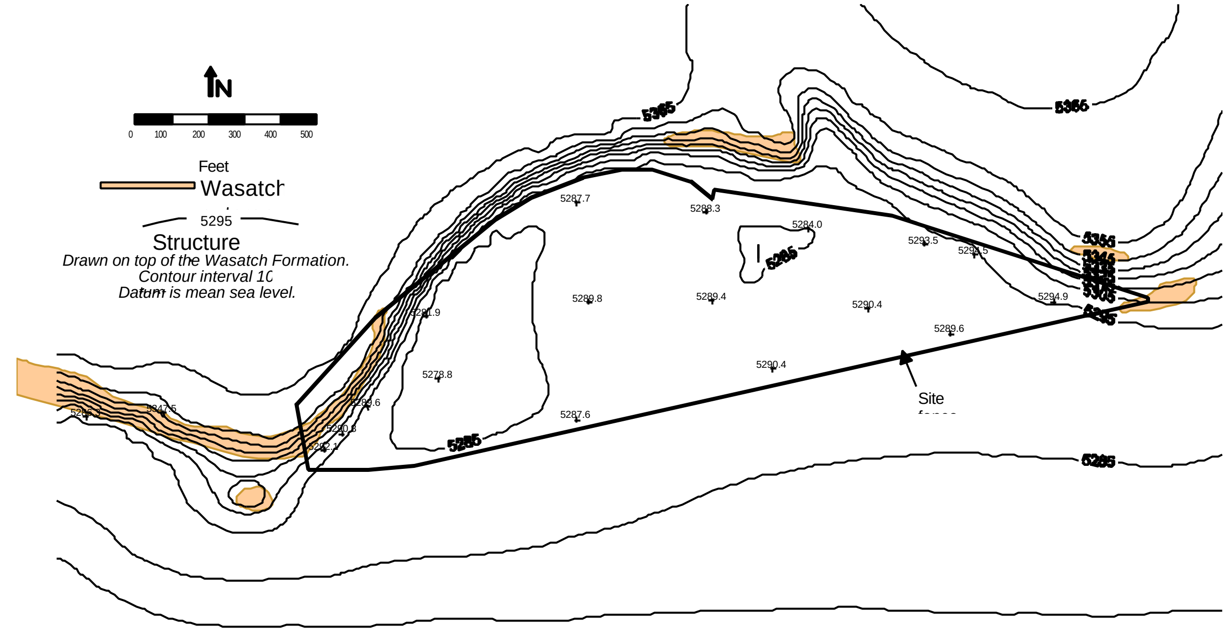


Figure 5–6. Structure Contour Map of the Wasatch Formation at the Old Rifle Site

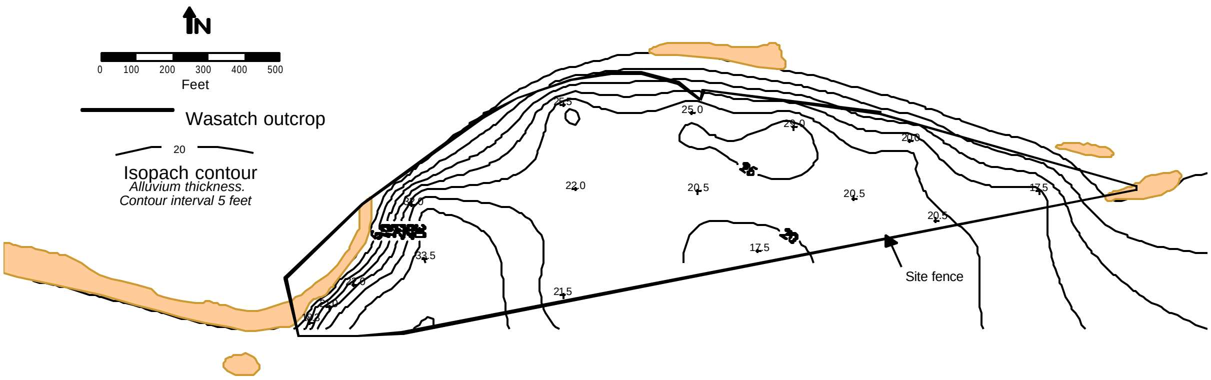


Figure 5–7. Isopach Map of the Alluvium at the Old Rifle Site

The major components of the local hydrologic system at the Old Rifle site include the Colorado River, unsaturated alluvial sediments, saturated alluvial sediments, and saturated claystone, siltstone, and sandstone of the Wasatch Formation. The saturated alluvial sediments form the unconfined alluvial aquifer. Claystone is the predominant rock type of the Wasatch Formation that directly underlies the unconsolidated deposits of the alluvial aquifer as indicated by the cross-section and lithologic descriptions presented in Section 5.1. These relatively low-permeability claystone beds of the Wasatch Formation separate the overlying alluvial aquifer from the lower more permeable siltstone and sandstone interbeds of the Wasatch Formation aquifer.

5.2.1 Surface-Water Hydrology

Surface-water features at the Old Rifle site include the City of Rifle's detention lagoons located above the site on Graham Mesa to the northeast; seeps and springs that flow along the contact between the older alluvial terrace gravels and the underlying, relatively impermeable Wasatch bedrock formation; surface irrigation runoff ditches located above the site on the north side of U.S. Highway 6; an unnamed drainage ditch extending north to south across the center of the site; and the Colorado River to the south.

The City of Rifle operates two detention lagoons on Graham Mesa just northeast of the site. These unlined ponds are used as settling basins for Colorado River backwash water containing high concentrations of sediment. The average volume of backwash discharged to the lagoons is approximately 35 gpm (DOE 1996d). Infiltration from these ponds enters the terrace sediments north of U. S. Highway 6 and then discharges horizontally as seeps along the alluvial and Wasatch contact. Some of the discharge flows to an unlined ditch that parallels U.S. Highway 6 above the site.

Precipitation falling on the site drains south directly into the river and into the unnamed ditch that extends north to south across the site. This ditch also receives surface drainage from the seeps and springs along and above U. S. Highway 6 via an underground culvert beneath the highway. The culvert empties directly into the north end of the ditch that flows south across the site and discharges to the river. Measurements at the north end of the ditch indicate the flow varies between 86 gpm in the fall (September 1998) to 31 gpm in the winter (January 1999).

The Colorado River forms the southern boundary of the Old Rifle site and is the dominant surface-water feature, ultimately receiving most of the surface drainage from the Old Rifle site. Daily averages of river-gauging measurements obtained for the Colorado River are available from the U.S. Geological Survey (USGS). The nearest flow data are collected approximately 20 miles upstream at a location near Glenwood Springs, Colorado, and approximately 25 miles downstream at a location near the town of DeBeque, Colorado. The daily average flow rate, measured over the 20-year period from 1978 through 1997, is approximately 11 percent higher at the downstream DeBeque gauging station than at the upstream Glenwood Springs gauging station (4,060 versus 3,660 cubic feet per second [cfs]). Rifle is located approximately halfway between these two stations; therefore the average flow between the upstream and downstream gauging stations presented in Figure 5–8 is considered the best estimate of the river flow at the site. On average, the maximum discharge occurs in the spring and early summer months from the middle of May to the first of July due to snow melt. Minimum discharge occurs in the fall and winter months from October through March. Over the 20-year measurement period the average runoff was 3,848 cfs, the maximum observed was 33,800 cfs, and the minimum observed was 938 cfs.

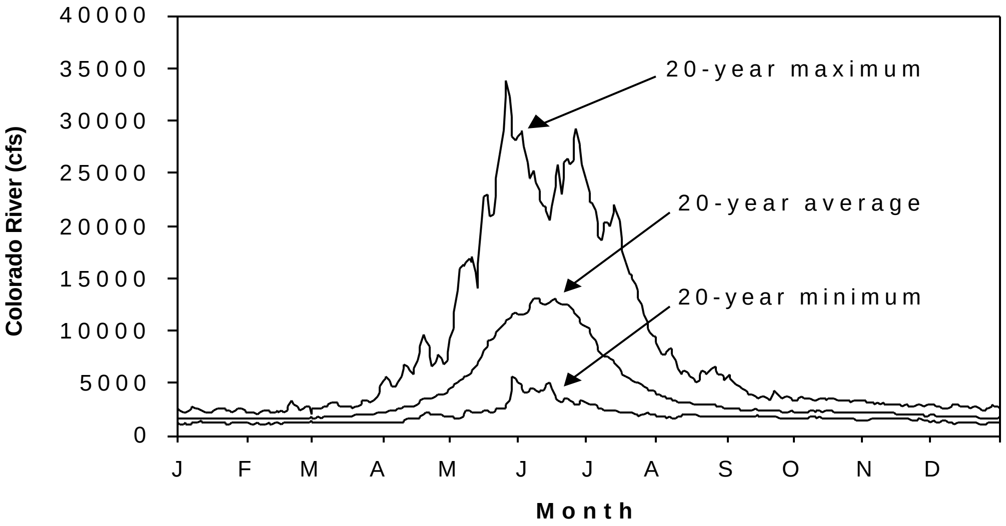


Figure 5–8. Estimated Seasonal Runoff for the Colorado River at the Old Rifle Site

5.2.2 Alluvial Aquifer

The alluvial aquifer is the uppermost hydrostratigraphic unit at the Old Rifle site and is composed mostly of unconsolidated alluvial deposits that include clays, silts, sands, gravels, and cobbles (Section 5.1). Underlying the unconsolidated deposits is an 8- to 13-ft section of weathered Wasatch Formation claystone that appears to be hydraulically connected to and of similar hydraulic characteristics as the unconsolidated sediments.

The lateral extent of the alluvial aquifer at the Old Rifle site is largely limited to the site boundary as defined by Wasatch Formation outcrops and the Colorado River. Narrow sections of alluvium that extend east and west of the site pinch out between the river and prominent Wasatch outcrops (Figure 5–7). Similarly, the northern extent of the alluvium is confined to the site by the steep slopes of the Wasatch Formation.

Alluvial deposits at the Old Rifle site are approximately 20 to 25 ft thick over most of the site (Figure 5–7). Saturated thickness of the aquifer ranges from 5 to 20 ft. Depths to ground water, in May 1998, ranged from 5 ft near the south central part of the site at well 304 to 15 ft near the downgradient edge of the site at well 309. The relatively shallow depth to ground water at well 304 reflects a ground water mound created by infiltration of runoff water from the open irrigation ditch that crosses the site.

Hydraulic conductivities estimated from alluvial aquifer tests range from 96 to125 ft/day (Calculation Set U0042700). Hydraulic gradients, directed west-southwest, range from 0.0033 to 0.0047 ft/ft (Calculation Set U0048100). Average linear velocities, based on these estimates and an assumed effective porosity of 0.27, range from 1.4 to 2.0 ft/day.

Immediately north of the site is Graham Mesa, a relict Colorado River terrace resting on the Wasatch Formation which outcrops just above the site along U. S. Highway 6. Infiltration into the terrace deposits on Graham Mesa occurs from surface irrigation, precipitation, and from Colorado River backwash water stored in the lagoons northeast of the site. Some of this infiltration eventually discharges as seeps and springs along the contact between the older alluvial terrace gravels and the underlying, relatively impermeable Wasatch bedrock formation.

Some of the surface discharge from the seeps and springs flows to the unlined irrigation ditch that parallels U.S. Highway 6 above the site. A metal culvert under U.S. Highway 6 diverts the collected runoff to the center of the site where it is discharged to an open ditch that drains south into the Colorado River. Flow to the open ditch is year round.

Recharge to the alluvial aquifer at the site occurs mostly as infiltration of precipitation, leakage from the drainage ditches north of U. S. Highway 6, and leakage from the open ditch that extends north to south across the site. Recharge areas are graphically illustrated in the conceptual hydrostratigraphic model presented in Figure 5–9. Some recharge also likely occurs as horizontal discharge of ground water along the steep Wasatch subcrop that forms the northern boundary of the alluvial aquifer. Upward vertical hydraulic gradients average 0.005 ft/ft (Calculation Set U0048100) which indicates that movement between the Wasatch Formation and the alluvial aquifer may also contribute some recharge to the alluvial aquifer during low river flow conditions.

Discharge from the alluvial aquifer at the Old Rifle site is to the Colorado River. Plant transpiration and evaporation in areas of shallow ground water depths are the only other processes by which ground water may be discharged from the alluvial aquifer. Discharge by plant ET is considered minimal because the site is dominated by wheatgrasses (Section 4.9) which are shallow-rooted and not considered to be phreatophytes (plants that root in ground water).

5.2.2.1 Alluvial Aquifer and Colorado River Interactions

The majority of ground water in the alluvial aquifer at the Old Rifle site discharges into the Colorado River at the southern boundary of the site. Recharge to the alluvium by leakage from the irrigation ditches and horizontal discharges along the steep Wasatch subcrop that forms the northern boundary of the alluvial aquifer provides a sufficient source of ground water to sustain discharge to the Colorado River year round. This is evidenced by similar flow directions observed in the alluvial ground water during low and high river stage. For example, during the winter when the river is at low stage the ground water flow from the alluvium is directed to the southwest toward the river. The southwest flow direction is shown by the January 1999 ground water elevation contours presented in Figure 5–10. As the river stage rises approximately 5 ft in the spring and early summer, the horizontal flow gradient in the alluvial aquifer decreases, but the system maintains a southwest flow direction. The flow direction and ground water mounding associated with the irrigation ditches during high river stage are revealed by the ground water elevation contours presented in Figure 5–11 for May 1998.

Base flow discharge year-round to the Colorado River will eventually flush site-related constituents from the alluvial aquifer to background concentrations. The dilution effect on the constituents can be calculated to estimate the concentrations at the point of discharge to the

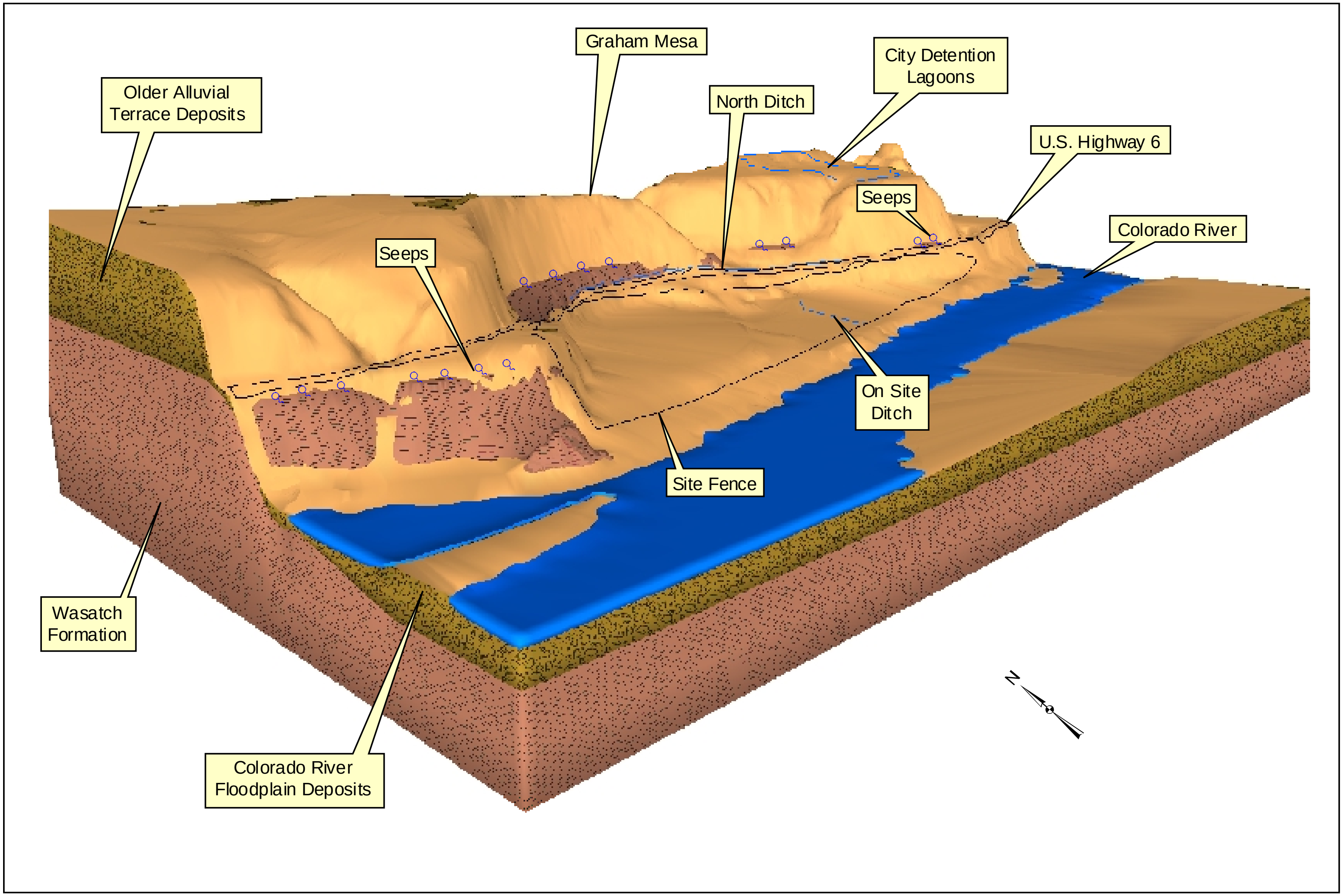


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Figure 5–9. Site Conceptual Hydrostratigraphic Model

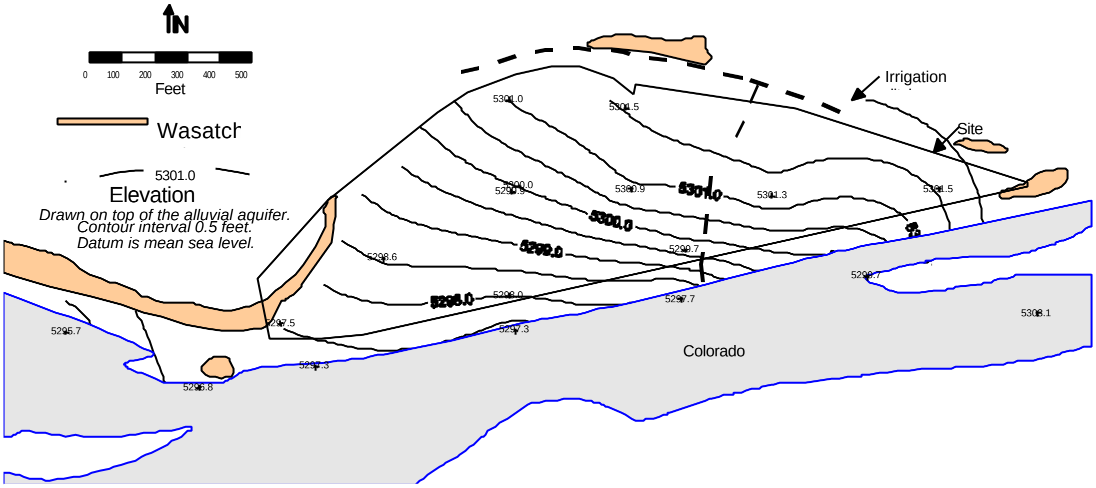


Figure 5–10. Alluvial Ground Water Elevations During Low River Stage, January 1999

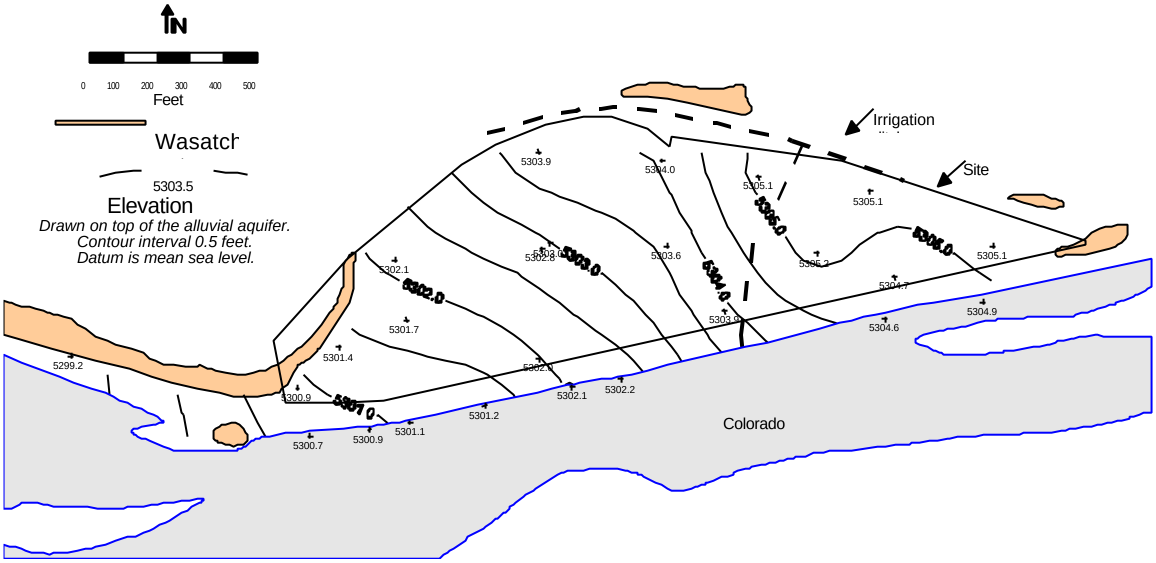


Figure 5–11. Alluvial Ground Water Elevations During High River Stage, May 1998

Colorado River. Several site-related constituents identified in the BLRA (DOE 1996a) are evaluated.

First, the contaminant flow rate to the Colorado River is calculated by multiplying the ground water concentration at the site by the base-flow discharge rate. The ground water concentration for each constituent is based on the maximum value obtained from the most current ground water sampling conducted in May and November 1998 (Appendix B). The base-flow discharge rate is estimated at 0.12 cfs (3.3 liters per second [L/s]) as the product of the average linear flow rate (1.7 ft/day), the saturated thickness (13 ft), and an estimated plume width (450 ft) at the point of discharge into the river.

The product of the ground water concentration and the base-flow discharge rate yields an average contaminant loading rate in mg/s for the four constituents. Resulting constituent concentrations in the Colorado River are estimated by dividing the loading rate by the 20 year average river flow rate of 3,848 cfs (108,952 L/s). The results, summarized in Table 5–1, indicate that the dilution factor of approximately 3.0E–05 for the Colorado River is so great, that the constituents are essentially undetectable when compared to background concentrations.

Table 5–1. Dilution Effects on Ground Water Contaminants Discharging to the Colorado River

Constituent	Ground Water Concentration (mg/L)	Discharge (L/s)	Constituent Loading to River (mg/s)	River Flow Rate (L/s)	Predicted Concentration in River (mg/L)	Dilution Factor
Arsenic	0.02	3.3	0.07	108,952	6.4E–07	3.2E–05
Selenium	0.09	3.3	0.30	108,952	2.8E–06	3.1E–05
Uranium	0.27	3.3	0.89	108,952	8.2E–06	3.0E–05
Vanadium	0.77	3.3	2.54	108,952	2.3E–05	3.0E–05

5.2.3 Wasatch Formation

The Wasatch Formation is a stratified hydrogeologic unit composed of interbedded claystone, siltstone, and sandstone. The claystone units form aquitards and the underlying siltstone and sandstone units form an aquifer or series of aquifers with semiconfined to confined characteristics. The uppermost 8 to 13 ft of the Wasatch Formation directly beneath the Old Rifle site consists of a very soft weathered claystone (Section 5.1). Aquifer test results indicate the uppermost weathered zone is hydraulically well connected to the overlying saturated alluvial deposits (Calculation Set U0042700). This uppermost zone of the weathered Wasatch is underlain by up to 80 ft of competent siltstone and claystone that forms an aquitard. Underlying this aquitard is a saturated semiconfined to confined sandstone aquifer of undetermined thickness.

Depth to the top of the weathered Wasatch Formation beneath the Old Rifle site is about 20 to 25 ft. The weathered surface dips gently to the south (Figure 5–6). Depth to water at two on-site monitor well clusters (RFO–646/–647 and –648/–649) typically ranges from 10 to 16 ft below ground surface (Figure 5–5). At each paired location, a shallow well was completed with a 10-ft screen beginning 10 ft below the contact between the alluvium and Wasatch Formation.

The other bedrock well was completed deeper with a 10-ft screen beginning 30 ft below the contact. Alluvial monitor wells 309 and 655 are nested with Wasatch well pairs 646/647 and

648/649, respectively. Ground water elevations in these groups of wells represent the hydraulic relationship between the alluvium and the section of the Wasatch Formation that is most susceptible to vertical contaminant invasion. Examination of the vertical hydraulic gradients reveals little or no driving force for downward contaminant migration. For example, the average vertical gradient from the Wasatch to the overlying alluvium is 0.005 ft/ft (Calculation Set 0048100). The product of the average vertical gradient and the hydraulic conductivity (0.017 ft/day) indicates an upward flux of 0.0001 ft/day, thereby limiting downward contaminant migration from the alluvium.

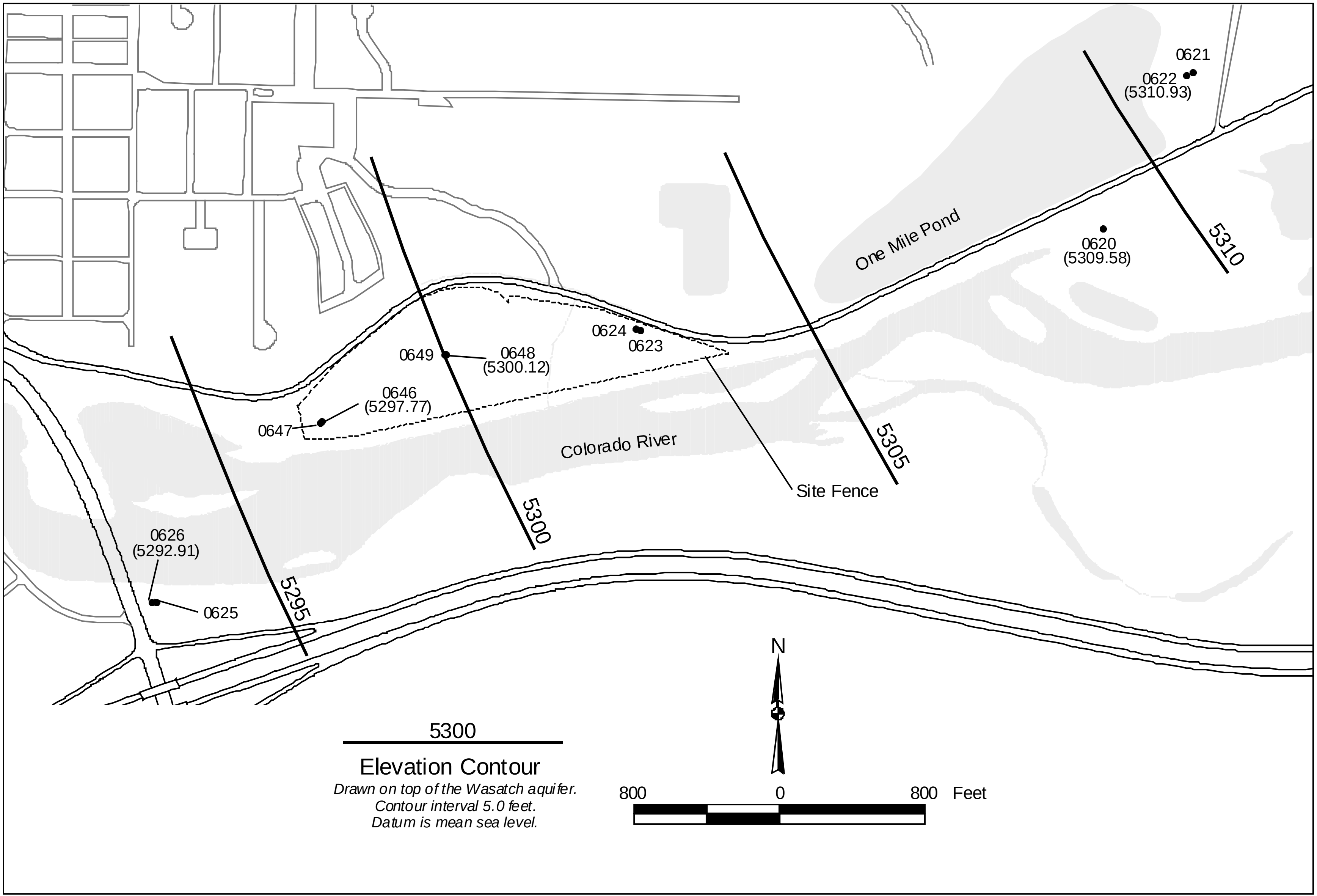
Depth to water in the deeper Wasatch Formation underneath the site can be evaluated by examining ground water elevations observed in monitor wells 623 and 624 which are nested together near the northeast boundary of the site (Figure 5–5). The top of the 10-ft well screens for these wells are completed approximately 71 and 44 ft below the top of the Wasatch contact, respectively. The deeper well (RFO–623) consistently shows a ground water elevation that is approximately 20 to 60 ft higher than in the shallow well (RFO–624). The water level in the shallow completion is near the bottom of the well. The relative lower water elevation in the shallow well suggests the presence of an aquitard or separate flow system separating the upper weathered zone from the deeper Wasatch.

Ground water elevations measured in monitor wells completed in the upper zone of the Wasatch Formation indicate the potentiometric gradient is to the southwest, as evidenced by the contour map presented in Figure 5–12. Similar flow directions are observed during high and low river stage. Horizontal hydraulic gradients in the upper Wasatch Formation range from 0.0023 during high river flow to 0.0031 during low river flow (Calculation Set U0048100). Slug test measurements indicate a geometric mean of 0.017 ft/day for the hydraulic conductivity (DOE 1992, 1996d) in the Wasatch Formation. Average linear velocities, based on these estimates and an assumed effective porosity of 10 percent, range from 0.0004 to 0.0005 ft/day.

Recharge to the Wasatch Formation occurs mainly as precipitation falling directly on the outcrop to the north in the vicinity of the Grand Hogback. Discharge occurs mainly as upward leakage through the alluvial aquifer to the Colorado River.

5.3 Geochemistry

The purpose of this section is to delineate the area where contamination exists, document the individual chemical constituents that contribute to the contamination, and evaluate the fate and transport of the site-related constituents. This is accomplished by first reviewing the historical literature to identify the most probable chemicals and quantities of process water used when the vanadium and uranium milling operation was active. Results of recent field investigations are then evaluated to characterize the former source areas where the contaminants were most likely to enter the ground water flow system. The most recent information available from the 1998 field investigation (Section 4.0) is then presented in a current assessment of the surface-water and ground water quality, including delineation of the nature and extent of site-related constituents occurring above natural background concentrations. Finally, computer flow and transport modeling is used to evaluate the long-term fate and transport of the site-related contaminants in the alluvial aquifer.



Drawn on top of the Wasatch aquifer.
Contour interval 5.0 feet.
Datum is mean sea level.

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Figure 5–12. Potentiometric Surface for the Upper Wasatch Formation at the Old Rifle Site

5.3.1 Source Areas and Contaminants

Some ground water contamination probably occurred as a result of rain water and snow melt percolating through ore stockpiled at the site. The area where potential ground water infiltration would have occurred is located at the east end of the site as designated by the former stockpile area on Figure 3–1. The primary contaminants would have been the relatively more water soluble components of the ore, such as uranium, calcium, and sulfate (the source of calcium and sulfate would have been gypsum, which was part of the ore matrix). Other ore-related contaminants include vanadium, selenium, molybdenum, and arsenic.

Process chemicals were an additional source of ground water contamination that probably occurred as a result of water draining from the sandy tailings that were placed as a slurry pile on the west central portion of the site. According to Merritt (1971) the mill was built in 1924 to recover vanadium from roscoelite-type ores by salt roasting, water leaching, and the addition of sulfuric acid (H_2SO_4) to the water solutions to precipitate a sodium hexavanadate red cake. In 1947, acid leaching and subsequent process steps were added to extract uranium from carnotite-type sandstone ores. Water leached residues were releached with sulfuric acid to precipitate an impure green sludge product by neutralization of the leach solutions with ammonia (NH_3). This product was purified by redissolving in sulfuric acid and sodium chlorate ($NaClO_3$), followed by the addition of sodium carbonate (Na_2CO_3) and ferric sulfate ($Fe_2(SO_4)_3$) to pH 2.5 to precipitate an iron vanadate. After filtration, the addition of additional sodium carbonate to pH 6 precipitated alumina, which was then removed by filtration. Uranium concentrate was finally precipitated from the purified solution by acidifying and boiling to expel carbon dioxide (CO_2) and then adding gaseous ammonia.

Infiltration of the contaminated process water from the salt roasting and acid leaching operations would have occurred at the former mill tailings area shown in Figure 3–1. Process chemicals in the water draining from the tailings would have contributed sodium (Na^+), chloride (Cl^-), sulfate (SO_4^{2-}), and ammonium (NH_4^+) ions to the ground water.

The origin of the site-related constituents that are associated with the former processing operations and the extent to which they are available to be dispersed in ground water downgradient from the site are evaluated in the following sections.

5.3.1.1 Quantity Estimates of Process Water and Chemicals

The quantity of water and process chemicals used at the Old Rifle site is estimated on the basis of typical usage in uranium mills reported by Merritt (1971) and by the U.S. Department of Health, Education, and Welfare (HEW 1962). Merritt reports water consumption rates from as low as 200 to as high as 1,000 gal per ton of ore. The amount of chemical usage in a typical acid leach mill per ton of ore processed, based on the HEW estimate, is 30 to 500 pounds of sulfuric acid for leaching, 1 to 30 pounds of ammonia and 10 to 15 pounds of sodium carbonate to adjust the pH, 1 to 3 pounds of sodium chlorate as an oxidant, and 50 to 160 pounds of sodium chloride for roasting vanadium ores.

5.3.1.2 Former Tailing Pile Contamination

Limited information is available on the chemical composition of the contaminated process water and pore fluids that could have infiltrated to the ground water from the former tailings and ore stockpile areas. However, an estimate of contaminant concentrations in the tailings pore fluids can be obtained from leach studies of the tailings material. Water leaching tests from tailings core samples obtained from the Old Rifle site were performed by Markos and Bush (1983). Average concentrations for selected contaminants (mass of analyte extracted per mass of tailings) are presented in Table 5–2. Also included in Table 5–2 are results of water leachate of soil core samples collected at selected background locations between the Colorado River and east of the former New Rifle millsite (3.3 miles west of the Old Rifle Site). Surface samples collected at these background locations were eliminated from the average to minimize any bias that may be introduced from windblown tailings since remediation was not yet completed.

Table 5–2. Average Concentration of Selected Contaminants in Leachate from Tailings and Background Soils

Constituent	Old Rifle Tailings Leachate (mg/Kg)	Background Leachate (mg/Kg)
Arsenic	5.4	0.5
Chloride	144.4	76.0
Manganese	2.8	0.4
Molybdenum	3.3	0.5
Selenium	2.3	0.4
Sulfate	2,123	303
Uranium	3.2	0.3
Vanadium	106.5	44.4
Number of samples	71	7

Average concentrations of all the selected constituents in tailings core samples collected at the Old Rifle site are elevated with respect to the average background values. These elevated constituents in the leachate represent water-soluble contaminants that could have entered the ground water as process water, precipitation, or irrigation runoff leached through the tailings pile. Thus, these are the constituents most likely to be present in the subpile soils and dispersed in the ground water downgradient from the former source areas.

5.3.1.3 Subpile Soil Contamination

The tailings pile and residuals in the soils that exceeded 15 pCi/g radium-226 were completely removed from the site by 1996 as part of the UMTRA Surface Project. However, site-related inorganic constituents may have leached into the soils below the former tailings pile and gone undetected during the radiometric assessment for the tailings removal.

Samples of the soils directly beneath the former tailings and ore stockpile areas were collected and analyzed for arsenic, molybdenum, selenium, uranium, and vanadium (Section 4.5), all of which were identified in the BLRA (DOE 1996a) as the most significant site-related constituents occurring in the alluvial aquifer to determine if these areas are likely to be continuing sources of ground water contamination.

Two background and four on-site locations were sampled. Selected soil samples were subjected to two sequential leachings in the laboratory. Each leach represents a scenario that might cause the mobilization of contaminants from soils into the ground water. The first leach used an uncontaminated synthetic ground water to represent the effects that a high water table might have if it were to contact contaminated soils. Concentrations of selected constituents extracted from background and subpile soils using the synthetic ground water leach are summarized in Table 5–3 and presented in Figure 5–13.

Table 5–3. Summary of Constituents Extracted by Synthetic Ground Water from Background and Subpile Soils

Monitor Well	**Area**	**Constituent (mg/Kg)**				
		As	**Mo**	**Se**	**U**	**V**
292	Background	0.31	0.12	<0.2	0.38	0.5
658	Background	0.26	0.1	<0.2	0.1	0.5
309	Tailings	0.2	0.1	<0.2	0.35	0.5
654	Tailings	0.27	0.1	<0.2	0.17	3.7
656	Ore Stockpile	0.2	0.18	<0.2	12.6	0.5
663	Tailings	0.28	0.12	<0.2	0.72	1.9

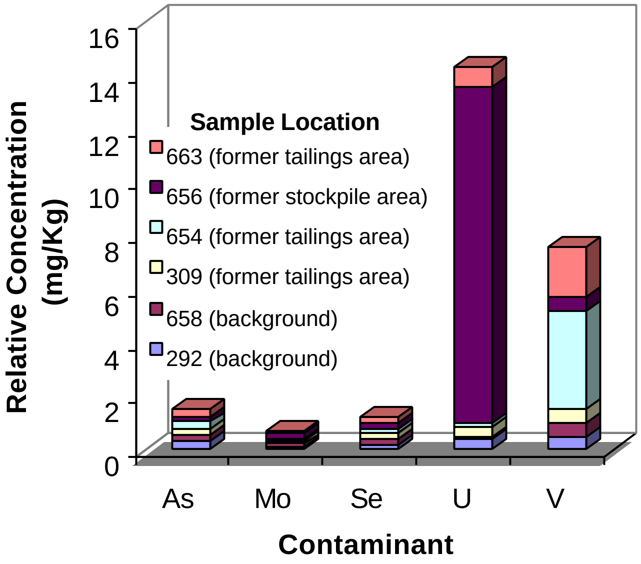

Figure 5–13. Comparison of Constituents Extracted by Synthetic Ground Water from Background and Subpile Soils

The second leach consisted of a 5 percent nitric acid solution that will remove carbonate minerals and iron and manganese oxyhydroxides. These phases are believed to be the main metal and uranium scavengers in the soils. Although it is not likely that water of this acidity would ever contact the soils, the removal of oxyhydroxides might occur if land uses changed significantly (for example, agricultural use could cause changes in redox conditions that would influence mineral dissolution). The 5 percent nitric acid is considered a worst-case scenario. Concentrations of selected constituents extracted from background and subpile soils using the 5 percent nitric acid leach are summarized in Table 5–4 and presented in Figure 5–14.

Table 5–4. Summary of Constituents Extracted by 5 percent Nitric Acid Solution from Background and Subpile Soils

Monitor Well	Area	Constituent (mg/Kg)				
		As	Mo	Se	U	V
292	Background	1.4	0.27	<0.2	0.67	4.3
658	Background	0.99	0.41	<0.2	0.27	1.7
309	Tailings	0.92	0.31	<0.2	1.1	2.2
654	Tailings	1.1	0.13	<0.2	0.28	25.5
656	ore stockpile	1.4	0.25	<0.2	8.4	12.8
663	Tailings	2.9	0.32	<0.2	1.3	29.2

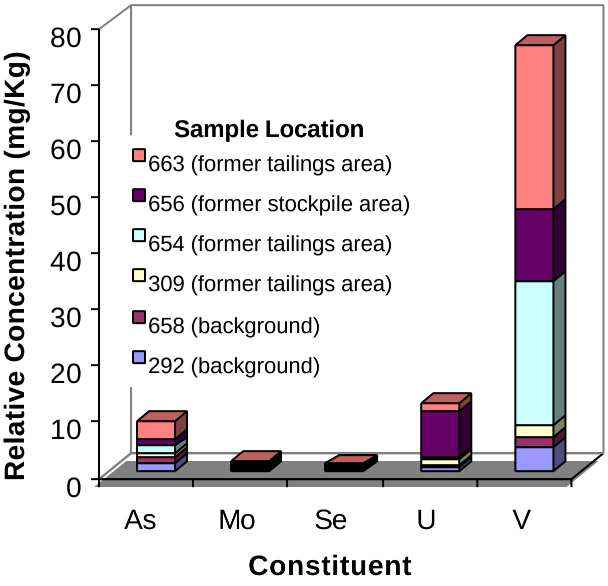

Figure 5–14. Comparison of Constituents Extracted by 5 percent Nitric Acid Solution from Background and Subpile Soils

The sum of the synthetic ground water and nitric acid leach results obtained for each sample are summarized in Table 5–5. These results provide an estimate of the total amount of leachable contaminants per mass of soil. For comparison, concentrations observed in background soils and sediments for the western United States are also presented (Shacklette and Boerngen 1984). Results obtained for the subpile soil samples are evaluated in combination with background soil results to qualitatively evaluate the likelihood that the subpile soils present a continuing contaminant source. Results for each site-related constituent are discussed separately below.

Table 5–5. Comparison of the Total Amount Extracted from Site-Specific Background and Subpile Soil Samples to the Average Background Concentrations in Soils and Sediments for the Western United States

Monitor Well	Area	Constituent (mg/Kg)				
		As	**Mo**	**Se** [a]	**U**	**V**
292	Background	1.71	0.39	0.2	1.05	4.8
658	Background	1.25	0.51	0.2	0.37	2.2
309	Tailings	1.12	0.41	0.2	1.45	2.7
654	Tailings	1.37	0.23	0.2	0.45	29.2
656	Ore Stockpile	1.6	0.43	0.2	21	13.3
663	Tailings	3.18	0.44	0.2	2.02	31.1
Average for the Western U.S.		5.5	0.85	0.2	2.5	70

[a] One-half the detection limit used to calculate the total for the site-specific locations

Arsenic in Subpile Soil

The amount of arsenic leached from the subpile soil samples by the synthetic ground water (Table 5–3) ranges from 0.20 to 0.28 mg/Kg. These values are consistent with the range in arsenic concentration of 0.26 to 0.31 mg/Kg leached from the background soil samples. Similarly, the amount of arsenic leached from the subpile soils by the relatively harsh 5 percent nitric acid solution (Table 5–4) is also consistent with the amount leached from the background soil samples at all locations with the exception of 663 which is located near the center of the former tailings pile. At location 663 the leachate concentration of 2.9 mg/Kg is approximately twice as high as the 1.4 mg/Kg obtained at background location 292. However, the total amount of arsenic (3.18 mg/Kg) extracted from the subpile soils (Table 5–5) at location 663 is less than the average arsenic concentration (5.5 mg/Kg) observed in background soils and sediments for the western United States. Overall, the extractable arsenic amounts are relatively low, especially for the synthetic ground water leach, and thus are probably not a significant contributor as a continuing source of ground water contamination.

Molybdenum in Subpile Soil

Relatively low amounts of molybdenum were leached from both the subpile and background soils using the synthetic ground water solution. The highest concentration of 0.18 mg/Kg in the leachate was obtained for sample 656 that was collected near the center of the former ore stockpile area. Similarly, relatively low molybdenum concentrations were leached from the subpile and background soil samples using the nitric acid solution. The highest molybdenum concentration using the nitric acid leach was 0.41 mg/Kg obtained from background soil sample 658. The total molybdenum concentrations extracted for all subpile soil samples are less than the total concentration of 0.51 mg/L obtained at background location 658 and are less than the average concentration of 0.85 mg/L observed in background soils and sediments for the western United States. Because the extractable concentrations from the on-site locations are relatively low, and the values are consistent with concentrations extracted from background soil samples, it is highly unlikely that molybdenum is present in amounts that could provide a continuing source for ground water contamination at the site.

Selenium in Subpile Soil

Leachate concentrations obtained from the background soil samples are less than the 0.2 mg/Kg detection limit for all the selenium analyses. This detection limit is consistent with the average concentration of 0.2 mg/Kg selenium observed in background soils and sediments for the western United States. All the subpile soil leachate analyses are also less than the detection limit indicating that relatively high selenium concentrations are not present in the subpile soil, thus selenium is highly unlikely to be present in concentrations that would provide a continuing source of ground water contamination.

Uranium in Subpile Soil

The amount of uranium leached from the subpile soils by the synthetic ground water solution is consistent with the amount leached from the background soil samples at all locations with the exception of 656 and 663. Subpile soil sample 656, collected from the former ore stockpile area, contains 12.6 mg/Kg uranium; a concentration which is significantly higher than the 0.38 mg/Kg uranium obtained for the background soil sample location 292 collected upgradient from the site. The uranium concentration of 0.72 mg/Kg, extracted at the former tailings area location 663, is approximately twice as high as the background soil sample.

The total amount of uranium (21 mg/Kg) extracted at location 656 is also higher than the 2.5 mg/Kg observed in background soils and sediments for the western United States. If a small continuing source near the former stockpile area is present, as suggested by the leachable uranium concentration at location 656, then the potential for uranium to persist to some extent in the ground water is possible. Conversely, most of the uranium was leached out of sample 656 with the synthetic ground water solution, as compared to the nitric acid solution, suggesting that uranium is highly mobile and readily partitions into the ground water and therefore will eventually naturally flush from the aquifer.

The total uranium concentration leached from the former tailings area subpile soil sample 663 and all the other subpile soil samples and background samples are comparable in composition to background soils and sediments for the western United States. Thus, uranium is highly unlikely to be present in concentrations that would provide a continuing source of ground water contamination from the former tailings area.

Vanadium

Concentrations obtained by the synthetic ground water extraction for the subpile soils collected from the former tailings area are elevated with respect to vanadium over the background soil samples. Subpile soil samples collected from borings 663 and 654 contain a concentration of 1.9 and 3.7 mg/Kg respectively, which are higher than the 0.5 mg/Kg extracted from the background samples.

Significantly more vanadium is extractable by the nitric acid leach as compared to the synthetic ground water solution. This is evident by the 29.2 and 25.5 mg/Kg vanadium extracted at subpile soil sample locations 663 and 654, respectively. These concentrations are also significantly higher than the 4.3 mg/Kg extracted by the nitric acid leach at background location 292.

The relatively small amount of vanadium leached out in the synthetic ground water solution as compared to the nitric acid solution suggests that vanadium is strongly sorbed in the subpile soils and therefore could persist as a continuing source that will slowly partition to the ground water and eventually naturally flush only gradually with time. However, the total amount of 31.1 and 29.2 mg/Kg vanadium extracted from subpile soil samples 663 and 654, respectively, is less than the 70 mg/Kg observed in background soils and sediments for the western United States. This suggests that while vanadium may be elevated in the subpile soils the amount present is probably not a significant contributor to vanadium concentrations in the ground water.

5.3.2 Surface Water Quality

Surface water features near the site include the Colorado River, ponds, seeps and springs, and the City detention lagoons on Graham Mesa to the northeast. One Mile Pond, located just east of the City detention lagoons, receives irrigation water discharge from the Lower Cactus Valley Ditch during the spring and summer. The Lower Cactus Valley Ditch carries Colorado River water from the Silt Pumping Plant located approximately 5 miles east of Rifle to low lying mesas between Silt and the site. Further upgradient of the site are also several large man-made ponds associated with gravel mining operations located along the Colorado River floodplain.

Surface discharge from seeps and springs to the unlined irrigation ditch that parallels U. S. Highway 6 north of the site and at a location northeast of One Mile Pond are the only other nearby surface water sources. The seeps discharge seasonally, often surrounding the point of discharge with precipitated salts. Springs provide water throughout the year. Infiltration from the lagoons on Graham Mesa enters the terrace sediments north of U. S. Highway 6 and then discharges horizontally as seeps along the alluvial and Wasatch contact and into the unlined ditch north of the site. This ditch is diverted under the highway via an underground culvert and empties into a ditch that flows south through the eastern portion of the site and discharges to the Colorado River.

5.3.2.1 Background Surface Water Quality

Background water quality is defined as the quality the water would have if uranium milling activities had not taken place. Background water quality was determined by collecting samples from the river, ponds, and seeps located upgradient and upstream from the site. Background sample locations include three seeps (399, 397, 573), One Mile Pond (539, 570, and 1200 series), an active gravel pond (580), and an upgradient river location (538); these are shown on Figure 5–15. Background water quality sampling results for 1998, summarized in Table 5–6, are available in Appendix B. Background results are used as a basis for evaluating potential site-related contamination at surface water locations present at the site.

Concentrations for most constituents in the pond samples are generally higher than for river samples. Water tends to evaporate from standing water bodies in the semiarid climate of western Colorado. Thus, the relatively higher chloride, sulfate, TDS, and trace metals levels observed in the pond samples than observed in the river water samples can probably be attributed to concentration through evaporation.

Concentrations in background samples collected from ditches, seeps, and springs are generally within the range observed for pond samples. However, certain constituents are significantly higher in the former—notably uranium, selenium, and sulfate. Highest detected levels of

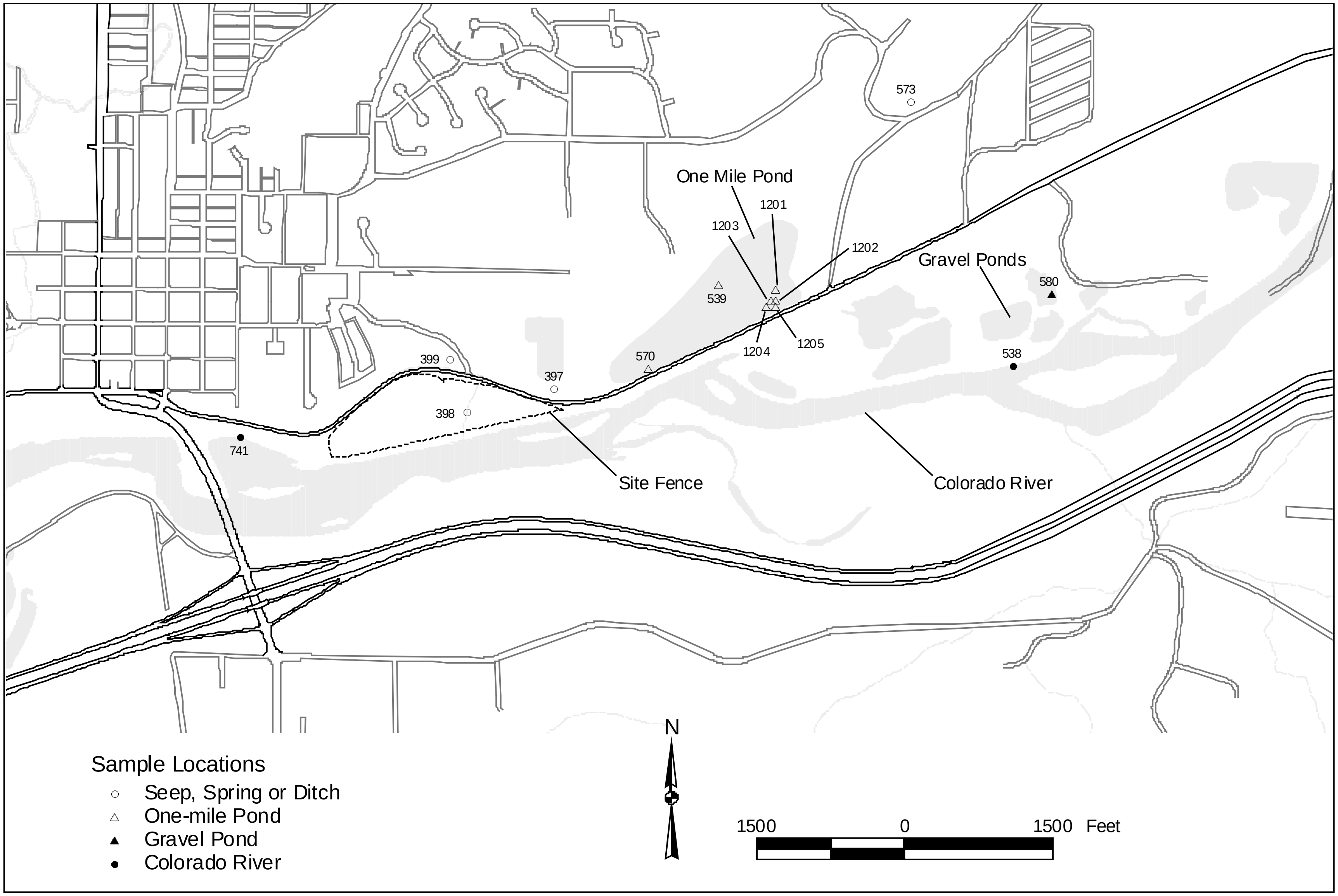

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Figure 5–15. Surface Water Sample Locations

Table 5–6. Background Water Quality for Surface Water

Analyte[b]	Unit	Background Ditches, Seeps, and Springs			Background Gravel Pond			Background One-Mile Pond[a]			Background River		
		FOD[c]	Range	Mean[d]	FOD	Range	Mean	FOD	Range	Mean	FOD	Range	Mean
Major													
Ammonia as NH_4	mg/L	6/7	<.001-.0231	.01667	4/4	.0094-.0468	.02345	8/8	.025-.111	.05666	3/4	.0082-.0368	.02078
Calcium	mg/L	7/7	102-251	181.8	4/4	54.6-84.5	72.63	3/3	77-112	91	4/4	37-68.2	58.7
Chloride	mg/L	7/7	45-120	76.77	4/4	176-203	192.5	3/3	18.4-96.7	47.87	4/4	33.7-171	126.7
Magnesium	mg/L	7/7	62.3-166	114.8	4/4	69.5-80.7	75.15	3/3	42.5-91.1	63.5	4/4	7.67-17.1	13.12
Nitrate	mg/L	5/7	<.0304-12.4	3.646	1/4	<.035-.0719	N/A	1/8	<.0406-3.03	N/A	3/4	<.011-.602	.3026
Sodium	mg/L	7/7	79.2-332	184.4	4/4	355-435	398.5	3/3	63.2-113	92.4	4/4	25.1-119	88.83
Sulfate	mg/L	7/7	380-1690	956.7	4/4	594-748	674.8	8/8	249-538	312.8	4/4	39.8-133	99.95
Metal													
Antimony	mg/L	0/7	<.001-<.001	N/A	0/4	<.001-<.001	N/A	0/3	<.001-<.001	N/A	0/4	<.001-<.001	N/A
Arsenic	mg/L	0/7	<.001-<.001	N/A	0/4	<.001-<.001	N/A	5/8	<.001-.0052	.00212	0/4	<.001-<.001	N/A
Cadmium	mg/L	0/7	<.001-<.001	N/A	0/4	<.001-<.001	N/A	0/8	<.001-<.001	N/A	0/4	<.001-<.001	N/A
Iron	mg/L	0/7	<.003-<.0137	N/A	0/4	<.003-<.005	N/A	7/8	.0096-.111	.05005	2/4	<.0102-.0321	.01911
Lead	mg/L	0/7	<.001-<.001	N/A	0/4	<.001-<.001	N/A	0/3	<.001-<.001	N/A	0/4	<.001-<.001	N/A
Manganese	mg/L	7/7	.0024-.0793	.01721	4/4	.0015-.108	.02903	8/8	.0341-.695	.2363	4/4	.0088-.343	.0961
Molybdenum	mg/L	7/7	.0058-.0161	.01138	4/4	.0193-.0241	.02178	7/8	.001-.011	.003663	3/4	.0011-.0098	.006
Selenium	mg/L	7/7	.0011-.011	.005589	2/4	<.001-.0012	.00085	4/8	.0019-.007	.002427	0/4	<.001-<.001	N/A
Uranium	mg/L	7/7	.021-.0546	.0413	4/4	.023-.0301	.02638	8/8	.0047-.0293	.01387	3/4	<.001-.0027	.0019
Vanadium	mg/L	6/7	.0018-.0161	.005678	0/4	<.001-<.0079	N/A	4/8	.0018-.0104	.004127	0/4	<.001-<.0072	N/A
Other													
Alkalinity as $CaCO_3$	mg/L	7/7	248-400	334.7	4/4	354-475	427.5	5/5	109-322	201.7	4/4	93-158	125.3
Fluoride	mg/L	5/5	.523-1.12	.8047	2/2	.803-.816	.8095	7/7	.238-.408	.3106	2/2	.129-.257	.193
Redox Potential	mV	7/7	71-223	175.4	4/4	164-214	198.5	3/3	20-175	91	4/4	56-271	123
Specific Conductance	umhos/cm	7/7	1404-3530	2261	4/4	2340-2960	2515	5/5	600-1585	983.8	4/4	1061-8720	3662
Total Dissolved Solids	mg/L	5/5	1110-3140	1862	3/3	1510-1880	1677	2/2	912-1080	996	3/3	520-632	579
pH	s.u.	7/7	7.15-8.44	8.051	4/4	7.84-8.64	8.248	5/5	7.22-8.44	8.085	4/4	7.52-9.01	8.513
Radioactive													
Gross Alpha	pCi/L	7/7	10.74-32.77	21.86	3/4	12.79-37.86	N/A	3/3	6.95-18.97	13.14	0/4	<2.26-<10.6	N/A
Gross Beta	pCi/L	5/7	<10.09-32.37	18.54	1/4	<11.18-25.45	10.08	1/3	<5.49-19.53	N/A	1/4	3.1-12.56	N/A
Lead-210	pCi/L	0/7	<.91-<1.37	N/A	0/4	<.91-<1.37	N/A	0/3	<.89-<1.31	N/A	0/4	<.94-<1.33	N/A
Polonium-210	pCi/L	0/7	<.05-<.4	N/A	0/4	<.06-<.16	N/A	0/3	<.08-<.37	N/A	0/4	<.05-<.22	N/A
Radium-226	pCi/L	7/7	.13-.25	.1567	1/4	<.1-.84	N/A	3/3	.18-.47	.2833	3/4	<.09-.23	.1513
Radium-228	pCi/L	0/7	<.4-<1	N/A	0/4	<.63-<.92	N/A	0/3	<.6-<.95	N/A	0/4	<.42-<.71	N/A
Thorium-230	pCi/L	0/7	<.8-<1.6	N/A	0/4	<.8-<1.6	N/A	0/3	<.8-<1.6	N/A	0/4	<.8-<1.6	N/A

[a] Two 1993 samplings of location 539 included in the One-Mile Pond group. The five One-Mile Pond wetland locations (1201–1205) were pooled as one location to calculate the mean.

[b] All measurements are filtered except specific conductance, pH, redox potential, and alkalinity (as $CaCO_3$) which are unfiltered.

[c] Frequency of detection.

[d] One-half the detection limit was used to calculate the mean; mean was not calculated if fewer than half of the samples were above detection.

uranium and selenium actually exceed the UMTRA ground water standards. Concentrations of sulfate are significantly higher on the average; the maximum from seep-related samples is more than double the highest levels detected in the other surface water locations. These differences in seep, spring, and ditch samples are probably attributable to the fact that this water actually resides as ground water before discharging to the surface. Interaction with subsurface materials is likely responsible for the difference in character of these waters compared to waters confined to the surface environment.

5.3.2.2 Site Impacts on Surface Water

The Colorado River and the open irrigation ditch that extends north to south across the eastern portion of the site are the only permanent surface water present at the site. The on-site ditch receives surface drainage from the seeps and springs along and above U. S. Highway 6. Samples were collected from the on-site ditch at location 398. Samples were also collected from the river downstream of the site at location 741 (Figure 5–15) to determine impacts on the river, if any, from site contamination. Results summarized in Table 5–7 are available in Appendix B.

Table 5–7. Old Rifle Site Surface Water—February through November 1998

Analyte[a]	Unit	Site River			Site Ditch		
		FOD[b]	Range	Mean[c]	FOD	Range	Mean
Major							
Ammonia as NH_4	mg/L	2/3	<.001–.0352	.02187	2/3	<.001–.0139	.008433
Calcium	mg/L	3/3	36.7–66	55.83	3/3	184–227	210.3
Chloride	mg/L	3/3	33–175	126.3	3/3	73.8–114	97.93
Magnesium	mg/L	3/3	7.71–14.1	11.97	3/3	93.4–97.8	95.5
Nitrate	mg/L	3/3	.385–.583	.5027	3/3	3.6–7.65	5.32
Sodium	mg/L	3/3	25.2–113	83.4	3/3	94.9–105	98.7
Sulfate	mg/L	3/3	39.5–119	89.17	3/3	658–847	749.3
Metal							
Antimony	mg/L	0/3	<.001–<.001	N/A	0/3	<.001–<.001	N/A
Arsenic	mg/L	0/3	<.001–<.001	N/A	0/3	<.001–<.001	N/A
Cadmium	mg/L	0/3	<.001–<.001	N/A	0/3	<.001–<.001	N/A
Iron	mg/L	1/3	<.0108–.0323	N/A	0/3	<.003–<.0065	N/A
Lead	mg/L	0/3	<.001–<.001	N/A	0/3	<.001–<.001	N/A
Manganese	mg/L	3/3	.0066–.0264	.0158	3/3	.0025–.0068	.004067
Molybdenum	mg/L	3/3	.0012–.0082	.0058	3/3	.0107–.015	.0125
Selenium	mg/L	0/3	<.001–<.001	N/A	3/3	.0059–.0091	N/A
Uranium	mg/L	2/3	<.001–.0022	.0016	3/3	.0276–.0381	.03437
Vanadium	mg/L	1/3	<.001–.007	N/A	2/3	.0068–.0108	.0068
Other							
Alkalinity as $CaCO_3$	mg/L	3/3	92–166	130.7	3/3	247–333	276.3
Fluoride	mg/L	2/2	.109–.249	.179	2/2	.948–1.04	.994
Redox Potential	mV	3/3	205–222	210.7	3/3	124–219	181.7
Specific Conductance	umhos/cm	3/3	1036–3890	2005	3/3	1855–1952	1890
Sulfate/Chloride		3/3	.6374–1.197	.8381	3/3	7.009–8.916	7.785
Total Dissolved Solids	mg/L	2/2	528–615	571.5	2/2	1330–1570	1450
pH	s.u.	3/3	7.43–8.54	8.05	3/3	7.56–8.89	8.193
Radioactive							
Gross Alpha	pCi/L	1/3	3.63–10.53	N/A	2/3	<15.62–23.81	17.05
Gross Beta	pCi/L	1/3	3.3–12.56	N/A	0/3	<10.37–<12.89	N/A
Lead-210	pCi/L	0/3	<.92–<1.34	N/A	0/3	<.9–<1.24	N/A
Polonium-210	pCi/L	0/3	<.06–<.44	N/A	0/3	<.06–<.42	N/A
Radium-226	pCi/L	2/3	<.11–.26	.1917	3/3	.21–.55	.3467
Radium-228	pCi/L	0/3	<.64–<1	N/A	0/3	<.6–<.72	N/A
Thorium-230	pCi/L	0/3	<.8–<1.6	N/A	0/3	<.8–<1.6	N/A

[a] All measurements are filtered except specific conductance, pH, redox potential, and alkalinity (as $CaCO_3$) which are unfiltered.
[b] Freqeuncy of detection.
[c] One-half the detection limit was used to calculate the mean; mean was not calculated if fewer than half of the samples were above detection.

A comparison of ditch and river sampling results indicates that they are virtually indistinguishable from results obtained from respective background locations. Concentrations from site ditch and river samples are generally within the range of background or are not significantly different. Based on these results it can be concluded that contamination associated with the site has had no adverse impact on surface water at or adjacent to the site.

5.3.3 Alluvial Aquifer Water Quality

Water quality data for the alluvial aquifer in the vicinity of the Old Rifle site have been collected since 1985, though frequency and location of wells sampled have varied. Most of the following discussion focuses on results from the most current 1998 sampling events. Historical data are referenced where appropriate.

5.3.3.1 Background Alluvial Ground Water Quality

Regional background water quality of the alluvial aquifer in the Rifle area is naturally variable and generally poor (Wright Water Engineers 1979). A broad evaluation of the regional ground water in the Rifle area indicates that concentrations of several chemical constituents, including arsenic, barium, molybdenum, radium, selenium, and uranium have exceeded UMTRA standards (DOE 1996d).

Local water quality underneath the site prior to the milling operations is inferred by characterizing the water quality in areas upgradient of the site that are unaffected by process contamination, but which are located in the same flow system that influences the Old Rifle site. Previous work has shown that alluvial water quality from the south side of the Colorado River is significantly different and of substantially higher quality than that on the north side (DOE 1996d). This is attributed to the fact that ground water south of the river receives water from the recharge area that drains basalt mesas; the basalts are relatively insoluble and contribute little to dissolved salts in ground water, unlike the lithologies found on the north side of the river. Therefore, only wells located north of the river are used to characterize background water quality for the site.

Wells RFO–597, –598, –605, and –606 were previously determined to be representative of background (DOE 1996d); since that time well RFO–605 has been removed and additional background wells installed (RFO–291, –292, –659, –660). Locations of the background alluvial monitor wells are shown in Figure 5–16. Background alluvial water quality results for the 1998 sampling events are presented in Appendix C and summarized in Table 5–8. These results can be used as a basis for comparison against potential ground water contamination observed at the site.

Sampling results confirm that alluvial ground water in the Rifle area is generally poor. Maximum detected concentrations of uranium and selenium are higher than the UMTRA standards of 0.044 and 0.01 mg/L, respectively. Sulfate values from all background samples exceed the secondary drinking water standard of 250 mg/L. Concentrations for some samples are also higher that the secondary standards for chloride (250 mg/L), iron (0.3 mg/L), and manganese (0.05 mg/L). While the secondary standards are not enforceable or health-based levels, the fact that they are exceeded does give an indication of the poor quality of the ground water. Most of the other trace elements including antimony, arsenic, cadmium, lead, and vanadium were detected at low concentrations or below the analytical detection limit.

Time-concentration plots for selected constituents are shown in Figures 5–17 through 5–19 for four background wells having the greatest amount of historical data. These figures show

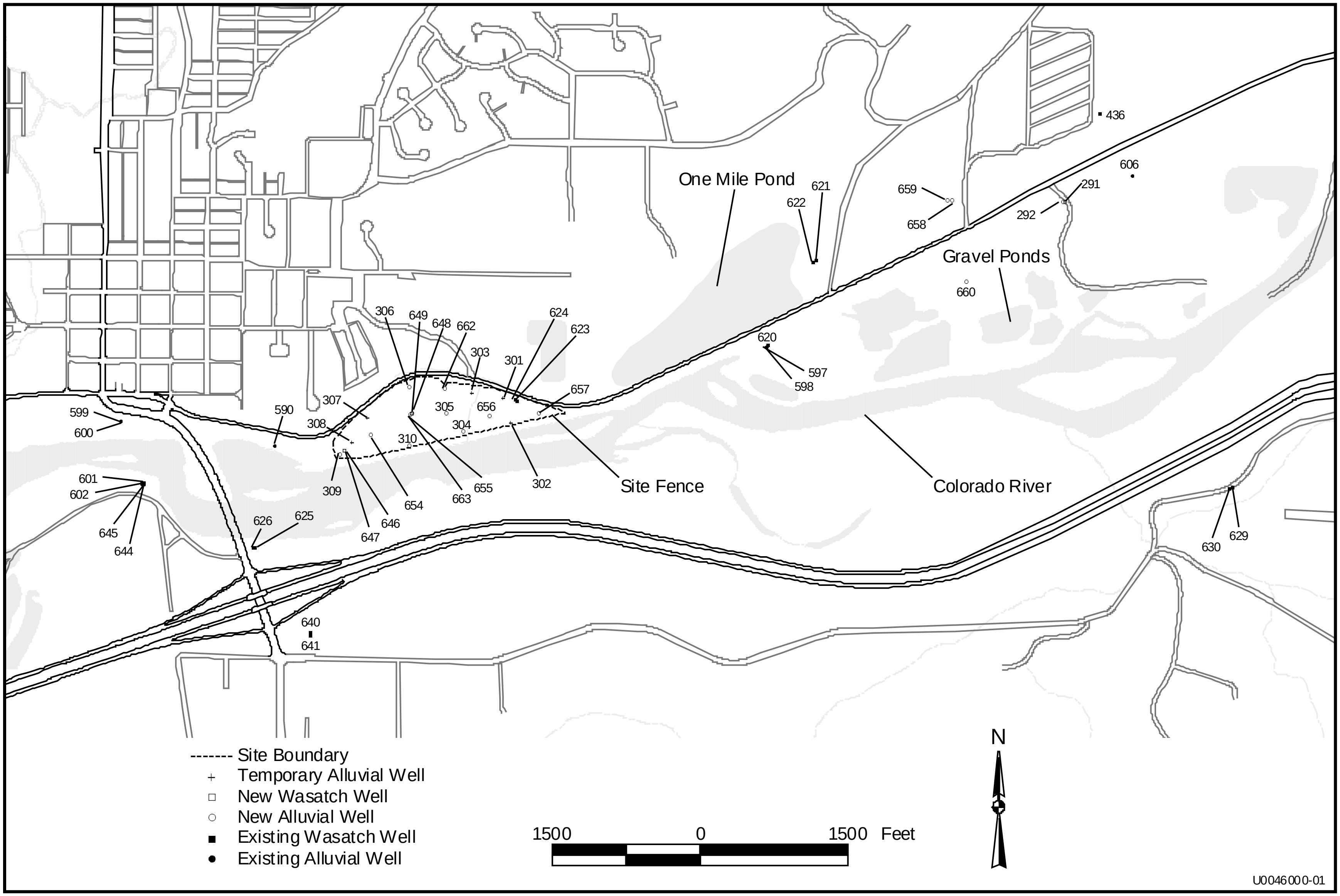


Figure 5–16. Ground Water Monitor Well Sampling Locations

considerable variability in constituent concentration over time, but with no consistent trends indicated.

Table 5–8. Background Water Quality for the Alluvial Aquifer

Analyte[a]	**Unit**	**Alluvial Background**		
		FOD[b]	**Range**	**Mean[c]**
Major				
Ammonia as NH4	mg/L	12/15	<.001–.61	.1596
Calcium	mg/L	15/15	44.1–295	154.6
Chloride	mg/L	15/15	66–274	176.3
Magnesium	mg/L	15/15	50.6–174	115.1
Nitrate	mg/L	11/15	<.011–2.81	1.56
Sodium	mg/L	15/15	164–655	453.3
Sulfate	mg/L	15/15	482–2240	1131
Metal				
Antimony	mg/L	0/15	<.001–<.001	N/A
Arsenic	mg/L	6/15	<.001–.0034	N/A
Cadmium	mg/L	0/15	<.001–<.001	N/A
Iron	mg/L	11/15	<.003–3.03	.4721
Lead	mg/L	1/15	<.001–.0012	N/A
Manganese	mg/L	15/15	.0492–3.66	1.036
Molybdenum	mg/L	15/15	.0034–.0345	.01873
Selenium	mg/L	9/15	<.001–.0298	.009306
Uranium	mg/L	15/15	.0055–.0594	.0377
Vanadium	mg/L	3/15	<.001–.0016	N/A
Other				
Alkalinity as CaCO3	mg/L	15/15	336–645	504.3
Fluoride	mg/L	15/15	.422–1.45	.8789
Redox Potential	mV	15/15	-293–105	-64.44
Specific Conductance	umhos/cm	15/15	1866–4490	2958
pH	s.u.	15/15	6.8–8.5	7.124
Radioactive				
Gross Alpha	pCi/L	13/15	<14.86–73.62	38.01
Gross Beta	pCi/L	8/15	<12.84–42.69	20.88
Lead-210	pCi/L	0/15	<.93–<1.33	N/A
Polonium-210	pCi/L	1/15	<.05–.18	N/A
Radium-226	pCi/L	7/15	<.04–.17	N/A
Radium-228	pCi/L	0/15	<.4–<.8	N/A
Thorium-230	pCi/L	0/15	<.8–<1.6	N/A

[a] All measurements are filtered except specific conductance, pH, redox potential, and alkalinity (as $CaCO_3$) which are unfiltered.

[b] Frequency of detection.

[c] One-half the detection limit was used to calculate the mean; mean was not calculated if fewer than half of the samples were above detection.

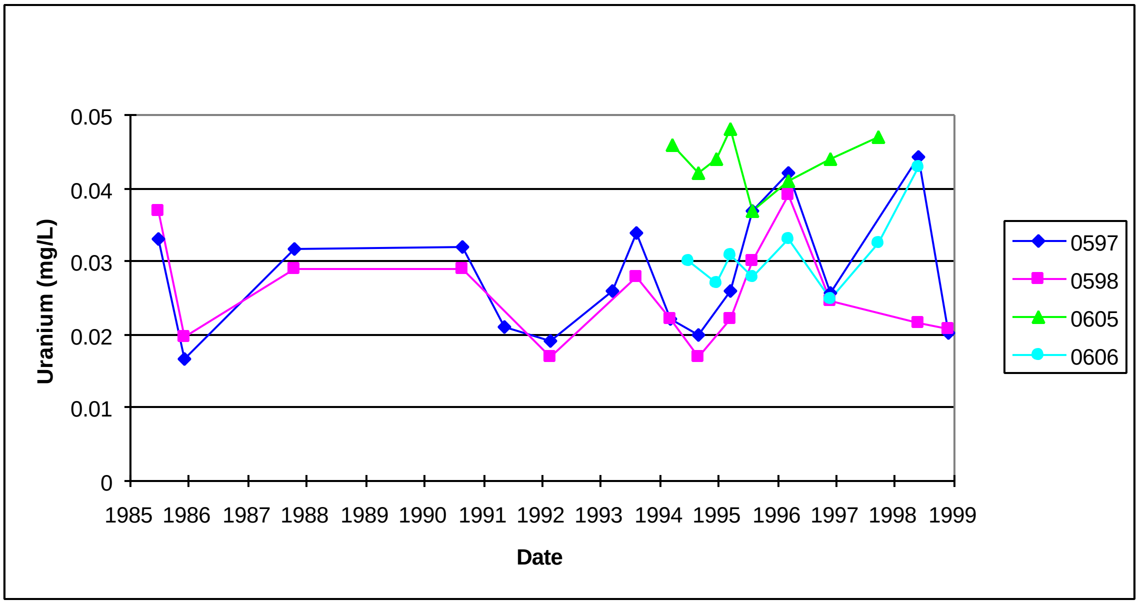


Figure 5–17. Time Concentration Plot for Background Alluvial Wells—Uranium

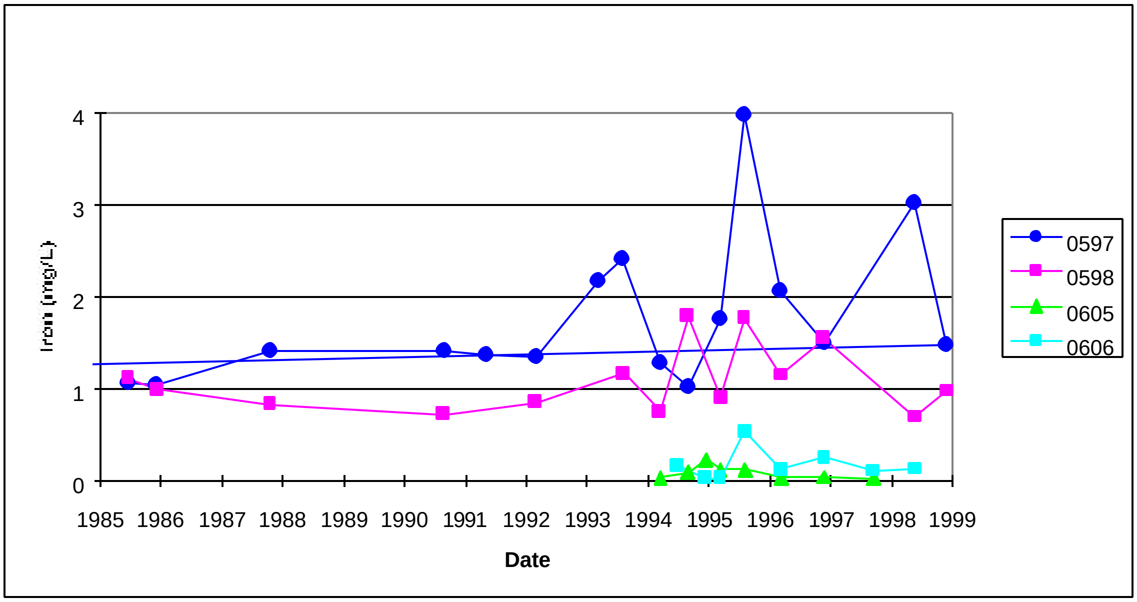


Figure 5–18. Time Concentration Plot for Background Alluvial Wells—Iron

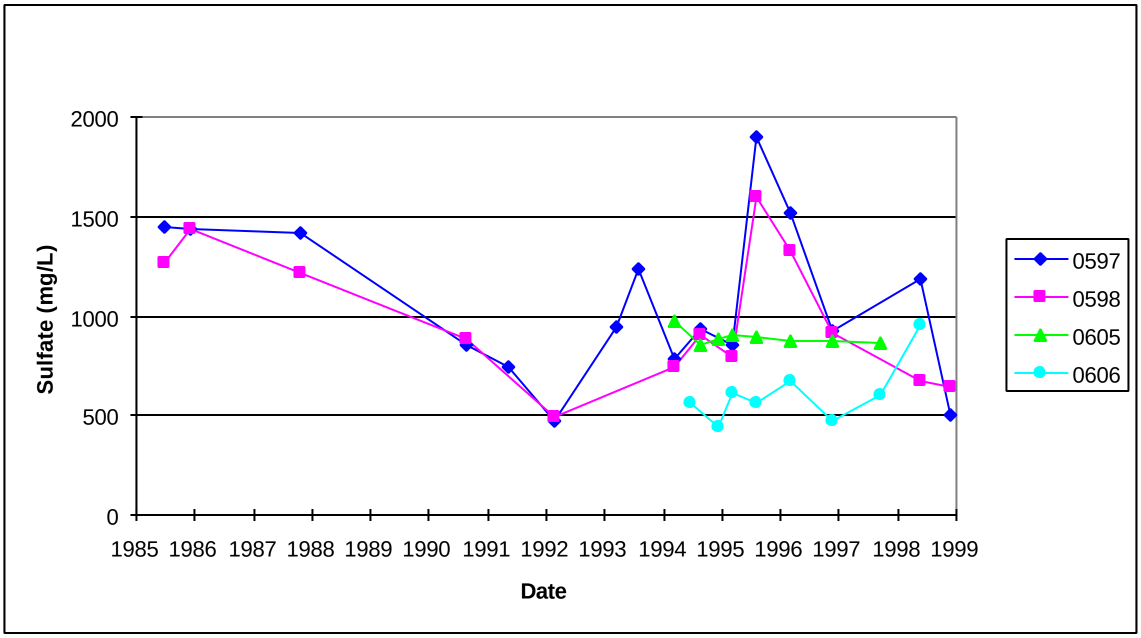


Figure 5–19. Time Concentration Plot for Background Alluvial Wells—Sulfate

Water quality results presented in the Piper diagram (Figure 5–20) indicate the dominant anionic species in the alluvial background water is sulfate. This water has a mixed sodium-calcium-magnesium cation composition with a tendency for sodium to dominate. The background alkalinity, as calcium carbonate, ranges from 330 to 552 mg/L. Sulfate concentrations range from 482 to 2,240 mg/L. Calcium concentrations range from 44 to 295 mg/L. Magnesium ranges from 51 to 174 mg/L. On average, the alluvial water pH is near neutral (7.1 s.u.) and the redox condition is slightly reducing (oxidation-reduction potential –64 mV).

Geochemical modeling of the alluvial background water from monitor wells RFO–597 and –605, using the PHREEQE software program (Parkhurst 1980), indicates the water is at or near equilibrium with respect to calcite (calcium carbonate), siderite (ferrous iron carbonate), rhodochrosite (manganese carbonate), and gypsum (calcium sulfate) (DOE 1996d). Equilibrium with these minerals is consistent with the relatively high concentrations of iron, manganese, sulfate, and alkalinity in the background alluvial ground water.

5.3.3.2 Nature and Extent of Alluvial Ground Water Contamination

On-site ground water quality has been monitored with varying frequency since 1985. Older wells were monitored until 1992, after which time surface remediation commenced and the wells were abandoned. Surface remediation was completed in 1996. New on-site monitoring wells were installed in 1998 during characterization efforts for this SOWP (Figure 5–16). The new wells were sampled twice in 1998; sampling results are presented in Appendix C and summarized in Table 5–9. Data include results from 16 wells (RFO–301 through–310, –654 through –657, –662, and –663). Monitor well locations are shown in Figure 5–16.

Table 5–9. Old Rifle Alluvial On-Site Ground Water—May through November 1998

Analyte[a]	Unit	On-site Alluvial Aquifer				Percent Exceeding Upper Range in Background	Background Range
		FOD[b]	Range	Mean[c]	Max Well		
Major							
Ammonia as NH_4	mg/L	23/26	<.001–7.4	.8005	0304	23	<.001–.61
Calcium	mg/L	26/26	130–340	191.8	0657	8	44.1–295
Chloride	mg/L	26/26	67.3–219	100.5	0657	0	66–274
Magnesium	mg/L	26/26	78.4–172	112.5	0308	0	50.6–174
Nitrate	mg/L	22/26	<.0691–13.4	3.742	0307	50	<.011–2.81
Sodium	mg/L	26/26	90.1–449	155.7	0657	0	164–655
Sulfate	mg/L	26/26	478–1770	805.6	0657	0	482–2240
Metal							
Antimony	mg/L	0/26	<.001–<.001	N/A	0663	0	<.001–<.001
Arsenic	mg/L	21/26	<.001–.0216	.004013	0655	35	<.001–.0034
Cadmium	mg/L	2/26	<.001–.0059	N/A	0304	8	<.001–<.001
Iron	mg/L	16/26	<.003–4.3	.5857	0308	4	<.003–3.03
Lead	mg/L	0/26	<.001–<.001	N/A	0663	0	<.001–.0012
Manganese	mg/L	25/26	<.001–1.3	.39678	0310	0	.0492–3.66
Molybdenum	mg/L	25/26	.0024–.05	.01399	0310	8	.0034–.0345
Selenium	mg/L	22/26	<.001–.0929	.02588	0305	38	<.001–.0298
Uranium	mg/L	26/26	.0268–.27	.1053	0310	73	.0055–.0594
Vanadium	mg/L	19/26	<.001–.765	.1459	0305	73	<.001–.0016
Other							
Alkalinity as $CaCO_3$	mg/L	28/28	228–425	332.8	0663	0	336–645
Fluoride	mg/L	26/26	.142–1.18	.7141	0305	0	.422–1.45
Redox Potential	mV	29/29	-364–214	-45.15	0662	14	-293–105
Specific Conductance	umhos/cm	29/29	1360–3650	1854	0657	0	1866–4490
pH	s.u.	29/29	6.62–7.42	6.935	0305	0	6.8–8.5
Radioactive							
Gross Alpha	pCi/L	24/26	<15.36–160.1	56.14	0310	31	<14.86–73.62
Gross Alpha - Uranium	pCi/L	24/26	0–19.8		0657		
Gross Beta	pCi/L	25/26	15.41–88.38	35.14	0310	35	<12.84–42.69
Lead-210	pCi/L	3/26	<.87–10.43	N/A	0306	12	<.93–<1.33
Polonium-210	pCi/L	4/26	<.05–.6	N/A	0306	12	<.05–.18
Radium-226	pCi/L	20/26	<.07–3.67	.3594	0302	35	<.04–.17
Radium-228	pCi/L	1/26	<.4–<1	N/A	0301	0	<.4–<.8
Thorium-230	pCi/L	0/26	<.8–<1.6	N/A	0662	0	<.8–<1.6
Uranium-234	pCi/L	3/3	19.2–67.4	44.43	0663	N/A	N/A
Uranium-235	pCi/L	3/3	.69–3.5	2.13	0663	N/A	N/A
Uranium-238	pCi/L	3/3	14.4–70.6	43.4	0663	N/A	N/A

[a] All measurements are filtered except specific conductance, pH, redox potential, and alkalinity (as $CaCO_3$) which are unfiltered.
[b] Frequency of detection.
[c] One-half the detection limit was used to calculate the mean; mean was not calculated if fewer than half of the samples were above detection.

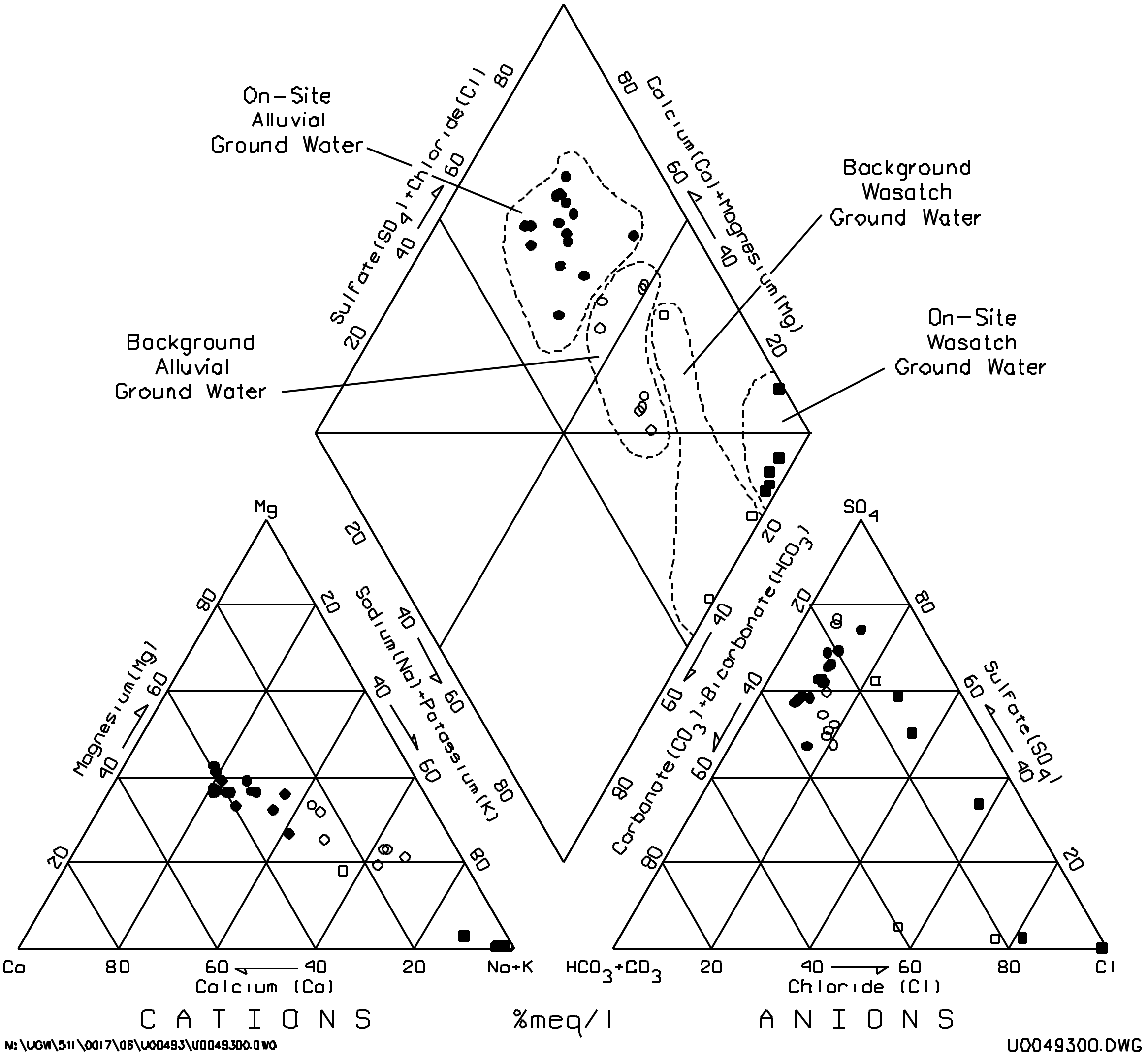


Figure 5–20. Piper Diagram

Monitor well RFO–590, located just downgradient of the site, is not considered to be a "plume" well, and, therefore, is not included in the on-site data summary, though sampling results from this well have been included on figures in this section showing contaminant distributions. Recent hydrogeologic and geologic data collected for the site indicates that an outcrop of Wasatch Formation along the western site boundary effectively forms a ground water divide between well 590 and the contamination at the site (Figure 5–5). Alluvial water from the site discharges into the Colorado River and does not affect the alluvial aquifer west of the site. Water quality at location 590 is believed to be influenced by ET and by the recharge areas to the north, including a culvert that directs the water under U.S. Highway 6 to an open ditch just east of well 590.

Uranium, vanadium, and nitrate are the site-related constituents most prevalent in the alluvial aquifer as evidenced by the relatively high frequency (greater than 50 percent) of samples that exceed the upper range in natural background (Table 5–9). Uranium and vanadium also provide the greatest contrast to natural background. That is, the maximum concentration of 0.27 mg/L uranium is 4.6 times the upper range in natural background. The maximum vanadium concentration of 0.77 mg/L is 480 times the upper range in natural background. Conversely, nitrate occurs frequently above natural background, but the maximum concentration of 13 mg/L is relatively low and less than the UMTRA ground water standard of 44 mg/L (as NO_3).

Other constituents in the ground water are present at concentrations above the upper range in natural background, however they occur less frequently. For example, selenium exceeds the upper range in natural background in approximately 38 percent of samples, while arsenic exceeds 35 percent, and ammonium exceeds 23 percent. Calcium, cadmium, and molybdenum all occur above natural background in 8 percent of the samples. Iron occurs above natural background in 4 percent of the samples. Several uranium decay products exceed the upper range in natural background, including radium-226 that exceeds background in 35 percent of the samples, and lead-210 and polonium-210 that both exceed background in 12 percent of the samples.

Ground water concentrations of arsenic, cadmium, lead, molybdenum, nitrate, selenium, uranium, gross alpha, and combined radium-226 and radium-228 are regulated by UMTRA standards (Section 2.0). Uranium, selenium, and gross alpha activity (excluding contributions from radon and uranium) are the only site-related constituents that exceed their respective standards of 0.044 mg/L, 0.01 mg/L, and 15 pCi/L. The remaining regulated constituents, arsenic, cadmium, lead, molybdenum, nitrate, radium-226, and radium-228, are present in the alluvial ground water at relatively low concentrations or were not detected. Non-regulated constituents occurring above natural background, including ammonium, calcium, and iron, are also present in the ground water at relatively low concentrations.

Uranium, vanadium, selenium, and arsenic are selected as the focus for the remainder of the discussion on contamination in the alluvial aquifer. Uranium and selenium are selected because they are site-related constituents that both exceed their respective UMTRA ground water standard. Vanadium is selected because it is present at concentrations significantly greater than natural background. Arsenic is present at concentrations below the UMTRA ground water standard; however, it has historically been shown to be significantly elevated above applicable standards.

To provide an indication of the manner in which ground water contamination has been affected by surface remediation, data from three wells (RFO–582, –655, –663) installed at the same on-site location and screened over similar depths were examined. These wells were installed at the approximate center of the historic contaminant plume. Well RFO–582 was sampled from 1985 to 1992. Wells RFO–655 and –663 were sampled in 1998. Means for selected contaminants are presented in Table 5–10.

Table 5–10. Mean Historic and Current Contaminant Concentrations for Plume Center

Contaminant	**Mean (mg/L)**	
	Historic Well 582; 1985–1992	**Replacement Wells 655 & 663; 1998**
Arsenic	1.09	0.016
Selenium	0.027	0.0395
Uranium	1.44	0.183
Vanadium	7.156	0.499

Significant decreases in arsenic, uranium, and vanadium are indicated by the data in Table 5–10. Uranium and vanadium have decreased by one order of magnitude and arsenic has decreased by two orders of magnitude. Selenium concentrations actually appear to have increased slightly at this location. However, for the most part it can be concluded that surface remediation has resulted in a large decrease of site contaminants in ground water.

Current contaminant distributions at the site for uranium, vanadium, selenium and arsenic are presented in Figures 5–21 through 5–24. Only portions of the plumes exceeding proposed threshold values are contoured (see Sections 6.3 and 7.0 for further discussion of proposed cleanup goals). These figures are based on results from the May 1998 sampling event. Similar distribution patterns are observed for the November 1998 results. These figures and recent results from the November 1998 sampling event are discussed below on a contaminant-by-contaminant basis.

Uranium

The uranium plume associated with the site is shown in Figure 5–21 for May 1998. The colored areas on the figure exceed the UMTRA standard of 0.044 mg/L. It can be seen that all but two wells at the westernmost edge of the site have concentrations higher than the standard. The figure also shows that there is not a single uranium plume at the site, but that uranium exists in two distinct plumes separated by the north-south drainage ditch. The mounding effect from recharge of the aquifer by the ditch water serves as a partial ground water divide and is responsible for the two resulting plumes. The highest concentrations in the two plumes are in wells at the downgradient edge of the site, closest to the river. Historically, highest plume concentrations were located farther upgradient on the site near well RFO–655. This suggests that the plume center has already migrated to the farthest downgradient edge of the plume and that concentrations of uranium should generally be declining across the site.

Samples collected in November 1998 (Appendix C) generally do indicate decreases in uranium for most wells, although a couple of wells have slightly increased and others have stayed essentially the same. While these decreases in uranium could be attributed to natural flushing, not enough data are available to confidently make this conclusion, particularly given the natural fluctuations in ground water chemistry over time as discussed in Section 5.3.3.1. However, the downgradient movement of the plume centers and the large decreases in uranium concentrations that have occurred since the completion of surface remediation are consistent with the low K_ds determined for uranium (Section 4.0) and its correspondingly high predicted mobility.

Selenium

The distribution of selenium, as shown in Figure 5–22, is somewhat similar to that of uranium, in that elevated concentrations are present on both sides of the north-south drainage ditch. The highest concentrations for selenium, however, are located upgradient of those for uranium. Selenium concentrations rapidly decrease in the direction of ground water flow as observed in ground water samples collected at several downgradient wells that are at or near the detection limit (0.001 mg/L). Samples from wells at the farthest downgradient edge of the site near the river are low; the well that displayed the maximum concentration for uranium (RFO–310) is at the detection limit for selenium. This suggests that maximum selenium concentrations have yet to migrate to the leading edge of the plume.

From May to November 1998, the highest concentrations in ground water west of the ditch shifted from well RFO–305 to well RFO–655. Concentrations decreased at location 305 while they increased at location 655. This would be expected with downgradient migration of the plume. However, with the limited data available, this conclusion cannot be made with confidence. On the east side of the ditch, the location with the highest selenium concentration in the May sampling event (well RFO–657 at 0.048 mg/L) actually increased to almost double (0.093 mg/L) during the November sampling round. No explanation is immediately apparent for this increase.

The upgradient locations of the plume centers and concentration distributions for selenium compared to uranium is consistent with the relative immobility of selenium as predicted by results of K_d testing. The K_ds determined for selenium were significantly higher than those for uranium were and it would be expected that the selenium plumes would move more slowly over time.

Additionally, the large drop in concentration of selenium with distance from the plume would be expected as selenium is readily adsorbed by alluvial material, which curtails the extent of spreading of the plume. Based on current plume configuration, it appears that maximum concentrations of selenium have not yet reached the wells at the leading edge of the plume. It would be expected that while selenium concentrations should begin to decrease near the plume centers, downgradient well concentrations may experience an increase as the plumes continue to migrate in this direction.

Vanadium

The distribution of vanadium, as shown in Figure 5–23, bears some similarity to that of selenium. There are two fairly localized high concentration areas, one on each side of the drainage ditch. With distance from these locations, concentrations drop rapidly, in this case one or two orders of magnitude. At the western edge of the site, concentrations of vanadium are not much above the detection limit of 0.001 mg/L. Highest concentrations are in wells that are located near the historic plume center. From May to November, the highest concentration well (RFO–305) decreased slightly in concentration from 0.765 mg/L to 0.717 mg/L. The two wells located downgradient (southwest; wells RFO–655 and –654) of RFO–350 actually increased slightly in concentration. As with selenium, this could be interpreted as representing the downgradient migration of the vanadium plume; again, however, the limited data do not allow this conclusion to be made with confidence.

The observed vanadium distribution is consistent with its predicted immobility based on the high K_ds determined for vanadium. The plume center on the west side of the ditch is still located at the approximate historic plume center and concentrations drop rapidly with distance from that location because of adsorption by alluvial materials. As with selenium, it would be expected that the highest concentration wells should slowly begin to decrease in concentration with time, while wells at the leading edge of the plume should display an increase as the plume migrates in that direction.

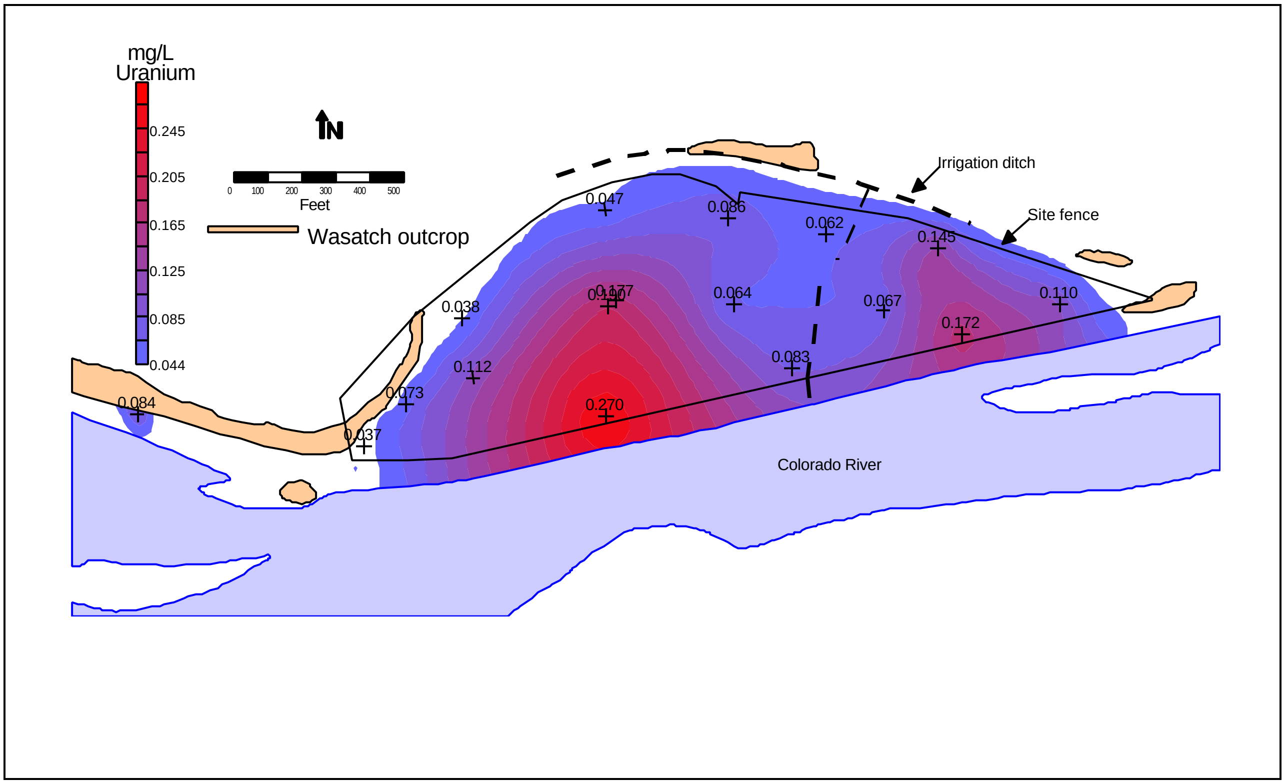


Figure 5–21. Uranium Distribution in Alluvial Aquifer–Old Rifle, May 1998

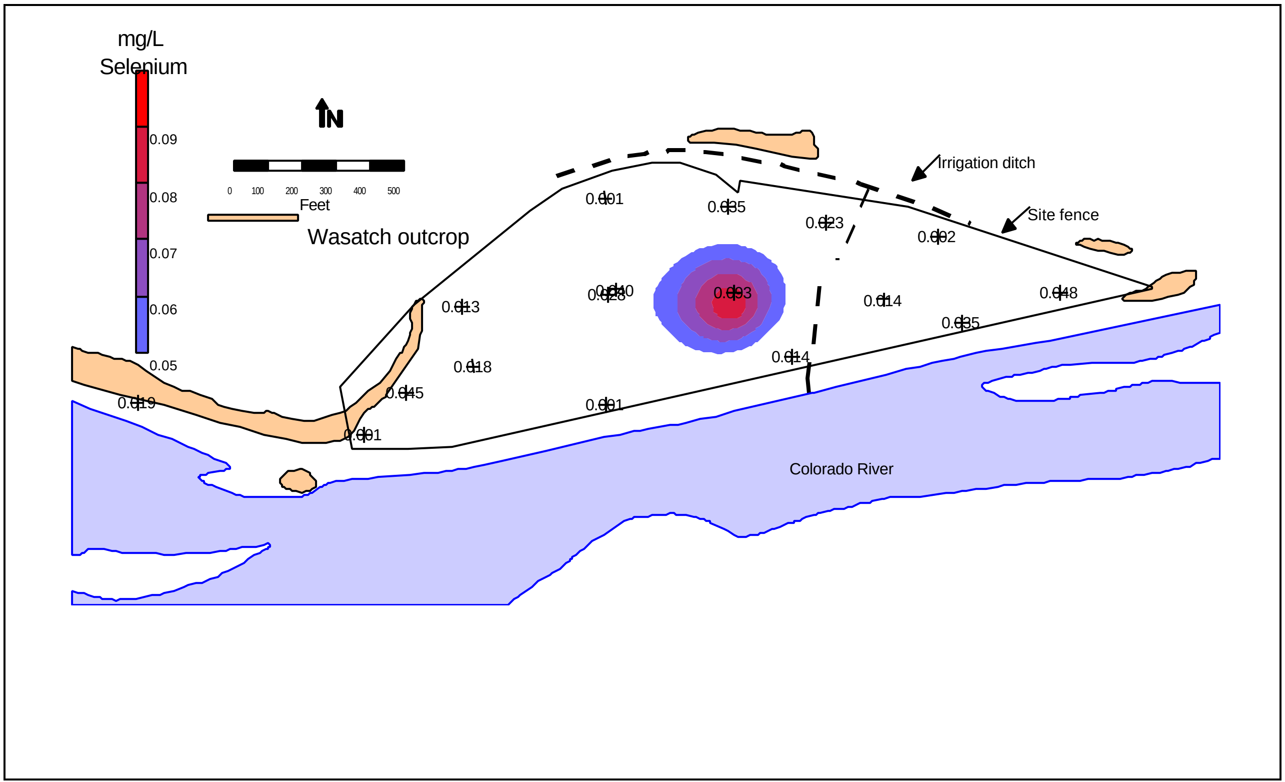


Figure 5–22. Selenium Distribution in Alluvial Aquifer–Old Rifle, May 1998

Arsenic

Arsenic concentrations (Figure 5–24) in ground water collected at most wells are at the detection limit (0.001 mg/L). Only one location (at well pair RFO–665 and –663) had concentrations of arsenic in ground water remotely approaching the UMTRA standard of 0.05 mg/L. The maximum detected concentration of arsenic for the May sampling event was 0.022 mg/L at well RFO–655 (less than half the UMTRA standard). In November this concentration decreased by almost half to 0.013 mg/L. The limited distribution of arsenic near the historic plume center and the rapid drop in concentration with distance from the highest concentration well is consistent with the high K_ds determined for this contaminant. The low concentrations of arsenic downgradient of the historic plume center may be attributed to slow plume migration and adsorption by alluvial materials. Because of the very low concentrations of arsenic present and the lack of a well-defined contaminant plume, it is likely that concentrations of arsenic will slowly continue to decrease over time across the site. Most wells are already within the range of background and any fluctuation of arsenic concentration that is likely to occur in these wells will probably be indiscernible from natural background variation.

5.3.4 Water Quality of the Wasatch Formation

5.3.4.1 Background Water Quality in the Wasatch Formation

Background water quality in the Wasatch Formation can be evaluated by examining analytical results of water samples collected from upgradient monitor wells RFO–620, –621, and –622. Wasatch monitor wells RFO–629, –630, and –641 are all located south of the Colorado River. As with the alluvial aquifer south of the river, these wells receive water from the recharge area that drains basalt mesas that are geochemically distinct from the drainage systems north of the river. Because the Wasatch Formation near the site is influenced primarily by the drainage systems north of the site, the wells south of the river were excluded from the background analysis. Locations of the background monitor wells used in the evaluation are shown in Figure 5–16. Available water quality results for monitor wells RFO–620, –621, and –622 are presented in Appendix C and summarized in Table 5–11.

Concentrations of most constituents in Wasatch background ground water are lower than those found in alluvial background ground water. The exceptions are molybdenum, chloride, fluoride, and Ra-226. The average concentration of molybdenum in Wasatch ground water exceeds the UMTRA standard of 0.1 mg/L and is significantly higher than molybdenum concentrations detected in the alluvial aquifer. Other commonly detected trace constituents include arsenic, iron, manganese, uranium, and vanadium. Most of the remaining trace constituents, including antimony, lead, and selenium, occur in concentrations below the analytical detection limit. Historical concentrations of background Wasatch ground water have been as high as 0.34 mg/L for selenium, 0.57 mg/L for uranium, and 0.26 mg/L for vanadium (DOE 1996d). Nitrate values as high as 11 mg/L have also been reported (DOE 1996d).

Table 5–11. Background Water Quality for the Wasatch Formation

Analyte[a]	**Unit**	**Wasatch Background**		
		FOD[b]	**Range**	**Mean**[c]
Major				
Ammonia as NH_4	mg/L	5/5	.126–.3	.236
Calcium	mg/L	5/5	3.53–281	81.77
Chloride	mg/L	5/5	121–855	411
Magnesium	mg/L	5/5	.873–117	33.71
Nitrate	mg/L	2/5	<.0617–.674	N/A
Sodium	mg/L	5/5	443–661	524.8
Sulfate	mg/L	5/5	33.7–1350	438.7
Metal				
Antimony	mg/L	0/5	<.001–<.001	N/A
Arsenic	mg/L	3/5	<.001–.0064	.004167
Cadmium	mg/L	0/5	<.001–<.001	N/A
Iron	mg/L	3/5	<.003–.186	.05645
Lead	mg/L	0/5	<.001–<.001	N/A
Manganese	mg/L	5/5	.0043–1.04	.2854
Molybdenum	mg/L	5/5	.0102–.234	.1548
Selenium	mg/L	0/5	<.001–<.001	N/A
Uranium	mg/L	5/5	.0013–.0244	.008983
Vanadium	mg/L	1/5	<.001–.0014	N/A
Other				
Alkalinity as CaCO3	mg/L	5/5	283–403	350.5
Fluoride	mg/L	5/5	.237–4.01	2.413
Redox Potential	mV	5/5	-65–88	21.83
Specific Conductance	umhos/cm	5/5	2170–3780	3022
pH	s.u.	5/5	7.04–8.54	8.08
Radioactive				
Gross Alpha	pCi/L	2/5	<10.74–31.26	N/A
Gross Beta	pCi/L	0/5	<10.97–<25.69	N/A
Lead-210	pCi/L	0/5	<.87–<1.3	N/A
Polonium-210	pCi/L	1/5	<.07–.16	N/A
Radium-226	pCi/L	4/5	<.1–.35	.15
Radium-228	pCi/L	0/5	<.66–<.75	N/A
Thorium-230	pCi/L	0/5	<.8–<1.6	N/A

[a] All measurements are filtered except specific conductance, pH, redox potential, and alkalinity (as $CaCO_3$) which are unfiltered.
[b] Frequency of detection.
[c] One-half the detection limit was used to calculate the mean; mean was not calculated if fewer than half of the samples were above detection.

Time-concentration plots for selected constituents in Wasatch background wells are shown in Figures 5–25 through 5–29. As with the alluvial background wells, concentrations vary significantly for some wells over time; there is also a large degree of difference in concentrations between different wells. Wells showing the least variability generally contain constituents present at very low concentration levels. No readily discernible patterns or trends can be identified.

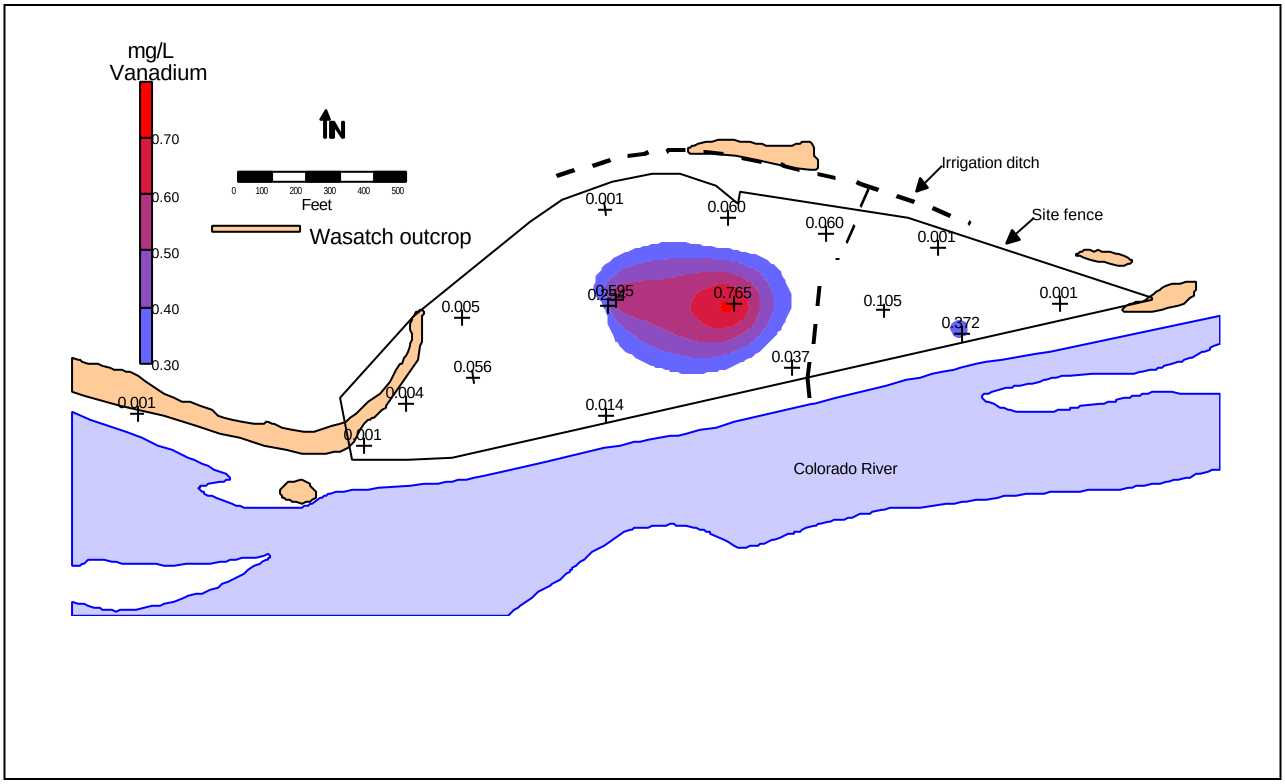


Figure 5–23. Vanadium Distribution in Alluvial Aquifer–Old Rifle, May 1998

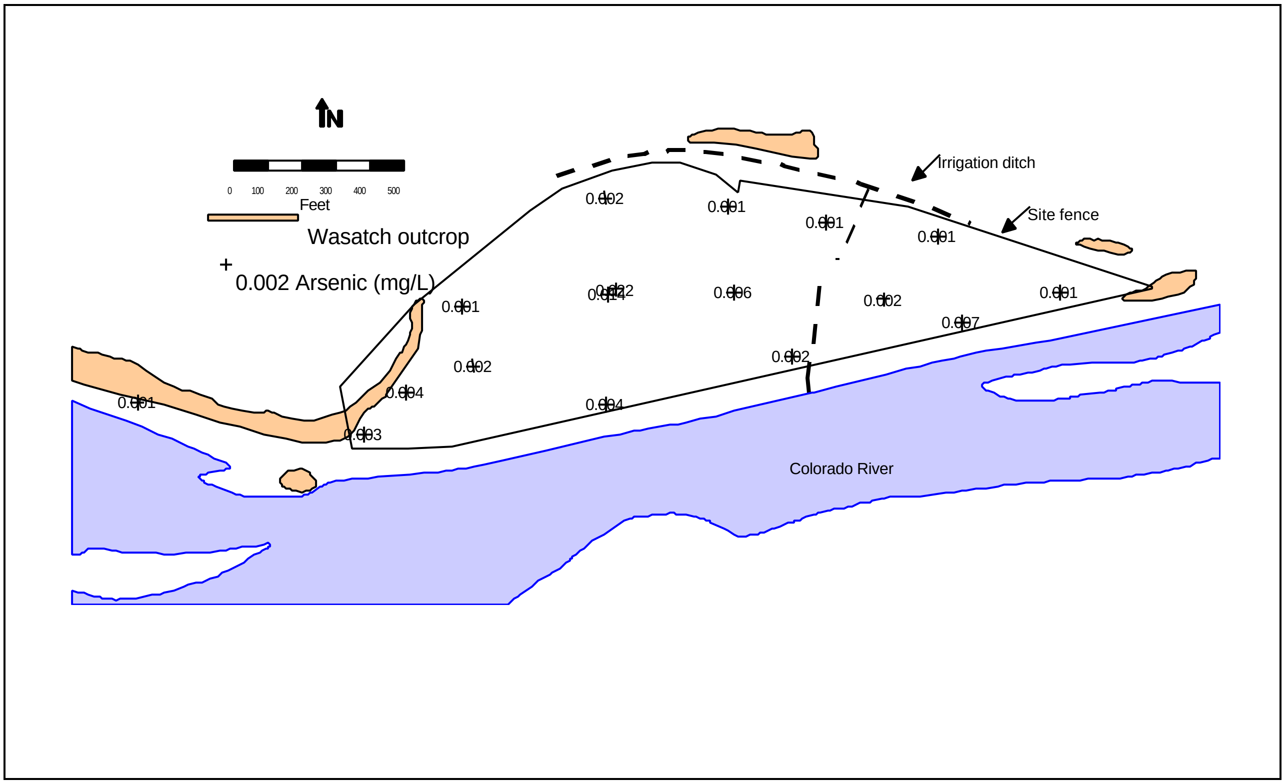


Figure 5–24. Arsenic Distribution in Alluvial Aquifer–Old Rifle, May 1998

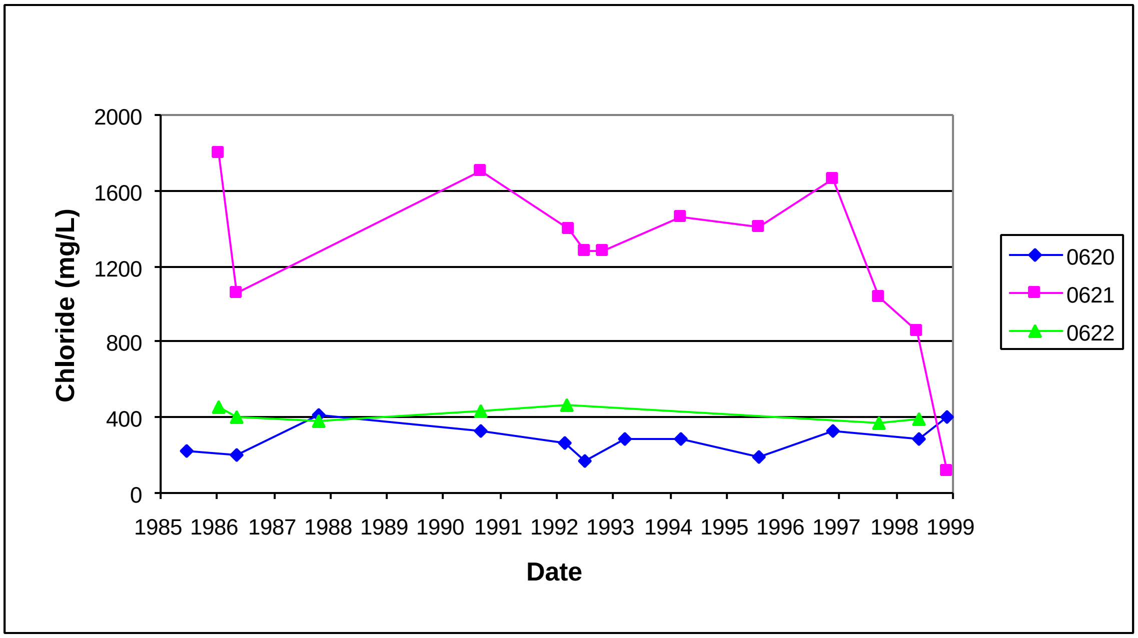


Figure 5–25. Time Concentration Plot for Chloride

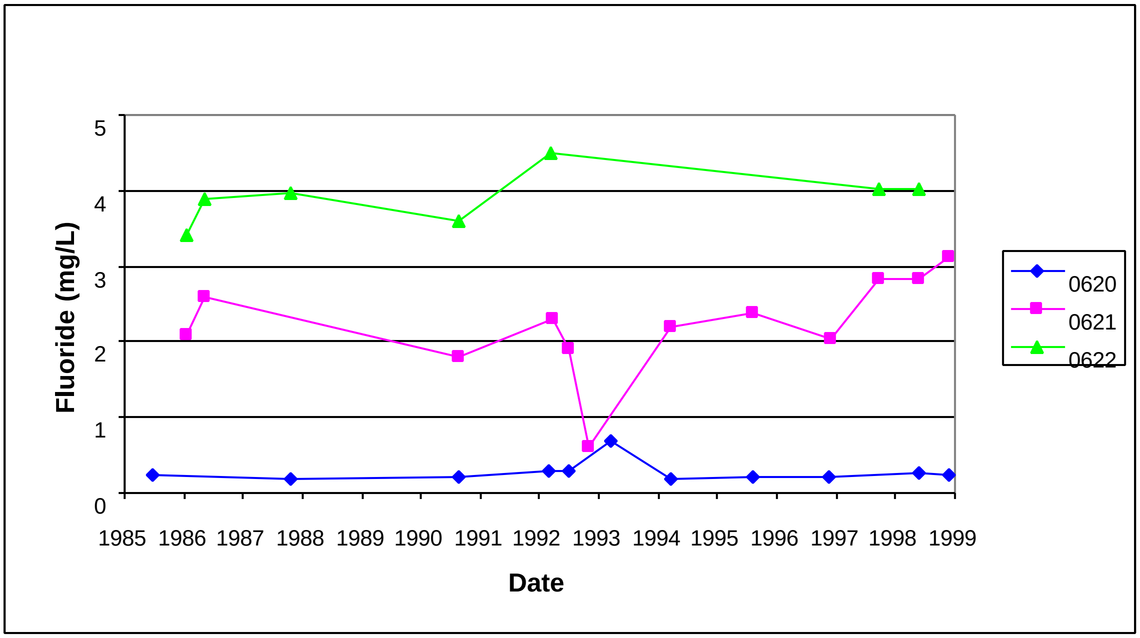


Figure 5–26. Time Concentration Plot for Fluoride

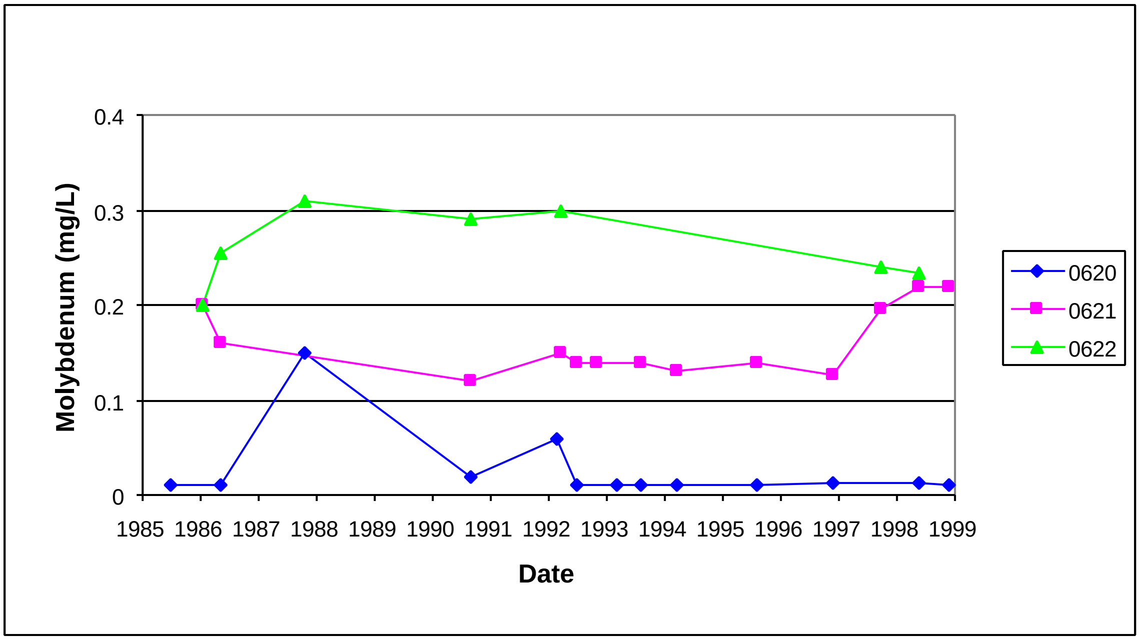


Figure 5–27. Time Concentration Plots for Molybdenum

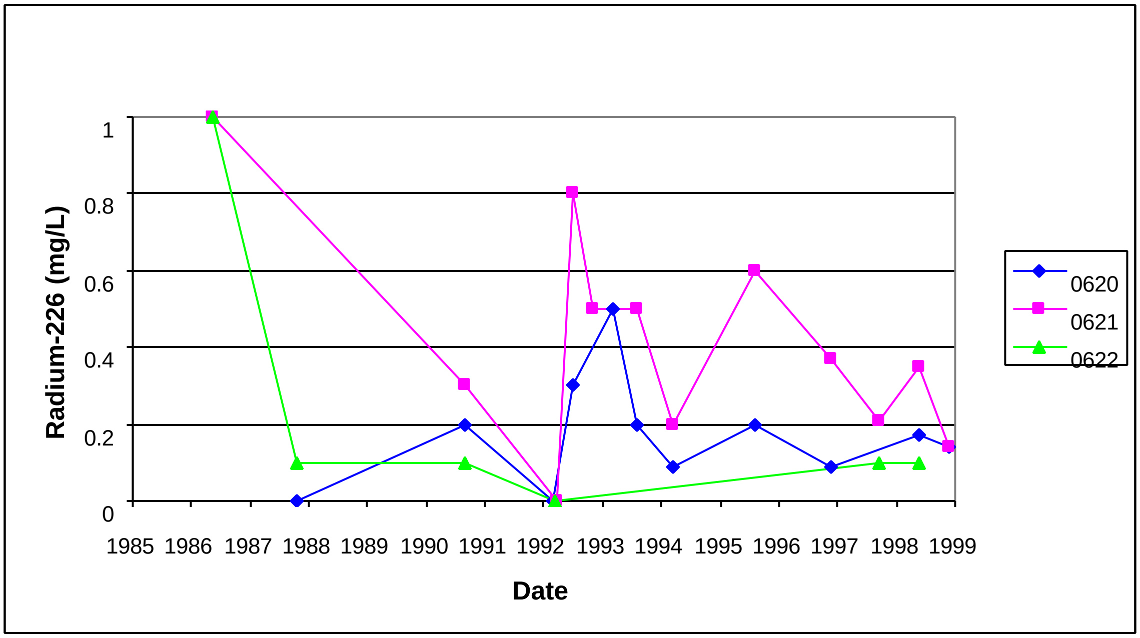


Figure 5–28. Time Concentration Plot for Radium-226

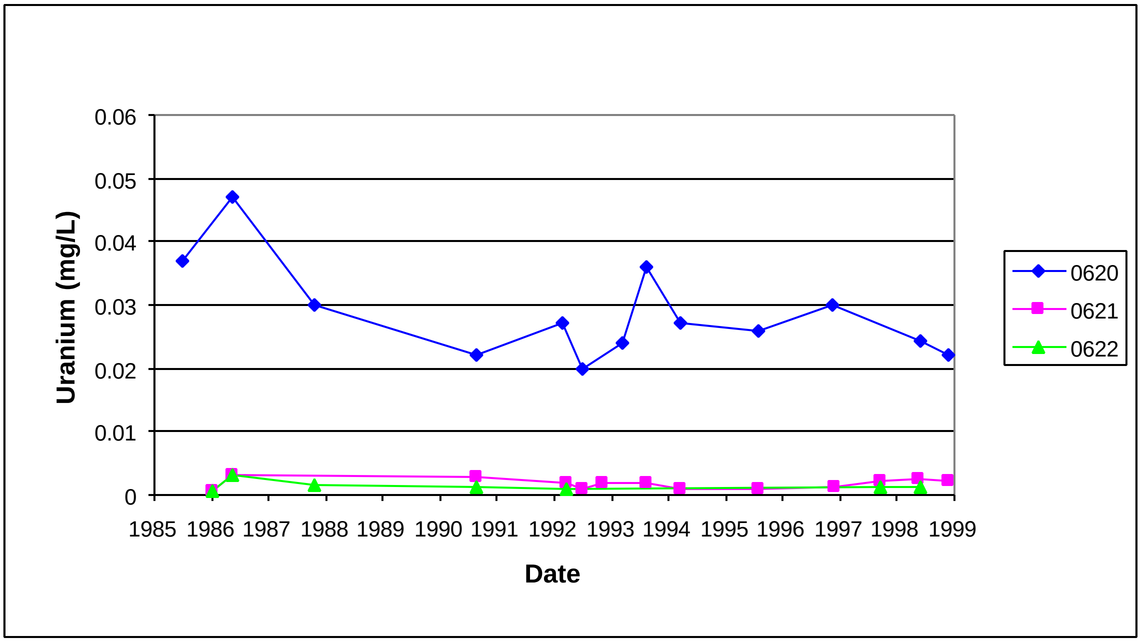


Figure 5–29. Time Concentration Plots for Uranium

Background water in the Wasatch Formation is characterized by a predominance of the sodium cation (Figure 5–20). The dominant anionic species is either sulfate or chloride. Sodium concentrations range from 443 to 661 mg/L, sulfate from 34 to 1,350 mg/L, and chloride from 121 to 855 mg/L. Alkalinity, as calcium carbonate, ranges from 293 to 342 mg/L. On average, the Wasatch ground water pH is above neutral (8.1 s.u.) and the redox condition is slightly oxidizing (oxidation-reduction potential 22 mV).

Geochemical modeling of ground water from the Wasatch monitor well RFO–621, using the PHREEQE computer software program (Parkhurst 1980), indicates the background water is at or near saturation with respect to calcite (calcium carbonate), magnesite (magnesium carbonate), and fluorite (calcium fluoride). Equilibrium with fluorite is consistent with observed concentrations of fluoride as high as 4.0 mg/L (Table 5–11).

5.3.4.2 Site Impacts on the Wasatch Formation

Ground water samples were collected in May and November, 1998 at five on-site monitor wells completed in the Wasatch Formation. Monitor well locations are shown in Figure 5–16. Two of the wells, RFO–647 and –649, are completed with 10-ft screens beginning 20 ft below the contact between the alluvium and Wasatch Formation (Figure 5–5). Monitor wells RFO–646 and –648 are installed with 10-ft screens beginning approximately 30 ft below the Wasatch contact. Monitor well RFO–623 is constructed with a 10 ft screen beginning approximately 71 ft below the top of the Wasatch contact. Sampling results are summarized in Table 5–12 and presented in Appendix C. The range in natural background is provided in Table 5–12 for comparison. Note that the background ranges are based on a maximum of five samples.

Table 5–12. Old Rifle Wasatch On-Site Ground Water—May and November 1998

Analyte[a]	Unit	On-site Wasatch Aquifer				Background Range
		FOD[b]	Range	Mean[c]	Max Well	
Major						
Ammonia as NH_4	mg/L	9/9	.277–4	1.301	0623	.126–.3
Calcium	mg/L	9/9	14.6–336	84.05	0623	3.53–281
Chloride	mg/L	9/9	248–7550	2127	0623	121–855
Magnesium	mg/L	9/9	1.09–65.5	15.71	0623	.873–117
Nitrate	mg/L	5/9	<.022–.368	.1654	0646	<.0617–.674
Sodium	mg/L	9/9	8.99–3940	1436	0623	443–661
Sulfate	mg/L	9/9	2.14–992	516	0647	33.7–1350
Metal						
Antimony	mg/L	0/9	<.001–<.001	N/A	0649	<.001–<.001
Arsenic	mg/L	9/9	.0011–.0112	.00656	0649	<.001–.0064
Cadmium	mg/L	0/9	<.001–<.001	N/A	0649	<.001–<.001
Iron	mg/L	5/9	<.003–.783	.1719	0623	<.003–.186
Lead	mg/L	0/9	<.001–<.001	N/A	0649	<.001–<.001
Manganese	mg/L	8/9	<.001–.778	.1799	0623	.0043–1.04
Molybdenum	mg/L	9/9	.0196–.439	.156	0648	.0102–.234
Selenium	mg/L	1/9	<.001–.0017	N/A	0649	<.001–<.001
Uranium	mg/L	7/9	<.001–.0039	.00183	0647	.0013–.0244
Vanadium	mg/L	7/9	<.001–.0341	.00573	0649	<.001–.0014
Other						
Alkalinity as $CaCO_3$	mg/L	9/9	113–353	220	0648	283–403
Fluoride	mg/L	9/9	.618–2.11	1.154	0648	.237–4.01
Redox Potential	mV	9/9	-106–60	-14.6	0646	-65–88
Specific Conductance	umhos/cm	9/9	2350–19040	7046	0623	2170–3780
pH	s.u.	9/9	7.37–9.96	8.417	0649	7.04–8.54
Radioactive						
Gross Alpha	pCi/L	0/9	<11.04–<107.55	N/A	0623	<10.74–31.26
Gross Beta	pCi/L	0/9	<10.98–<109.66	N/A	0623	<10.97–<25.69
Lead-210	pCi/L	0/9	<.84–<1.29	N/A	0649	<.87–<1.3
Polonium-210	pCi/L	6/9	<.11–.42	.181	0649	<.07–.16
Radium-226	pCi/L	9/9	.11–5.37	1.365	0623	<.1–.35
Radium-228	pCi/L	1/9	<.57–4.27	N/A	0623	<.66–<.75
Thorium-230	pCi/L	0/9	<.8–<1.6	N/A	0649	<.8–<1.6

[a] All measurements are filtered except specific conductance, pH, redox potential, and alkalinity (as $CaCO_3$) which are unfiltered.
[b] Frequency of detection.
[c] One-half the detection limit was used to calculate the mean; mean was not calculated if fewer than half of the samples were above detection.

Several constituents in ground water samples collected from monitor well RFO–623 exceed the upper range in natural background. However, most of these constituents, including ammonium, calcium, chloride, sodium, and iron can be attributed to natural variations within the Wasatch Formation rather than downward vertical contaminant migration from the alluvial aquifer plume. Monitor well RFO–623 is the deepest on-site well completed in the Wasatch Formation and is believed to be separated from the upper Wasatch by an aquitard or screened in a separate flow system (Section 5.2.3). Furthermore, uranium, with its high concentrations in the overlying alluvial plume and its high mobility, should be the most likely indicator of contamination to the Wasatch. However, uranium concentrations in ground water samples collected from all the on-site Wasatch monitor wells are less than natural background and nearly two orders of magnitude lower than the average uranium concentrations observed in the alluvial plume water.

Molybdenum is the only regulated constituent that exceeds an UMTRA ground water standard in the Wasatch Formation. The maximum molybdenum concentration of 0.4 mg/L, which is greater than the 0.1 mg/L standard, was detected at monitor well RFO–648. However, the standard is also exceeded by the 0.2 mg/L molybdenum concentration observed in the upper range of natural background water samples (Table 5–12). Historically, molybdenum concentrations have been reported above 0.3 mg/L at background monitor well RFO–622 (Figure 5–27). In addition, molybdenum was not identified as a prevalent site-related contaminant in the alluvial aquifer. Molybdenum concentrations observed in the alluvial plume water are an order of magnitude lower than the concentrations observed in the Wasatch formation; thus the source of molybdenum observed in the Wasatch is most likely naturally occurring.

The absence of elevated uranium concentrations in on-site Wasatch ground water samples provides a good indication that the Wasatch Formation at the Old Rifle site has not been negatively impacted by site-related contamination. Natural variations within the formation probably account for the observed elevated molybdenum. Furthermore, molybdenum was not identified as a site-related contaminant in the overlying alluvial plume. The upper 8 to 13 ft of weathered claystone directly beneath the alluvial plume, and the slight upward vertical hydraulic gradient, limits downward migration from the alluvium. For these reasons, it is concluded that the Wasatch Formation is not impacted.

5.3.5 Contaminant Fate and Transport

Ground water discharge to the Colorado River and geochemical processes will eventually decrease the contaminant concentrations in the alluvial aquifer at the Old Rifle site to background levels. The time required for one pore volume of ground water to migrate from the most contaminated upgradient location on the site, to the most downgradient point of discharge into the Colorado River, is estimated at 2.4 years. This estimate assumes 1,500 ft for the maximum length of the plume and 1.7 ft/day as the average linear ground water flow rate. However, as contaminated ground water migrates downgradient, some of the contaminant is subject to dispersion as the water moves through the heterogeneity of the aquifer. In addition to dispersion, as contaminated ground water migrates through the alluvial aquifer, some of the contamination transfers between the solid and liquid phases. These geochemical phenomenon cause the contamination to travel at a slower rate than the average ground water velocity. Therefore, the time required for contaminants in the alluvial system to naturally flush clean can be significantly greater than 2.4 years and one pore volume of ground water.

The geochemical processes that cause contaminant retardation can include adsorption, absorption, precipitation, diffusion into immobile porosity, transfer to vapor phases, and so on (these collective processes will simply be referred to as "adsorption" in the rest of this discussion). It is generally not possible to differentiate among all of these processes. However, for many aquifer systems, a bulk parameter (the distribution coefficient or K_d) has been used with some success to describe the retardation of contamination. Single-point K_d values were determined for As, V, Mo, U, and Se (Section 4.0). A summary of the results is presented in Table 5–13.

Table 5–13. Summary of Distribution Coefficients in Alluvium at the Old Rifle Site

Monitor Well	Sample Depth (ft below surface)	Sample Description	K_d (mL/g)				
			As	V	Mo	U	Se
RFO–292	8—9.5	alluvium at top of saturated zone	59	93	-0.1	0.2	44
	17—18.5	alluvium at base of saturated zone	26	37	-0.1	0.1	N/A
RFO–658/659	3—9	alluvium at top of saturated zone	22	18	-0.4	0.1	14
	23—24	alluvium at base of saturated zone	4.4	3.6	-0.2	-0.04	6.5
		Mean	28	38	-0.2	0.1	22
		Minimum	4.4	3.6	-0.1	-0.04	6.5
		Maximum	59	93	-0.4	0.2	44

The average K_d values presented in Table 5–13 indicate that As, V, and Se are likely to sorb to soils in the subsurface, while Mo and U are not. In addition, the range of K_d values is highly variable for As, V, and Se. The highest values were obtained from samples collected near the top of the alluvial aquifer that reportedly contain some organic matter (Appendix A). The lowest values occur in samples collected from the greatest depth (23 to 24 ft). The negative values observed for Mo and U suggest that even background levels in the subsurface could be contributing to levels detected in ground water. In general, the observed K_d values at the Old Rifle site indicate that movement in alluvial aquifer ground water is expected to be significantly retarded for V, and to a lesser extent for As and Se, through adsorption by aquifer materials. Conversely, Mo and U are expected to be conserved in the ground water, as evidenced by average K_d values close to 0, which indicate little or no retardation. The relative mobility of As, Se, V, and U is consistent with the contaminant dispersion patterns observed in ground water samples collected from the most recent sampling in 1998 (Figures 5–21, –22, –23, and –24).

A quantitative computer model was developed to predict the concentration and distribution of U, V, and Se in the future (Appendix D). The model incorporates the various flow and transport parameters that affect the hydraulic head and contaminant distribution.

5.3.5.1 Computer Flow and Transport Model

Natural flushing is an acceptable remediation strategy that allows natural processes to reduce the ground water contaminants to background levels, MCLs, or ACLs provided that: (1) contaminant concentrations decrease to the regulatory limits within 100 years, (2) institutional controls to protect the public health and environment are maintained during the cleanup period, and (3) the ground water is not currently, and is not projected to become, a source for a public water system (Section 2.0). A ground water flow and transport model was developed to evaluate if natural processes will reduce site-related concentrations of U, V, and Se to regulatory levels in the alluvial aquifer within the 100-year time frame.

The existing ground water flow pattern at the Old Rifle site was modeled with the MODFLOW software package (McDonald and Harbaugh 1988), a multi-layered, three-dimensional hydrologic flow model published by the USGS. Results of the flow model were then coupled to MT3D (Zheng 1990), a modular three-dimensional transport model to simulate advection and dispersion of U, V, and Se in the ground water system. Details regarding the model's construction, calibration, sensitivity analysis, and stochastic parameters are presented in Appendix D. These codes are fully described in the references cited and have been verified, benchmarked, and approved for use by most government and regulatory agencies.

Natural Flushing Uranium

Predicted uranium concentrations above the UMTRA 0.044 mg/L ground water standard at 3 years into the future is presented in Figure 5–30. Uranium concentrations and the relative extent of the plume are predicted to decline significantly from the observed distribution in May 1998, as seen in Figure 5–21 for comparison. On average, the maximum uranium concentration is predicted to decrease to 0.06 mg/L after 5 years of natural flushing (Figure 5–31). After 10 years, all the site-related uranium is predicted to be essentially flushed from the alluvial aquifer.

Hydraulic conductivity, dispersivity, and K_d are identified as the most sensitive input parameters to the MODFLOW and MT3D simulations (Appendix D). By varying these sensitive input parameters during each of the 100 simulations that were performed to predict the mean concentration, the variance associated with the mean predicted concentration was used to calculate the probability that the uranium concentration will exceed the 0.044 mg/L UMTRA standard. Probability contour maps showing areas beneath the Old Rifle site that are expected to exceed the UMTRA 0.044 mg/L uranium ground water standard at 3 and 5 years into the future are illustrated in Figures 5–32 and 5–33, respectively.

At 3 years into the future, the probability ranges between 5 percent and 100 percent that the 0.044 mg/L uranium standard will be exceeded in ground water beneath approximately half of the site. The probability decreases to between 5 and 50 percent that the standard will be exceeded at 5 years into the future in ground water beneath a relatively small area near the downgradient edge of the site. At 10 years into the future, the probability is less than 5 percent that the uranium concentrations in ground water beneath any area of the site will exceed the UMTRA 0.044 mg/L standard.

Results of the MT3D simulations indicate that, on average, the maximum uranium concentration in the ground water at the Old Rifle site will decline below the UMTRA standard of 0.044 mg/L in less than 10 years. Stochastic simulations predict the uranium concentrations after less than 10 years of natural flushing have less than a 5 percent probability of exceeding the standard.

Natural Flushing Vanadium

Vanadium concentrations above the proposed 0.33 mg/L cleanup goal (Section 6.3 and 7.0) are associated with a relatively small ground water plume beneath the center of the site as illustrated by the distribution of concentrations observed in May 1998 (Figure 5–23). Predicted ground water concentrations above the proposed 0.33 mg/L cleanup goal at 100 years into the future are presented in Figure 5–34. As evidenced from Figure 5–34, the areal extent of the ground water plume is predicted to decrease significantly in size after 100 years of natural flushing. The maximum predicted vanadium concentration of 0.35 mg/L within the plume at 100 years is only slightly above the proposed 0.33 mg/L cleanup goal.

A probability contour map showing the area beneath the Old Rifle site that exceeds the proposed 0.33 mg/L vanadium ground water cleanup goal at 100 years into the future is presented in

Figure 5–35. As the areal extent of the plume is predicted to shrink in size with time, the probability that concentrations within the plume will exceed the cleanup goal also decreases. For example, at 100 years into the future the maximum probability that the 0.35 mg/L vanadium concentration in the plume will exceed the proposed 0.33 mg/L goal is 74 percent. This maximum probability is limited to a very small area within the center of the plume.

Predictive simulations for vanadium indicate that the proposed 0.33 mg/L cleanup goal will be met in approximately 100 years. The maximum predicted concentration at 100 years is 0.35 mg/L; a value only slightly above the proposed goal. Furthermore, the stochastic simulations predict a 26 percent probability that the maximum concentration will be less than the proposed goal. In addition, the potential occurrence of the maximum concentration is limited to a very small areal extent in the aquifer.

Natural Flushing Selenium

Selenium concentrations above the 0.05 mg/L SDWA standard (proposed ACL for the site; Sections 6.3 and 7.0) are associated with a relatively small ground water plume beneath the center of the site as illustrated by the concentration map presented in Figure 5–22 for ground water samples collected in May 1998. Predicted ground water concentrations above the 0.05 mg/L selenium standard at 25 years into the future is presented in Figure 5–36. The maximum selenium concentration is predicted to decrease from 0.09 mg/L observed in May 1998, to 0.06 mg/L after 25 years of natural flushing. The maximum predicted concentration in the ground water after 50 years of natural flushing is 0.049 mg/L, effectively meeting the 0.05 mg/L SDWA standard.

After 100 years of natural flushing the maximum selenium concentration is predicted to be 0.037 mg/L, a value that is less than the SDWA standard. A relatively low probability of less than 10 percent is predicted that this maximum value will exceed the 0.05 mg/L standard. The relatively small areal extent where selenium concentrations in the ground water after 100 years of natural flushing have a probability between 5 and 10 percent of exceeding the standard is shown in Figure 5–37.

The maximum predicted selenium concentration in the ground water after 50 years of natural flushing is 0.049 mg/L, indicating that on average, the 0.05 mg/L SDWA standard will be met in approximately 50 years. Stochastic simulations indicate the there is only a 5 to 10 percent probability that the standard will be exceeded beneath a very small area of the site, as the ground water plume naturally flushes for 100 years into the Colorado River.

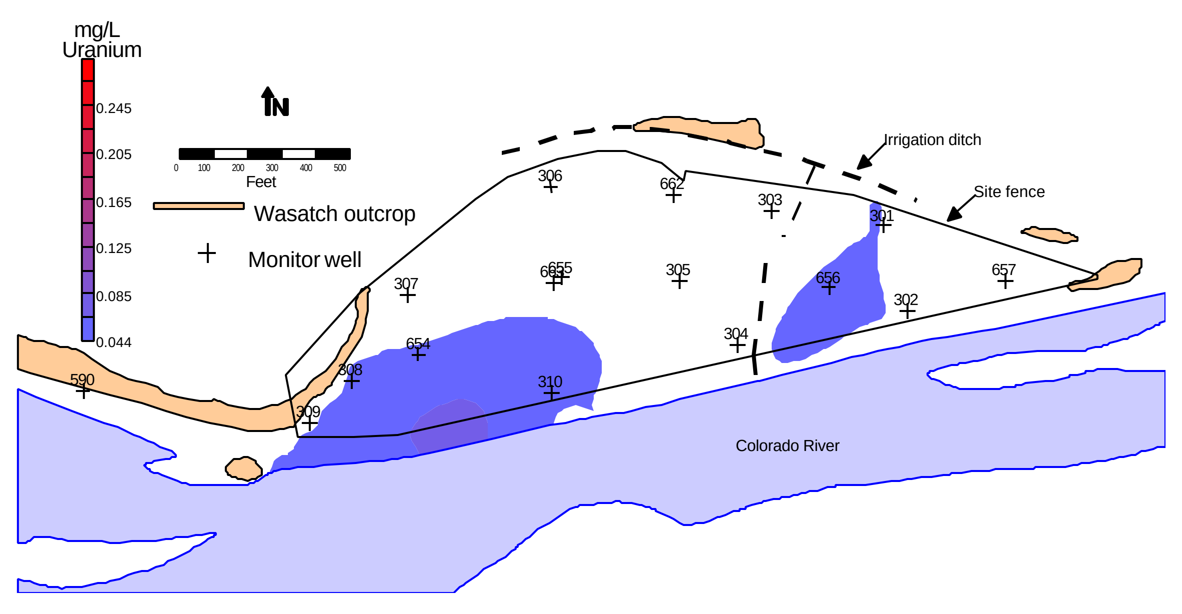


Figure 5–30. Predicted Uranium Concentrations in the Ground Water at the Old Rifle Site at 3 Years – 100 Simulations

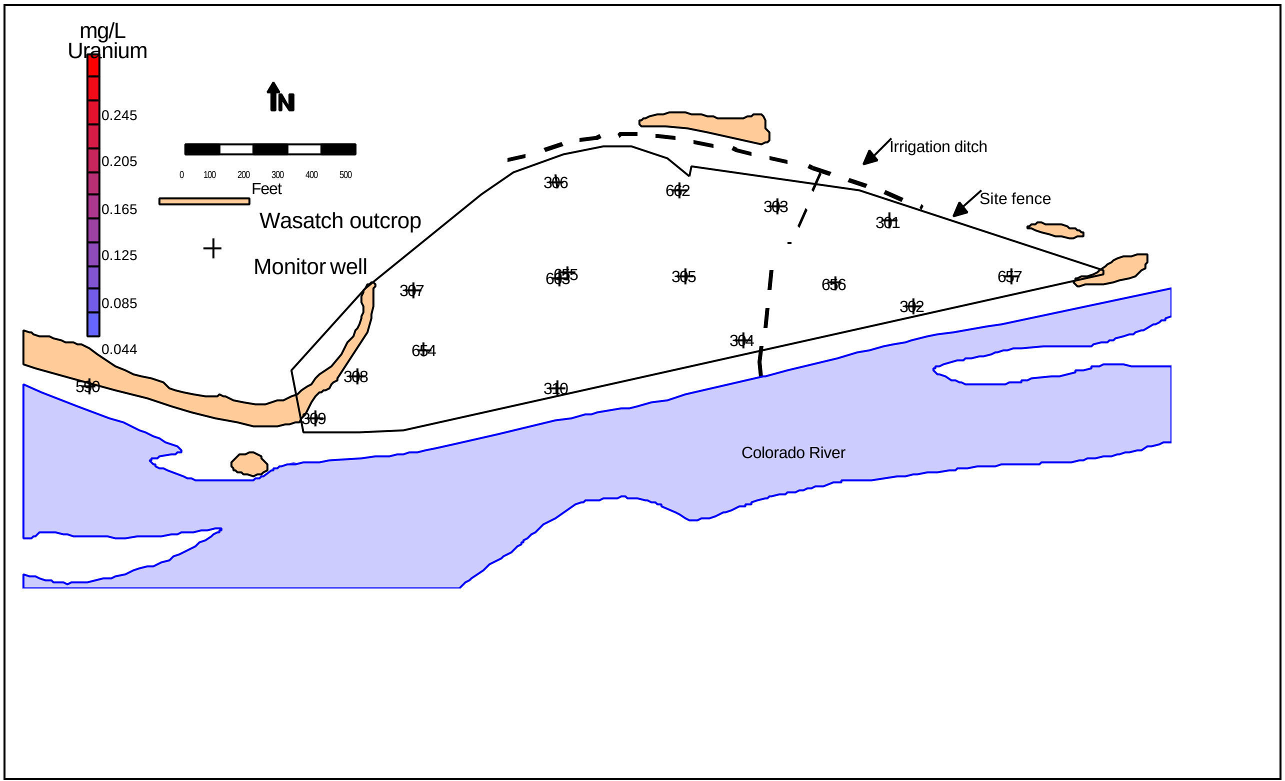


Figure 5–31. Predicted Uranium Concentrations in the Ground Water at the Old Rifle Site at 5 Years – 100 Simulations.

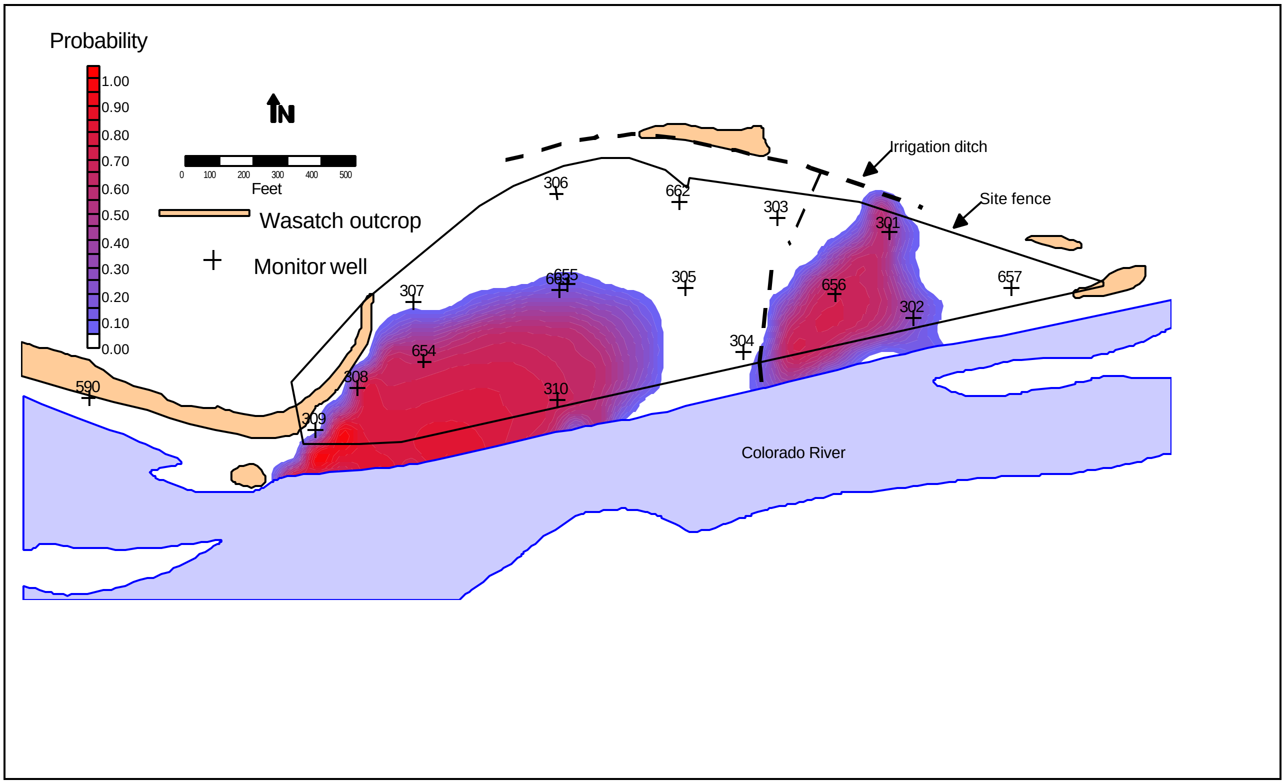


Figure 5–32. Probability of Uranium Concentrations Exceeding the 0.044 mg/L UMTRA Ground Water Standard at the Old Rifle Site at 3 Years – 100 Simulations

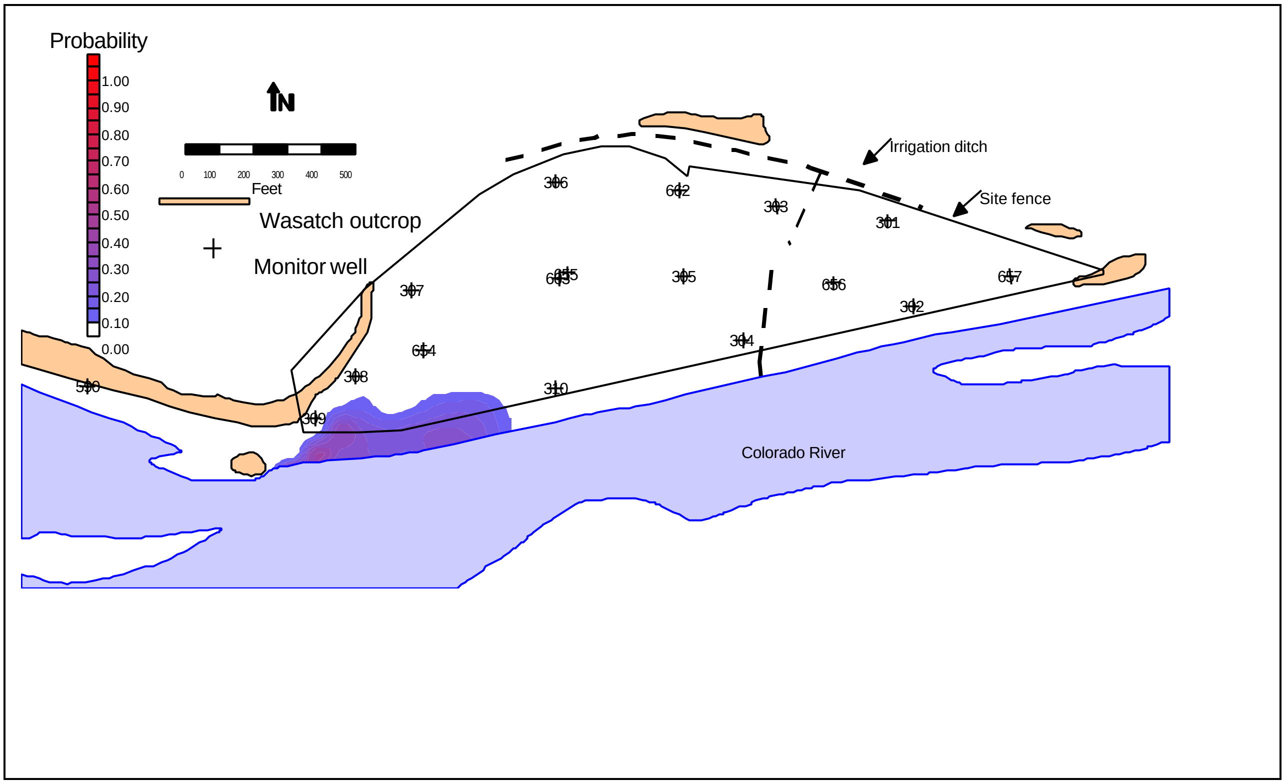


Figure 5–33. Probability of Uranium Concentrations Exceeding the 0.044 mg/L UMTRA Ground Water Standard at the Old Rifle Site at 5 Years – 100 Simulations

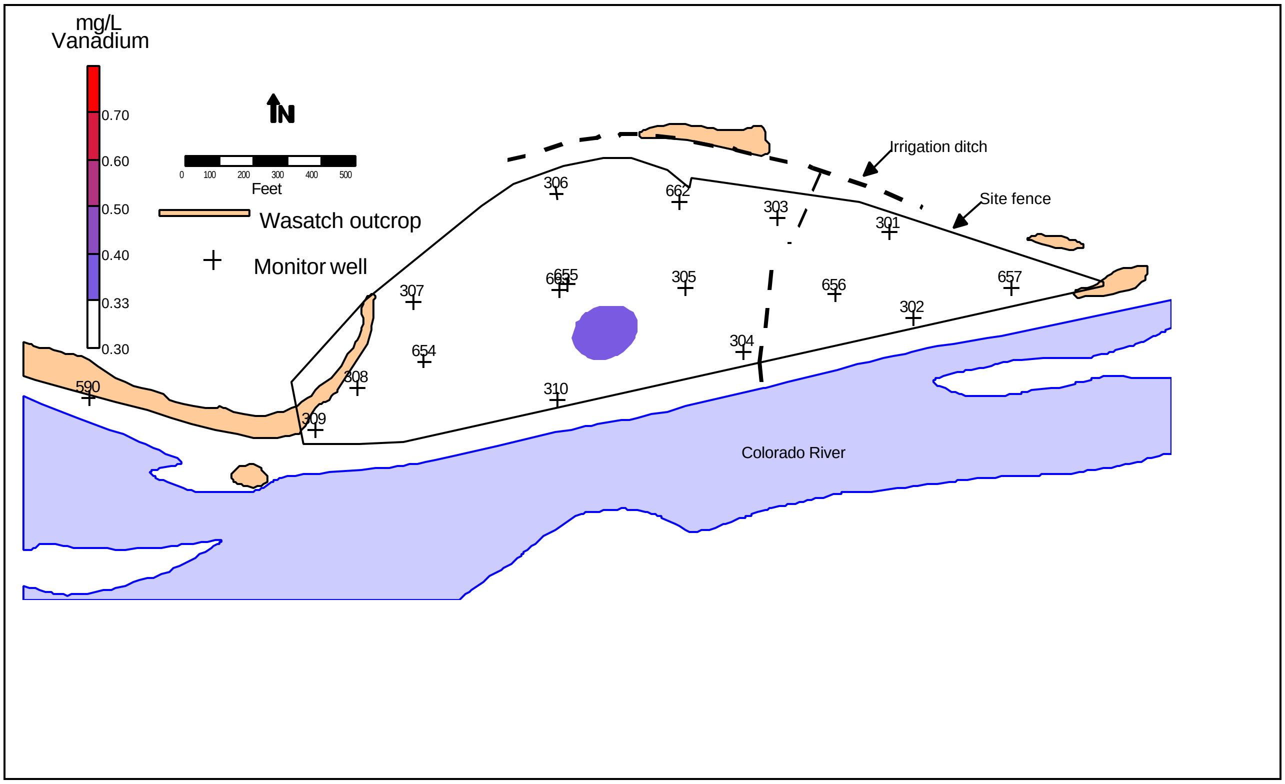


Figure 5–34. Predicted Vanadium Concentrations in the Ground Water at the Old Rifle Site at 100 Years – 100 Simulations

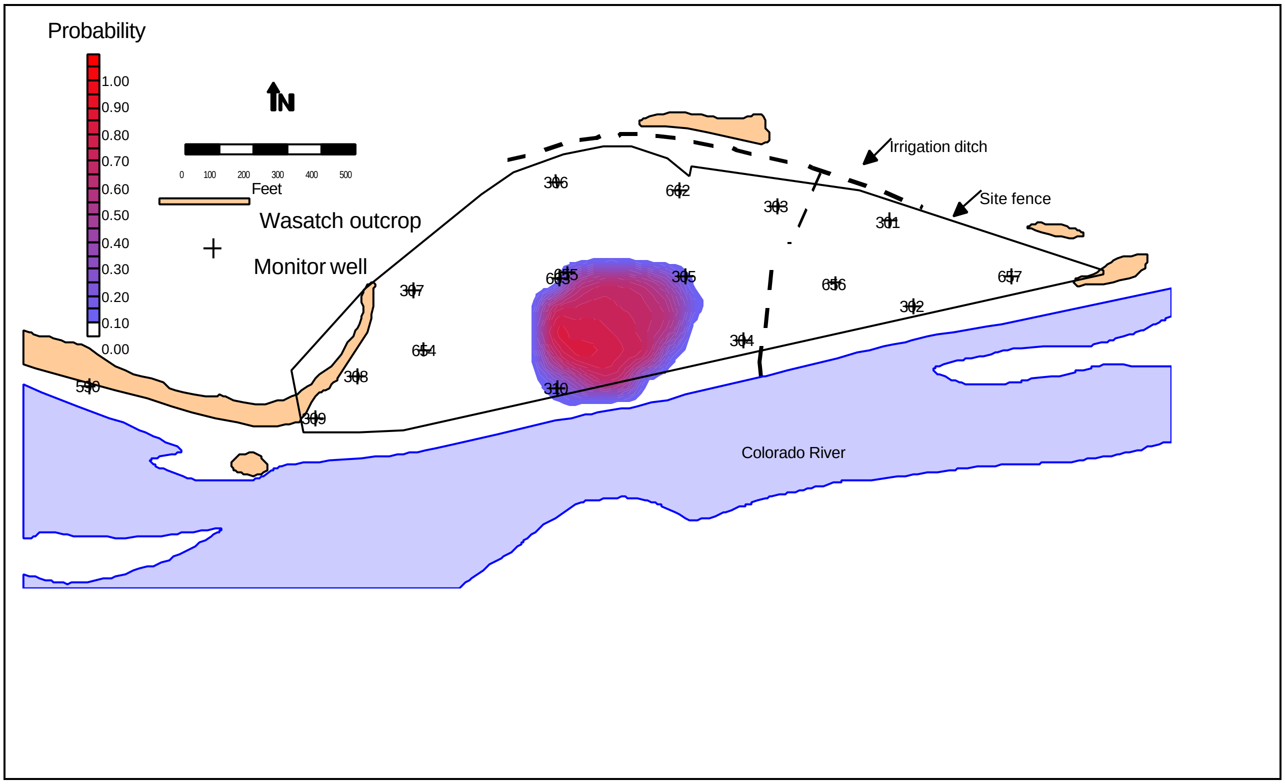


Figure 5–35. Probability of Vanadium Concentrations Exceeding the Proposed 0.33 mg/L Cleanup Goal at the Old Rifle Site at 100 Years – 100 Simulations

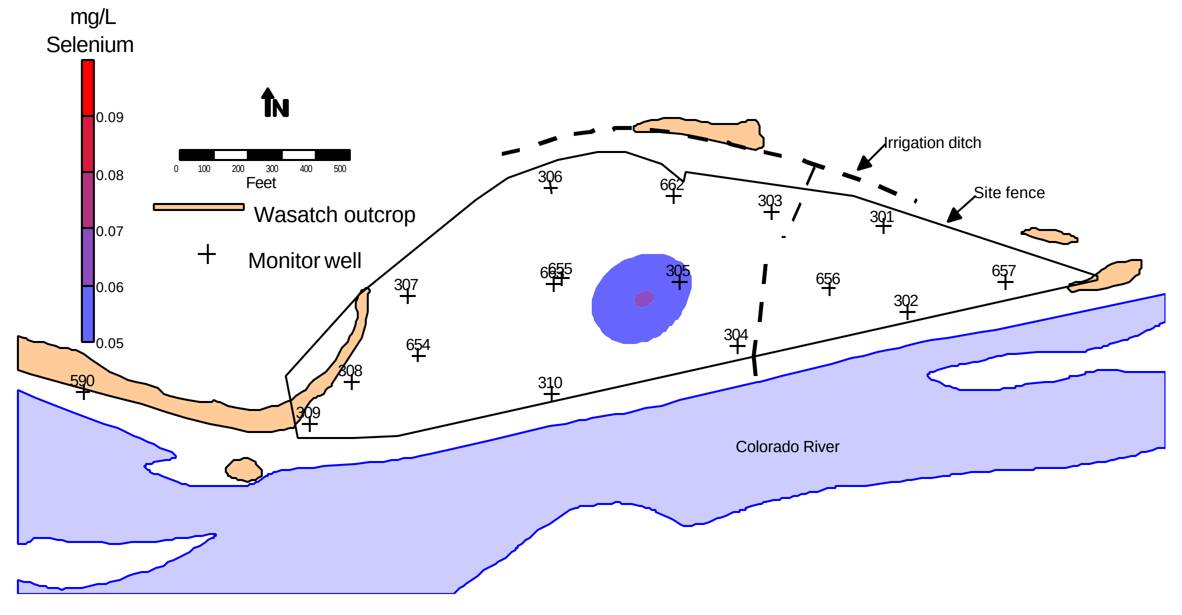


Figure 5–36. Predicted Selenium Concentrations in the Ground Water at the Old Rifle Site at 25 Years – 100 Simulations

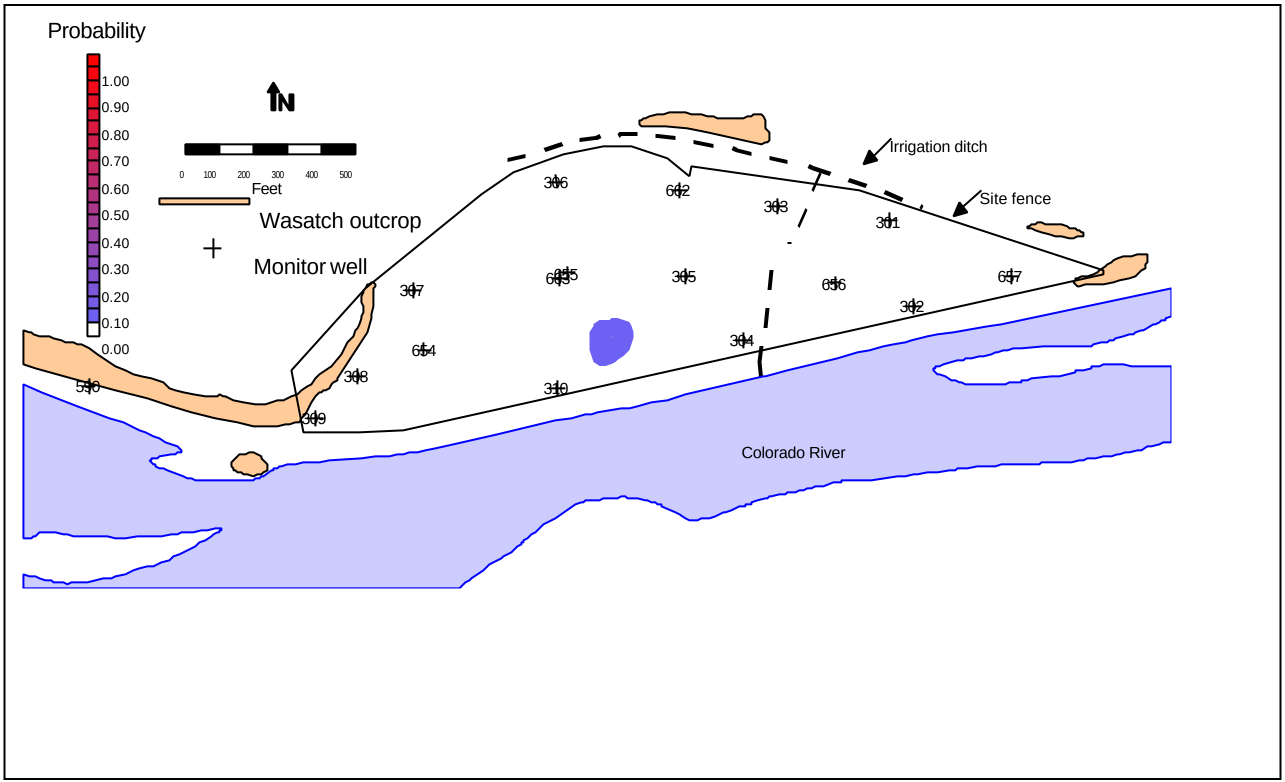


Figure 5–37. Probability of Selenium Concentrations Exceeding the 0.05 mg/L SDWA Standard at the Old Rifle Site at 100 Years – 100 Simulations

5.4 Ecology

Results of the 1998 field investigation indicate that no wetlands are associated with the site and that plant diversity is limited to seeded plants and weedy invaders (Section 4.9). The only phreatophytes observed growing at the Old Rifle site was one tamarisk shrub, which was found growing along the open irrigation ditch that discharges surface runoff water from north of the site.

In the absence of disturbance, the plant community at the site will trend towards shrubland dominated by either greasewood (*Sarcobatus vermiculatus*) or rabbitbrush (*Chrysothamnus viscidiflorus*). There is also potential for cottonwoods (*Populus fremontii*) and tamarisk *(Tamarix ramosissima*) to inhabit the site. Greasewood, cottonwood, and tamarisk are phreatophytic (plants that root in ground water), creating the potential for future exposure pathways on the site. Cottonwood establishment on the site would depend largely on available moisture. Both tamarisk and cottonwoods could use the ditch water to become established; eventually enabling their roots to reach ground water.

Soil type and vegetation condition can be important factors in evaluations of site water balance. For example, ET can remove almost all precipitation entering deep, fine- to medium-textured soils in upland semiarid areas where a diverse, late-successional plant community dominates (Richard et al. 1988). Where these conditions occur, recharge is negligible. In contrast, at the Old Rifle site, recharge may be a high as 50 percent of annual precipitation because of the coarse-textured soils and grass monoculture. Coarse-textured soils store little water (Hillel 1982) and ET may be considerably less from grass monocultures than from native shrub-grass vegetation (Waugh et al. 1994, Gee et al. 1991). If, in the future, the Old Rifle plant community trends towards phreatophytic shrubs such as greasewood, then the site may shift from a recharge zone to a discharge zone.

A complete exposure pathway does not currently exist at the Old Rifle site. There is, however, potential for phreatophytes to inhabit the site, which would create possible future exposure pathways at the site. The investigation of these potential pathways is discussed as part of the site ecological risk assessment (Section 6.0).

6.0 Risk Assessment

6.1 Human Health Risk Assessment

A BLRA has previously been prepared for the Old Rifle site (DOE 1996a) according to methodologies provided in the PEIS (DOE 1996c). Much of the data used in that risk analysis were collected before completion of surface remediation in 1996 (data for characterizing contaminant plume was collected from 1990 to 1994) and were obtained from monitoring wells that no longer exist. Additional wells have been installed since 1994 and more recent samples were collected. Many contaminants have shown significant changes, mainly decreases in concentration since completion of the original BLRA. This necessitates a reevaluation of COPC identification and assessment of associated risks. The intent of this BLRA update is not to repeat the original risk assessment process, but to use those earlier results and conclusions as a starting point from which to evaluate the more recent data.

6.1.1 Summary of 1996 Risk Assessment Methodology and Results

The 1996 BLRA identified 15 nonradiological contaminants associated with the Old Rifle site as being at levels statistically above background concentrations for the area. This list of contaminants was screened first to eliminate contaminants within nutritional ranges and then to eliminate contaminants of low toxicity and/or high dietary ranges. These two steps eliminated two and four contaminants, respectively. In addition, four radiological contaminants were detected at the site; all were retained as COPCs because they are known human carcinogens. The screening process resulted in the following COPC list: arsenic, fluoride, iron, manganese, molybdenum, selenium, sulfate, uranium, vanadium, lead-210, polonium-210, radium-226, and thorium-230. These contaminants were retained for further risk analysis.

A number of potential routes of exposure were evaluated: ingestion of ground water as drinking water, dermal contact with ground water while bathing, ingestion of garden produce irrigated with ground water, ingestion of milk/livestock watered with ground water, ingestion of fish from the Old Rifle pond, and recreational exposure to the Old Rifle pond surface water and sediments. [Note that the Old Rifle pond no longer exists so that these are not currently plausible exposure routes.] Screening calculations were performed for exposure routes that could be quantified with confidence; other routes were evaluated qualitatively only. The potential receptors assessed were infants, children, and adults.

Results indicated that adverse toxic responses from exposure to contaminants from routes other than drinking water would not be expected. Therefore, it was determined that ingesting ground water as drinking water would be the primary contributor to total exposure, relative to all other exposure routes. Consequently, the use of ground water as drinking water was evaluated probabilistically. For additional information on other potential exposure routes and for the probabilistic methodology, see the BLRA (DOE 1996a).

Results of the BLRA showed that the most severe noncarcinogenic health effects could occur due to the water’s sulfate, manganese, iron, molybdenum, and fluoride content. Exposure intakes for arsenic, selenium, and vanadium were determined to be at nontoxic levels. Exposure intakes for uranium were inconclusive because of a low level of confidence in toxicological data; however uranium exceeded established reference doses and was considered a potential health problem. Refer to the BLRA for specific toxicological effects (DOE 1996a). The estimated risk level of 3E-04 for the maximum detected concentration of the radiological carcinogen uranium (total of 234 and 238) exceeds the EPA-recommended risk range of 1E-04 to 1E-06. Lead-210, radium-226, polonium-210, and thorium-210 were all within the acceptable risk range. The total excess lifetime cancer risk was calculated as 4E-04, which is above the acceptable risk range. The maximum detected concentration of arsenic at Old Rifle corresponded to a risk of 5E-03, exceeding the acceptable risk range.

6.1.2 BLRA Update

6.1.2.1 COPC List Update

Table 6–1 lists the COPCs identified in the 1996 BLRA along with a summary of historic plume data (data from the SOWP and BLRA) and current (May 1998 and November 1998) plume and background data. UMTRA ground water standards and risk-based concentrations (RBCs) are also included for comparison of data to benchmarks. Background locations include wells upgradient of the Old Rifle site that have been shown to be representative of background water quality in the past (DOE 1996d). Plume data for 1998 include onsite wells and wells immediately downgradient of the site that can reasonably be assumed to be influenced by site activities. Historic plume data are from onsite wells RFO–583 and RFO–584, which no longer exist. Table 6–1 lists wells included in both plume and background groupings for 1998 data.

A brief explanation is warranted here regarding the risk-based concentrations presented in Table 6–1. In this table, the RBC for a given contaminant represents a concentration in drinking water that would be protective of human health provided

- A residential scenario is appropriate;
- Ingestion of contaminated drinking water is the only exposure pathway;
- That contaminant contributes nearly all of the health risk;
- EPA's risk level of 1E-6 for carcinogens and an HI of 1 for noncarcinogens is appropriate.

If any of these assumptions is *not* true, contaminant levels at or below RBCs cannot automatically be assumed to be protective. For example, if multiple contaminants are present in drinking water, a single contaminant may be below its respective RBC, but still be a significant contributor to the total risk posed by drinking that water. However, if a RBC is exceeded, it is an indication that further evaluation of the contaminant(s) is warranted. RBCs are intended to be used in screening-level evaluations.

For contaminants having UMTRA standards, it is interesting to compare these with calculated RBCs. For example, the standard for arsenic is 0.05 mg/L while the RBCs are 0.011 and 0.000045 mg/L for noncarcinogenic and carcinogenic effects, respectively. Thus the standard was set at a level higher than that believed to result in some adverse health effect. On the other hand, the standard for molybdenum is 0.1 mg/L; the RBC is nearly twice this value at 0.18 mg/L. Therefore the standard is more protective than the RBC. There are a variety of contaminant-specific reasons for differences between UMTRA standards and RBCs and that discussion is

Table 6–1. Old Rifle Site—Data Summary

Contaminant	Frequency of Detection	Minimum mg/L	Maximum mg/L	Mean mg/L	UMTRA Standard mg/L	RBC mg/L	%Exceeding Benchmark[a]
Arsenic					0.05	0.011N	
Background	6/15	0.001	0.0034	N/A		0.000045C	0%
Current Plume	21/26	0.001	0.0216	0.004			0%
Historic Plume		0.15	0.24	0.23			
Fluoride						2.2N	
Background	15/15	0.422	1.45	0.879			0%
Current Plume	26/26	0.142	1.18	0.7141			0%
Historic Plume		0.4	1.4	1.2			
Iron						11N	
Background	11/15	0.003	3.03	0.472			0%
Current Plume	16/26	0.003	4.3	0.5857			0%
Historic Plume		3.4	12	9.2			
Lead-210 (pCi/L)						0.068C	
Background	0/15	0.93	1.33	N/A			DL > RBC
Current Plume	3/26	0.87	10.43	N/A			DL > RBC
Historic Plume		0	4.5	N/A			
Manganese						1.7N	
Background	15/15	0.0492	3.66	1.036			20%
Current Plume	25/26	0.001	1.3	0.3968			0%
Historic Plume		1.1	1.2	1.1			
Molybdenum					0.1	0.18N	
Background	15/15	0.0034	0.0345	0.0187			0%
Current Plume	25/26	0.0024	0.05	0.014			0%
Historic Plume		0.04	0.14	0.1			
Polonium-210 (pCi/L)							.14C
Background	1/15	0.05	0.18	N/A			DL > RBC
Current Plume	4/26	0.05	0.6	N/A			8%
Historic Plume		0	0.8	N/A			
Ra-226 (pCi/L)					5		
Background	7/15	0.04	0.17	N/A			0%
Current Plume	20/26	0.07	3.67	0.3594			0%
Historic Plume		0	0.9	0.2			
Selenium					0.01	0.18	
Background	9/15	0.001	0.0298	0.0093			33%
Current Plume	22/26	0.001	0.0929	0.0259			73%
Historic Plume		0.007	0.085	0.072			
Sulfate							
Background	15/15	482	2240	1131			
Current Plume	26/26	478	1770	806			
Historic Plume		1050	1530	1066			
Thorium-230 (pCi/L)						1.22C	
Background	0/15	0.8	1.6	N/A			0%
Current Plume	0/26	0.8	1.6	N/A			0%
Historic Plume		0	0	N/A			
Vanadium						0.33N	
Background	3/15	0.001	0.0016	N/A			0%
Current Plume	19/26	0.001	0.765	0.1459			18%
Historic Plume		0.51	0.75	0.55			
Uranium					0.044		
Background	15/15	0.0055	0.0594	0.0377			47%
Current Plume	26/26	0.0268	0.27	0.1053			88%
Historic Plume		1.6	2.1	1.8			

[a] Benchmark = UMTRA standard, if available; RBC used if no standard available

Alluvial Background Wells: 291,292, 597, 598, 606, 658, 659, 660
Current Plume Wells: 301–310, 654, 655–657, 662, 663
Historic Plume wells RFO–583, RFO–584; data from DOE 1996c, 1997

RBC = risk-based concentration
C = carcinogenic risk
N = noncarcinogenic risk

For mean calculations, values for samples below detection set at one-half the detection limit; means not calculated if fewer than one-half of samples above detection limit.

beyond the scope of this document. However, for purposes of risk management and decision-making, it is necessary to have some appreciation of what these benchmarks mean.

As noted previously, a comparison of historic and current plume data indicates that many constituents have demonstrated a decrease, particularly in mean concentrations. This is true for all COPCs, except the maximum plume concentrations for selenium, sulfate, and vanadium that are consistent with historic data. A comparison of current background and plume data indicate that plume concentrations for fluoride, manganese, molybdenum, and sulfate are within the range of background or their mean values are less than the mean values obtained for background. Therefore, based on a comparison to background, it is possible to eliminate fluoride, manganese, molybdenum, and sulfate from further consideration as COPCs. Thorium-230 was below detection in all plume and background samples and can also be eliminated as a COPC.

Through a qualitative evaluation, all of the other COPCs are deemed to be present in concentrations sufficiently elevated above background to be retained for further consideration in the update of risk calculations.

6.1.2.2 Risk Assessment Methodology

As mentioned previously, the original BLRA considered several potential routes of exposure to contaminants and eliminated all but one, ingestion of ground water, as insignificant. Therefore, the ground water ingestion pathway through residential use is the only route of exposure considered in this BLRA update. Currently, this pathway is incomplete and no risks from ground water exposure exist. Risk calculations present here pertain to potential future risks only.

Risk calculations presented here follow EPA's *Risk Assessment Guidance for Superfund* methodology (EPA 1989b), which involves determining a point estimate for excess cancer risk from current or potential carcinogenic exposures and a hazard quotient (HQ; ratio of exposure intake to an acceptable intake) for noncarcinogenic exposures. It is assumed that the receptors for ground water are residents who use alluvial ground water as their primary source of drinking water. This is an unlikely scenario because of institutional controls that are expected to be put in place at the site in the near future, but is consistent with that evaluated in the original BLRA. However, for the purposes of making risk management decisions, it must be kept in mind that results of these risk calculations are based on very conservative assumptions.

The original BLRA calculated noncarcinogenic risks using a probabilistic approach. Essentially, this means that instead of using a single value for each parameter required in the risk calculations (e.g., ground water concentration, body weight, frequency of exposure), a range of values with a given probability distribution was used. By performing numerous iterations of the standard risk calculations, with a value selected at random from each parameter distribution, a range of exposures and associated risks are determined. The original BLRA reported results for the most sensitive receptor population modeled—children.

In this update, using point exposure doses, single values are used for each parameter required in the risk calculations. Calculations to determine contaminant intakes use standard exposure factors for the adult population (EPA 1989a). Ground water concentrations (CW) used to calculate risks associated with ingestion of plume-related ground water are the maximum concentrations detected during the 1998 sampling events, most of which were from on-site wells. While use of adult exposure data is probably less conservative than use of the exposure data for children from the original BLRA, using maximum ground water concentrations and point-exposure dose calculations is probably more conservative with the net effect of producing comparably conservative results. For purposes of making risk management decisions, results of both methodologies are useable and both have their advantages and limitations.

The same methodology was used to calculate carcinogenic risks for this BLRA update as was used in the original BLRA (i.e., receptors are adults with exposure averaged over 70 years). For all risk calculations, benchmarks for acceptable contaminant intakes (e.g., reference doses, slope factors) were obtained from standard EPA sources (e.g., Integrated Risk Information System, Region III Risk-Based Concentration Table, etc.) All assumptions, equations, input values, and calculations for this BLRA update are included in Appendix E.

6.1.2.3 Results

Results of the risk calculations are included in Table 6–2. Additionally, the table shows the percentage that each noncarcinogenic contaminant contributes to the total hazard index (HI) (or overall risk).

Table 6–2. Old Rifle Risk Summary—1998 Plume Data

Non-Carcinogens—Ground water Ingestion Only (Adults)

Contaminant	**CW-max**	**HQ-max**	**%RISK**	**CW-mean**	**HQ-mean**	**%RISK**
Arsenic	0.0216	1.973	25.72	0.004	0.365	18.58
Iron	4.3	0.393	5.12	0.5857	0.053	2.72
Selenium	0.0929	0.509	6.64	0.0259	0.142	7.22
Uranium	0.27	2.466	32.15	0.1053	0.962	48.90
Vanadium	0.765	2.329	30.37	0.1459	0.444	22.59
	HI =	7.669	100.00	HI =	1.966	100.00

Carcinogens—Ground water Ingestion Only (Adults)

Contaminant		**CW**	**Risk**
Arsenic	Max	0.0216	3.80E-04
	Mean	0.004	7.05E-05
U234+238	Max	138	1.54E-04
	Mean	83.35	9.31E-05
Polonium 210	Max	0.6	4.11E-06
	2nd highest[a]	0.54	3.70E-06
Ra-226	Max	3.67	2.28E-05
	2nd highest[a]	0.3	1.86E-06
Lead-210	Max	10.4	1.47E-04
	2nd highest[a]	4.48	6.35E-05

Total risk from radionuclides = 3.29 E-04 max concentrations

[a] 2nd highest values used because only two values detected or highest value is much greater than majority of samples.

Major observations based on these results are as follows:

- Risks associated with maximum concentrations of plume ground water exceed the acceptable HI of 1 for noncarcinogens. Risks calculated using mean plume concentrations are significantly lower, though still unacceptable.

- Uranium, vanadium, and arsenic are the main risk contributors to noncarcinogenic risks posed by plume ground water.

- Carcinogenic risks calculated for maximum values of arsenic, U234, U238, and lead-210 associated with plume ground water exceed the upper end of EPA's acceptable risk range (1E-4 to 1E-6). Individual risks calculated for each carcinogen using mean concentrations falls within the acceptable risk range.

Results of this BLRA update are significantly different than those in the original BLRA. Since that time, several contaminants initially considered to be potential health threats have decreased to levels within the range of background. These contaminants include fluoride, manganese, molybdenum, and sulfate. They were eliminated as COPCs in the BLRA update on this basis.

The 1996 BLRA indicated that intakes calculated for arsenic, selenium, and vanadium were determined to be at nontoxic levels. However, a look at the exposure dose calculations for arsenic and vanadium in that document indicates that they exceeded reference doses. These results were confirmed in the BLRA update, which indicates that HQs calculated for both arsenic and vanadium exceed the acceptable value of 1, and that these two constituents are significant contributors to overall risks. While calculated exposure doses for selenium were below established reference doses in the original and updated BLRA, selenium exceeds the UMTRA ground water standard and was carried through the risk calculations in the update to determine its relative contribution to total risk at the site. The updated calculations show selenium contributes approximately 6 percent of the total noncarcinogenic risks.

The original BLRA noted that there is a considerable amount of uncertainty regarding the toxicity of uranium at low intake levels, such as those calculated for the Old Rifle site. However, it was concluded that uranium should be considered a potential health problem at the site. Calculations in this update indicate that uranium, like arsenic and vanadium, is a significant contributor to overall risk at the Old Rifle site.

Based on results presented in Table 6–2, arsenic, vanadium, and uranium can be considered as the major contaminants of concern (COCs) at the Old Rifle site. These contaminants account for approximately 90 percent of total noncarcinogenic risk associated with the site. Arsenic and uranium (as 234 and 238) also account for the bulk of carcinogenic risk at the site. (Note that for polonium-210 and lead-210, only 2 of the 17 samples analyzed had detectable levels of these radionuclides. Therefore, they are considered to be of minimal importance as risk contributors.) Iron and selenium account for several percent of the total risk, but are not considered to be key contaminants. Selenium does, however, exceed the UMTRA standard of 0.01 mg/L and should be retained as a COC on this basis.

Table 6–3 summarizes the results of the COPC evaluation for the BLRA update. Results of risk calculations and rationale included in this table indicate that for the purposes of development of the appropriate compliance strategy, arsenic, selenium, uranium, and vanadium should be retained as COCs for further evaluation. Other COPCs identified in the original BLRA have either decreased to within background concentrations or are insignificant with respect to total risk posed by use of ground water at the site.

Currently, no exposure pathways for site ground water are complete and no risks exist. All risk estimates assume that the contaminated ground water will be used in the future as the primary source of drinking water. This is a worst-case assumption because of the poor water quality of the alluvial aquifer and the availability of a municipal water supply, although alluvial water has been and continues to be used in the area. Note that this risk evaluation has focused on contaminants attributable to site processes that are present *in excess of background water quality concentrations.* If alluvial ground water is to be used as a future drinking water source (as has been proposed), contaminants other than arsenic, selenium, uranium, and vanadium would need to be considered in the design of any treatment system that is expected to produce potable water.

Table 6–3. COPC Evaluation

COPC From 1996 BLRA	Retained as COC In Update?	Comment
Arsenic	Y	risks higher than acceptable; UMTRA standard not exceeded; note RBC < detection limit
Fluoride	N	plume concentrations within background range
Iron	N	exceeds background; least significant contributor to risk
Lead-210	N	max. risk greater than acceptable; detected in only 2 of 17 samples
Manganese	N	plume concentrations within background range
Molybdenum	N	plume concentrations within background range; UMTRA standard not exceeded
Polonium-210	N	max. risk greater than acceptable; detected in only 2 of 17 samples
Ra-226	N	risks within acceptable range
Selenium	Y	contribution to overall risk relatively minor; UMTRA standard exceeded
Sulfate	N	plume concentrations within background range
Thorium-230	N	all samples below detection limit
Uranium	Y	HI greater than 1; max, concentration exceeds acceptable risk range; exceeds MCL
Vanadium	Y	HI greater than 1; significant contributor to overall risk

6.2 Ecological Risk Assessment

An ecological risk assessment (ERA) has previously been prepared for the Old Rifle site as part of the BLRA (DOE 1996a). Since that time, site conditions have changed and additional data have been collected. This necessitates some reevaluation of COPC identification and assessment of associated ecological risks. The intent of this ERA update is not to repeat the original risk assessment process, but to use those earlier results and conclusions as a starting point from which to evaluate the more recent data. Some reanalysis of previously collected data was performed for this ERA update to accommodate revised ecological benchmarks. Details of this analysis and of the ERA methodology are provided in Calculation Set U0045200. Results are summarized in this section.

6.2.1 Summary of 1996 Ecological Risk Assessment

The 1996 ERA identified potential pathways of exposure for ecological receptors, identified COPCs for each relevant pathway, and compared contaminant concentrations in those media to appropriate ecological benchmarks. The exposure scenarios evaluated included:

- Direct contact of terrestrial plants with contaminated ground water and uptake through root systems. It was assumed that the root systems of plants could extend below the shallow water table at the site and contact contamination.

- Discharge of ground water to the Old Rifle Pond with subsequent contamination of surface water and sediment. It was assumed that aquatic organisms could directly contact and ingest contaminated surface water and sediment.

- Discharge of ground water to the Colorado River with subsequent contamination of surface water and sediment. It was assumed that aquatic organisms could directly contact and ingest contaminated surface water and sediment.

Sampling results for ground water, surface water, and sediment were used to evaluate these pathways. Results of background sampling locations were compared with site-related locations to identify COPCs. COPCs were those constituents significantly elevated above background concentrations. Table 6–4 lists COPCs identified for each pathway considered. Note that no constituents in Old Rifle Pond surface water were detected at concentrations above background so it is not included in Table 6–4.

Table 6–4. Summary of Ecological Contaminant of Potential Concern in Ground Water, Surface Water, and Sediments

Constituents Above Background[a]	Old Rifle Ground Water	Colorado River Surface Water	Colorado River and Pond Sediment
Ammonium	X	X	
Arsenic	X		X
Cadmium			X
Calcium	X		
Fluoride	X		
Iron	X	X	X
Magnesium	X		
Manganese	X		X
Molybdenum	X		X
Phosphate	X		
Selenium	X		X
Silica	X		
Strontium	X		
Sulfate	X		
Uranium	X		X
Vanadium	X		X
Zinc			X

[a] Greater than concentrations in a reference area (e.g., upgradient well, upriver surface water, or upgradient pond) at the 99 percent confidence level.

Concentrations of COPCs in each medium were compared against appropriate ecological benchmarks. Alluvial ground water data were compared to benchmarks for terrestrial plants. Surface water and sediment data concentrations were screened against aquatic water quality criteria and sediment quality criteria established for the protection of aquatic life. Results of this toxicity screening indicated:

- Vanadium levels in alluvial ground water slightly exceeded the benchmark for terrestrial plants. However, it was concluded that the potential threat to vegetation from Old Rifle alluvial ground water was relatively low.

- Concentrations of iron in the Colorado River surface water were below the state water quality standard. No standard exists for ammonium. Ground water discharging to surface water from the Old Rifle site was assumed to be highly diluted and not to present a threat to ecological receptors.

- Concentrations of contaminants in Colorado River sediments were below values established for protection of aquatic organisms. It was concluded that contaminants from the Old Rifle site did not have a negative impact on river sediments.

- Concentrations of cadmium and zinc in Old Rifle Pond sediments exceeded sediment quality values for protection of aquatic life. Therefore, it was concluded that the potential existed for the sediment to have a negative impact on aquatic organisms.

6.2.2 ERA Update

6.2.2.1 Contaminants of Potential Concern

As discussed in Section 6.1.2 for the human health risk assessment update, 1998 sampling data for the Old Rifle site indicates that several previously identified COPCs are no longer considered to be present at concentrations significantly elevated compared to background concentrations. Of COPCs initially identified in the ERA, these contaminants include fluoride, manganese, molybdenum, and sulfate. Magnesium, also identified as a COPC in the ERA, is indistinguishable from background as well and can be eliminated from further consideration here. Recent monitoring data are not available for phosphate, silica, or strontium. However, a survey of toxicological benchmarks for terrestrial plants and wildlife indicate that these constituents, particularly compared to others associated with the site, are unlikely to pose a threat to ecological receptors (Sample et al. 1996; Efroymson et al. 1997) and have been eliminated from further consideration here. The revised ecological COPC list therefore includes the following contaminants that continue to be present at the site in concentrations exceeding background: ammonium, arsenic, calcium, iron, selenium, uranium, and vanadium.

6.2.2.2 Exposure Pathways

Based on the initial ERA, the exposure pathway posing the greatest ecological concern at the Old Rifle site was sediment contained in the Old Rifle Pond and its potential adverse effect on aquatic organisms. However, since the time that ERA was completed, high water levels in the Colorado River destroyed the Old Rifle Pond. Therefore, that exposure pathway no longer exists and can be eliminated from further consideration.

Additional surface water sampling of the Colorado River at the Old Rifle Pond substitute location (741) confirm that surface water concentrations remain at or below background concentrations (see Table 6–4) downstream from the Old Rifle site indicating no current exposure pathway. Calculations based on ground water discharge to surface water indicate that contaminants discharged to the Colorado River from the site would be diluted by more than five orders of magnitude. With this dilution rate, any contamination from the site would be reduced to either background levels or to levels below detection (see Section 5.2.2.1 on ground water and surface water interaction for further discussion). No additional Colorado River sediment sampling was conducted as results of the initial ERA did not indicate that it was warranted. Because available data do not indicate that site contamination has had an impact on Colorado

River surface water or sediment, these exposure pathways can also be eliminated from further consideration in this ERA update. Therefore, the only potential exposure pathways remaining are exposure of vegetation by rooting into shallow ground water or by potential future irrigation and indirect exposure of foraging wildlife feeding on contaminated vegetation. These possible exposure pathways are evaluated in terms of current and potential future exposure scenarios.

6.2.2.3 Current Exposure Scenario

No surface water or sediment resulting from contact with ground water was present at the Old Rifle site, nor were phreatophytes observed growing on the revegetated area. Although the depth to ground water is relatively shallow at the site, the predominant vegetation included wheatgrasses and weedy species which are not likely to have root systems capable of reaching the aquifer. The area is not currently used for livestock grazing and is fenced to prevent larger wildlife entry. The only surface water present was in a small, unlined, drainage ditch whose source is not associated with the site. Thus, no complete exposure pathways exist. No wetlands are associated with the remediated site, and very limited plant diversity was observed. The location does not represent a significant wildlife habitat by virtue of its size, ecology, or future potential land use. Railroad tracks mark the southern boundary of the site, while U.S. Highway 6 and a steep geological formation form the northern boundary. The Old Rifle Pond was removed from further ecological investigations since high water levels in the Colorado River washed away the pond boundaries. Based on current ecological conditions and analytical data associated with the area, no complete exposure pathway currently exists at Old Rifle.

6.2.2.4 Future Hypothetical Exposure Scenario

Since the potential exists for phreatophytes (e.g., black greasewood or cottonwood) to inhabit the site, plants, through extensive root systems, could take up contaminants in ground water. This is the most likely future exposure scenario.

Barring institutional controls, ground water could be pumped and used for irrigation, livestock watering, or other industrial uses. This would create a source for ground water/surface water ingestion and direct contact with terrestrial vegetation, as well as deposition of ground water/surface water on the soil. The soil would then represent an additional source medium for ingestion and direct contact. At present, these secondary exposure routes are considered incomplete since ground water is not currently used for these purposes, nor is ground water likely to be pumped in the future. Large-scale irrigation with ground water is not considered a likely future pathway because surface water is the main source of irrigation water in the Rifle area.

To evaluate risks to vegetation posed by future hypothetical exposure scenarios, phytotoxicity benchmarks are included with a summary of relevant current ground water data in Table 6–5. At present, benchmarks are exceeded by site ground water for vanadium and arsenic. Soil benchmarks indicate the degree to which contaminants would need to be concentrated in soil through the unlikely irrigation scenario before they would present a risk to vegetation.

Table 6–5. Ecological Screening Benchmarks for Old Rifle Site

Ecological COPC—GW	**Ground Water Concentration**		**Phytotoxicity Benchmarks**	
	Max mg/L	**Mean mg/L**	**Solution mg/L**	**Soil mg/Kg**
Ammonium	7.4	1.09	N/A	N/A
Arsenic	0.0216	0.004	0.001	10
Calcium	298	186	N/A	N/A
iron	3.03	0.542	10	N/A
Selenium	0.0929	0.026	0.7	1
Uranium	0.27	0,107	40	5
Vanadium	0.765	0.137	0.2	2

N/A = not available
Source: Efroymson et al. 1997

It is also possible for contaminants to bioaccumulate in various plant parts and exert a range of influences, depending on the specific COPC. Plant uptake rates and toxicities vary greatly among species, and are affected by factors such as soil characteristics (e.g., pH, redox potential, organic matter), plant sensitivity, input-output balance, and cumulative effects. Foraging wildlife could be indirectly exposed to contaminants in ground water by ingesting plants that have bioaccumulated certain contaminants. Table 6–6 summarizes toxicological benchmarks for selected contaminants in food that have been developed for several representative mammalian and avian species (Sample et. al 1996). These benchmarks represent the lowest estimated concentrations of contaminants in food that are believed to produce adverse effects in ecological receptors. The concentration ranges for many contaminants are large, reflecting the differing sensitivities of the receptors evaluated. Provided for comparison are maximum contaminant concentrations in ground water at the Old Rifle site. For most contaminants, bioaccumulation effects would need to increase contaminant concentrations in plants several orders of magnitude above those detected in ground water to reach or exceed wildlife benchmarks for food. While such degrees of bioaccumulation are possible, depending on plant type, adverse effects from this pathway are expected to be minimal. Wildlife feeding on site vegetation would be expected to do so only occasionally, minimizing their exposure to contaminated food sources.

Table 6–6. Selected Terrestrial Wildlife Benchmarks for Food—Old Rifle Site Ground Water Data

Contaminant	**Maximum Ground Water Concentration mg/L**	**LOAEL Benchmark Range mg/Kg**	**Required Magnification**
Arsenic	0.0216	2.4–428	111–19,000
Selenium	0.0929	.6–33	6.5–355
Uranium	0.27	11–48	41–178
Vanadium	0.765	7–28	9.2–37

LOAEL = Lowest observed adverse effects level; this is the lowest contaminant concentration estimated to produce adverse effects in ecological receptors.
Source: Sample et al. 1996

6.2.3 Ecological Risk Assessment Conclusion

Contaminant concentrations in surface water and sediment were at or below background or other screening levels; therefore, ecological effects are not considered likely under the current land use scenario for these exposure media. Ground water concentrations of some COPCs exceeded background or other screening criteria; however, no direct exposure pathway exists under the current ecological conditions. As such, quantitative risk estimates have not been calculated since no risk is apparent.

The future hypothetical exposure scenario could result in some low risks if phreatophytes rooted into the alluvial aquifer and were then ingested by herbivores. Vanadium and arsenic could potentially be harmful to the plants themselves, as maximum contamination levels in site ground water exceed terrestrial plant benchmark criteria. To present a possible risk to herbivores, site contaminants would have to accumulate in vegetation to levels that greatly exceed current ground water concentrations. Qualitatively, because contaminant levels are expected to decrease in the future through natural flushing, it is unlikely that contaminant levels in vegetation will increase to levels harmful to wildlife. Quantitative risk estimates were not performed for this unlikely scenario.

6.3 Risk Assessment Summary and Recommendations

An evaluation of present-day conditions at the Old Rifle site indicates that no risks currently exist for human or ecological receptors. All exposure pathways are incomplete at this time; the only potential risks from site ground water are associated with future changes in ground water use or with changes in site vegetation. However, development of a compliance strategy for the site must account for potential risks that could exist for up to 100 years in the future. Recommendations in this section are based on those potential future risks.

Table 6–7 summarizes the contaminants that could not be eliminated through application of human health or ecological screening criteria during the risk assessment updates described in the previous sections. Each of these contaminants is discussed below with respect to their role in development of a compliance strategy for the site.

Table 6–7. Summary of Current and Potential Future Risks—Old Rifle Site Ground Water Human Health and Ecological Assessments

Contaminant	Current Risks		Future Risks		Comments
	Human	Ecological	Human	Ecological	
Arsenic	N	N	Y	Y	MCL not exceeded, but risks exceed maximum acceptable for humans; plant phytoxicity levels exceeded in ground water
Selenium	N	N	Y	N	Exceeds UMTRA MCL; no ecological benchmarks exceeded
Uranium	N	N	Y	N	Exceeds MCL in near term; no ecological benchmarks exceeded
Vanadium	N	N	Y	Y	Exceeds risk-based values for human health; plant phytoxicity levels exceeded in ground water

6.3.1 Arsenic

Current concentrations of arsenic do not exceed the UMTRA standard (0.05 mg/L) at any location within the contaminant plume. These concentrations should not increase in the future as the contaminant source(s) has been removed. Because arsenic is not expected to exceed drinking water standards in the future, it is assumed that arsenic need not be further addressed from a human health perspective in development of a compliance strategy for the site.

Current arsenic concentrations do exceed phytotoxicity values for plants. However, because vegetation at the site is shallow rooted, this pathway is currently incomplete. Arsenic concentrations in ground water are projected to decrease through time through natural flushing and eventually will reduce to levels below phytotoxicity benchmarks. Arsenic levels at the site decreased two orders of magnitude from the 1990–1994 sampling period to the most recent 1998 sampling round. If this rate of decrease continues, arsenic should be down to background levels in a relatively short period of time. In the interim, no adverse ecological effects to current site conditions would be expected to occur as long as ground water use does not change. At worst, the establishment of certain deep-rooted plants sensitive to arsenic would be inhibited until arsenic levels have reduced to acceptable levels. If ground water were pumped and used for irrigation at the site, adverse effects on plants could be expected. However, this land use scenario is unlikely and institutional controls on ground water use are likely to be established that will prevent this usage. Levels of arsenic should be reduced in ground water beneath the vast majority of the site to concentrations acceptable for plants after 100 years of natural flushing, especially given the isolated occurrence of elevated arsenic concentrations. Therefore, if institutional controls can be implemented at this site, ecological risks associated with arsenic in ground water will decrease to acceptable levels within 100 years.

6.3.2 Selenium

Currently selenium concentrations in ground water are at concentrations below phytotoxicity benchmarks. Therefore, ecological risks are not of concern in the development of a compliance strategy. The average plume concentration of selenium exceeds the UMTRA standard of 0.01 mg/L, though it is below the SDWA MCL of 0.05 mg/L. The human health risk-based concentration for selenium in drinking water 0.18 mg/L; all wells had concentrations below this level (EPA 1997). Results of ground water modeling indicate that maximum selenium levels in the ground water plume are predicted to decrease to 0.050 mg/L after 50 years and to 0.037 mg/L after 100 years of natural flushing—below both the SDWA MCL and risk-based concentration. Therefore, if institutional controls can be implemented at this site, human-health risks associated with selenium in ground water will decrease to acceptable levels within 100 years.

6.3.3 Uranium

Currently uranium concentrations in ground water are at concentrations below phytotoxicity benchmarks. Therefore, ecological risks are not of concern in the development of a compliance strategy. Several monitoring wells have levels of uranium exceeding the UMTRA standard of 0.044 mg/L and the mean plume concentration is only marginally below this level at 0.042 mg/L. Results of ground water modeling indicate that the high mobility of uranium will cause it to flush rapidly through the ground water system. Maximum concentrations of uranium in alluvial ground water should reduce to below the UMTRA standard or background concentrations after 10 years of natural flushing. Therefore, if institutional controls can be implemented at this site, human-health risks associated with uranium in ground water will decrease to acceptable levels within a 10-year period.

6.3.4 Vanadium

No standard has been established for vanadium in drinking water. However, based on the most accepted reference dose for vanadium (0.009 mg/Kg-day; from EPA's Integrated Risk Information System), a risk-based concentration of 0.33 mg/L is most appropriate for the Old Rifle site. Maximum plume concentrations are more than twice this concentration, but the mean is less than half this value. The maximum vanadium concentrations in the plume have remained about the same from the 1990–1994 sampling period to the most recent 1998 sampling round. However, mean plume concentrations have decreased to about 25 percent of historical values.

Ground water modeling indicates that maximum vanadium concentrations should drop to approximately 0.35 mg/L after 100 years of natural flushing, which is very close to the risk-based concentration for residential use. A vanadium concentration of 0.33 mg/L is proposed as the ACL for this contaminant. This standard should be met for the vast majority of the alluvial aquifer after 100 years by a natural flushing compliance strategy and would allow for unrestricted use of the aquifer at this time. Any portion of the aquifer exceeding this concentration is expected to be very limited and should not pose an unacceptable risk.

Current maximum values of vanadium also exceed the phytotoxicity benchmark for terrestrial plants of 0.2 mg/L. As discussed above for arsenic, because vegetation at the site is shallow rooted, this pathway is currently incomplete. Vanadium concentrations should reduce to acceptable levels in water beneath most of the site in the 100-year time frame evaluated through ground water modeling. In the interim, no adverse ecological effects to current site conditions would be expected to occur as long as ground water use does not change. At worst, the establishment of certain deep-rooted plants sensitive to vanadium would be inhibited until vanadium levels have reduced to acceptable levels. If ground water were pumped and used for irrigation at the site, adverse effects on plants could be expected. However, this land use scenario is unlikely and institutional controls on ground water use will be established. While a small portion of the aquifer is predicted to have concentrations exceeding the phytotoxicity benchmark for vanadium after 100 years of natural flushing, the limited extent of contamination is not expected to pose an unacceptable ecological risk. Therefore, if institutional controls can be implemented at this site in the near term, ecological risks associated with vanadium in ground water will decrease to acceptable levels after 100 years of natural flushing.

7.0 Ground Water Compliance Strategy

The framework defined in the final PEIS for the UMTRA Ground Water Project (DOE 1996c) governs selection of the final strategy to achieve compliance with the EPA ground water protection standards. Stakeholder review and acceptance of the final PEIS is documented and supported by the Record of Decision. Presented below is a discussion of how the selection process was used to determine the final ground water compliance strategy at the Old Rifle site and a proposed future ground water sampling and analysis plan to monitor compliance and the effectiveness of the selected remedy.

7.1 Compliance Strategy Selection Process

The PEIS framework used to determine the appropriate ground water compliance strategy(ies) for the Old Rifle site is summarized in the flow chart provided as Figure 7–1. The framework takes into consideration human health and environmental risk, stakeholder input, and cost. A step-by-step approach is followed until one, or a combination of one or more, of three general compliance strategies is selected. The three compliance strategies are:

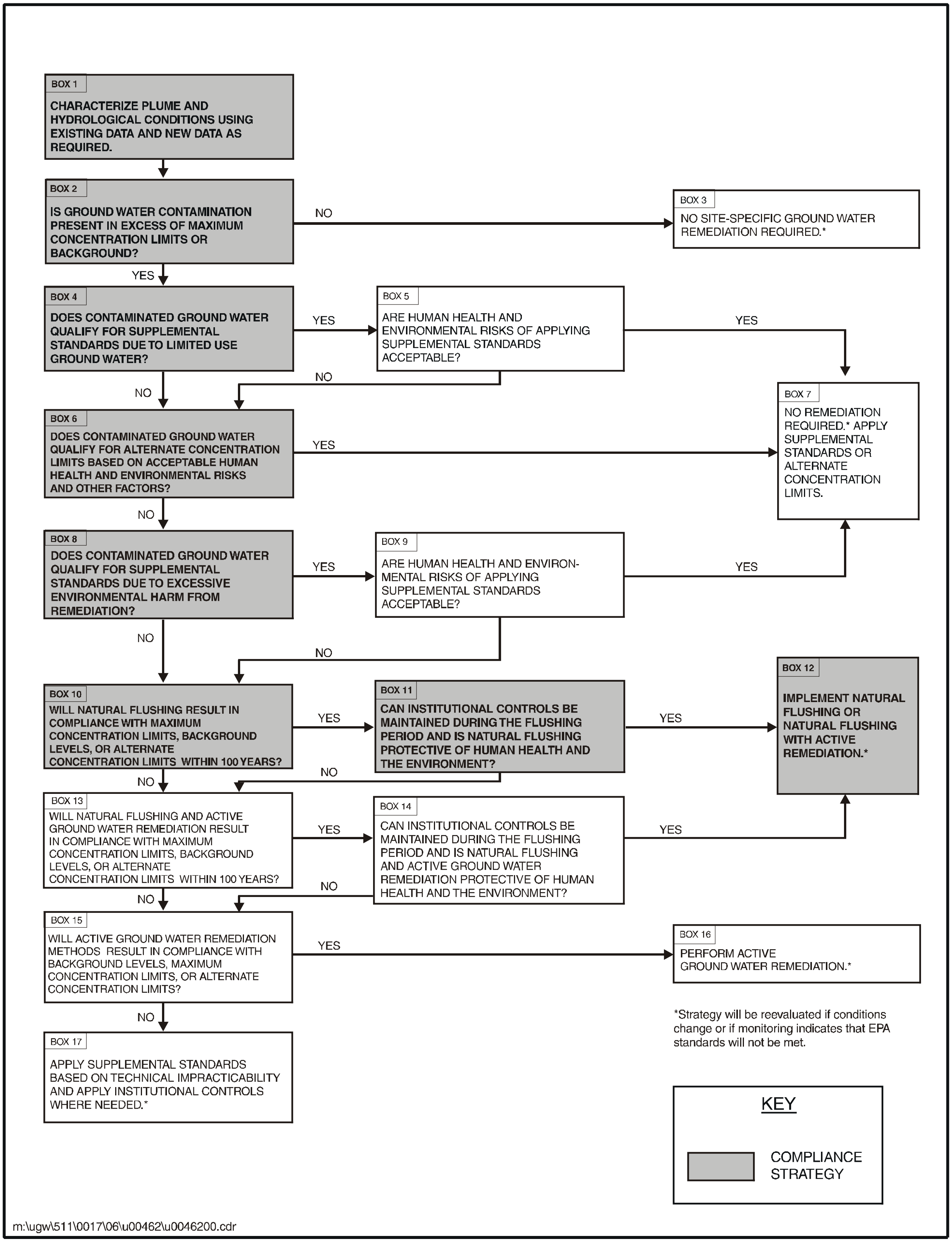
- ***No remediation***—Compliance with the EPA ground water protection standards would be met without altering the ground water or cleaning it up in any way. This strategy could be applied for those contaminants at or below maximum concentration limits or background levels or for those contaminants above maximum concentration limits or background levels that qualify for supplemental standards or ACLs as defined in Section 2.1.1.

- ***Natural flushing***—Allows natural ground water movement and geochemical processes to decrease contaminant concentrations to regulatory limits within a period of 100 years. The natural flushing strategy could be applied at a site if ground water compliance can be achieved within a 100 years or less, where effective monitoring and institutional controls can be maintained, and where the ground water is not and is not projected to be a source for a public water system.

- ***Active ground water remediation***—Requires application of engineered ground water remediation methods such as gradient manipulation, ground water extraction, treatment, land application, phytoremediation, and in situ ground water treatment to achieve compliance with the standards.

7.2 Old Rifle Compliance Strategy

DOE is required by the PEIS to follow the ground water compliance selection framework summarized in Figure 7–1 in selecting the appropriate compliance strategy(ies) to clean up the surficial aquifer affected by former processing activities at the Old Rifle site. The surficial aquifer here is understood to mean the alluvial aquifer and the upper weathered Wasatch Formation, which is hydraulically connected with the alluvium. The deeper Wasatch is not contaminated at the Old Rifle site and is therefore not considered in the development of a compliance strategy.



*Strategy will be reevaluated if conditions change or if monitoring indicates that EPA standards will not be met.

Figure 7–1. Summary of Ground Water Compliance Selection Framework

DOE has determined that natural flushing of the surficial aquifer, in conjunction with the establishment of alternate concentration limits and institutional controls, is the appropriate compliance strategy for the Old Rifle site. The compliance strategy focuses on COCs retained after completion of the updated human health and ecological risk assessment screening processes (Sections 6.1 and 6.2). The 100-year time period for natural flushing will commence upon finalization of the GCAP and concurrence by the NRC. An explanation of how the targeted strategy was selected is presented in Table 7–1.

Table 7–1. Explanation of the Compliance Strategy Selection Process for the Alluvial Aquifer

Box (Figure 7–1)	Action or Question	Result or Decision
1	Characterize plume and hydrological conditions.	See conceptual site model presented in Section 5.0 and contaminant screening presented in Section 6.0. Move to Box 2.
2	Is ground water contamination present in excess of UMTRA MCLs or background?	Selenium and uranium exceed the UMTRA MCL. Arsenic is below the UMTRA MCL at all monitoring. Vanadium is elevated compared to background and exceeds risk-based concentrations. Move to Box 4.
4	Does contaminated ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water is a current source of drinking water and therefore is not classified as limited use. Move to Box 6.
6	Does contaminated ground water qualify for ACLs based on acceptable human health and environmental risk and other factors?	Concentrations are above proposed ACLs at this time. Natural flushing is predicted to reduce to acceptable levels within 100 years. Move to Box 8.
8	Does contaminated ground water qualify for supplemental standards due to excessive environmental harm from remediation?	Although the applicability has not been formally assessed, it is unlikely that remedial action would cause excessive harm to the environment. Move to Box 10.
10	Will natural flushing result in compliance with UMTRA MCLs, background, or ACLs within 100 years?	Ground water modeling shows that natural flushing will reduce uranium to background or below MCLs well within the 100-year time frame. Vanadium and selenium will achieve proposed ACLs within 100 years. Move to Box 11.
11	Can institutional controls be maintained during the flushing period and is the compliance strategy protective of human health and the environment?	The final compliance strategy is protective of human health and the environment. Institutional controls will be in place soon and will prevent use of water. Ground water can be used without restriction after 100 years and will be protective of human health and the environment at that time. Move to Box 12 – implement natural flushing.

Each of the compliance strategy components is discussed in the following sections.

7.2.1 Natural Flushing

Computer ground water flow and contaminant transport modeling was done to assist in forecasting whether natural flushing of the major COCs (uranium, selenium, and vanadium) is a viable remediation alternative. Modeling was done using the MODFLOW code for ground water flow and the MT3D code for contaminant transport. These codes are described and referenced in this SOWP and have been verified, benchmarked, and approved for use by most government and regulatory agencies. Comparative modeling is being done using the probabilistic code GANDT, developed by Sandia National Laboratory.

Results of ground water contaminant transport modeling are presented in Section 5 and Appendix D. Predicted concentrations for selenium, uranium, and vanadium after 100 years of natural flushing are summarized here. Concentrations of arsenic are already below the UMTRA MCL and concentrations are only significantly elevated above background at a single location. Because compliance is already met, this constituent was not modeled.

Uranium is predicted to decrease to levels below the UMTRA standard after a period of just 10 years. However, it should be noted that a background concentration of 0.038 mg/L uranium was used for purposes of ground water modeling. This is the average calculated background uranium concentration. Levels of uranium in excess of 0.06 mg/L have been observed in one background well. Therefore, the compliance standard for uranium in site ground water may be either background or the UMTRA MCL. The monitoring strategy is designed to account for variations in background uranium that may exceed the UMTRA standard.

Based on modeling results, maximum selenium concentrations after 50 years are predicted to be at the SDWA standard of 0.05 mg/L in the most contaminated portion of the plume. Background wells had concentrations of selenium up to nearly 3 times the UMTRA standard based on results from the most recent sampling round. However, these concentrations have been determined to be protective of human health and the environment (see Section 7.2.2 below).

No drinking water standard exists for vanadium; however, plume concentrations currently exceed risk-based concentrations for human health as well as phytotoxicity values for plants. The maximum predicted concentration for vanadium after 100 years of natural flushing is approximately 0.35 mg/L; a value slightly above the risk-based concentration of 0.33 mg/L for human health. However, the volume of plume water exceeding the 0.33 mg/L risk-based concentration is considered to be so small that no unacceptable health or ecological risks are expected to be posed by the ground water. Therefore, concentrations of vanadium achieved after 100 years of natural flushing are considered to be protective of human health and the environment.

7.2.2 Alternate Concentration Limits

Because selenium may exceed the UMTRA standard after 100 years of natural flushing and because vanadium exceeds background and has no drinking water standard, ACLs are required for these contaminants. The SDWA MCL of 0.05 mg/L is proposed as the ACL for selenium. This value is below the risk-based value of 0.18 mg/L for protection of human health and is also below all ecological benchmarks. Therefore, the proposed ACL is protective of human health and the environment. Contaminant transport modeling indicates that the most contaminated portion of the plume will be reduced to levels at or below 0.05 mg/L within the 100-year natural flushing time frame and will thus achieve regulatory compliance.

A concentration of 0.33 mg/L is proposed for the ACL for vanadium. This is the human health risk-based concentration for use of water in a residential setting. Ground water modeling shows that natural flushing will achieve this level for vanadium within 100 years for the vast majority of the aquifer. Any portion of the aquifer exceeding this level is expected to be very limited and to not pose any unacceptable risk. Modeling results also indicate that a small portion of the plume is predicted to exceed the phytotoxicity benchmark of 0.2 mg/L after 100 years of natural flushing. However, because of the small volume of water that is likely to exceed this benchmark, unrestricted use of ground water meeting the proposed ACL of 0.33 mg/L is expected to be protective of human health and the environment.

7.2.3 Institutional Controls

To prevent use of potentially harmful contaminated ground water at the Old Rifle site during the 100-year natural flushing period, an institutional control in the form of a deed restriction is being placed on the site. The land is currently State-owned and is scheduled to be transferred to the City of Rifle during late 1999 or early 2000. A deed restriction will be initiated at the time the land is transferred, thus making the deed restriction legal and enforceable. The deed restriction will apply to the land within the boundaries of the Old Rifle site and will cover all areas in which contaminants in ground water are expected to exceed applicable standards. The restrictions will prohibit the installation of wells into the shallow alluvial aquifer for any purpose and will prohibit the use of ground water for ponds and fountains. The deed restriction will be in place for the 100-year period of natural flushing. If contaminants flush more quickly than predicted restrictions on ground water use may be lifted sooner. The deed restriction is currently going through the approval process.

An additional consideration at the Old Rifle site may be future modification of use and configuration of surface water features. Modeling predictions are based on ground water flow patterns resulting from recharge and discharge conditions currently existing. Any change in these conditions should be subject to approval by the State and DOE to ascertain that any modifications will not adversely impact the projected cleanup of contaminated ground water as determined in this document.

7.3 Monitoring Compliance Strategy

The monitoring strategy for the alluvial aquifer is designed to determine progress of the natural flushing process in meeting compliance standards for site COCs. Standards for Se and V are their proposed ACLs of 0.05 mg/L and 0.33 mg/L, respectively. For uranium the cleanup goal is the UMTRA ground water standard of 0.044 mg/L or background, whichever is higher. Monitoring will focus on these three contaminants. Arsenic, while exceeding human health and ecological risk benchmarks, has decreased to below the UMTRA standard of 0.05 mg/L and is at or below the detection limit for most on-site wells. Because of the limited extent of arsenic contamination and the fact that it meets UMTRA ground water standards, monitoring of arsenic at the Old Rifle site is not proposed because of the limited value it would add. By the time the other contaminants have decreased to target goals, arsenic should be at background concentrations based on its limited extent and historic trends.

Wells 656, 655, 309, 310, 304, and 292 have been established as appropriate for monitoring progress of natural flushing in the alluvial aquifer. Well 656 is located in the center of the plume on the east side of the ditch which flows through the site and well 655 is at the center of the plume on the west side of the ditch. The highest concentrations of Se and V were detected in these wells during the most recent sampling events. Elevated concentrations of U were also detected in samples from these wells. Wells 304, 309, and 310 are located on the farthest downgradient edge of the plume. Well 310 had the highest concentrations of U detected in samples collected in 1998, suggesting that the center of this plume has already migrated downgradient in this direction. Therefore, the wells included in this monitoring network should be adequate for tracking the progress of natural flushing. Well 292 is an upgradient background well. The proposed monitoring locations are shown on Figure 7–2.

Monitoring of wells 655 and 656 will take place until contaminants have decreased to their respective compliance standards for three consecutive years. At that time, monitoring for that contaminant will be discontinued. This is consistent with the approach established for monitoring Resource Conservation and Recovery Act corrective actions. Samples will also be collected from the onsite ditch at location 398 to monitor background uranium concentrations recharging the aquifer. If onsite wells appear to have leveled off in U concentration, but still exceed the UMTRA standard, results of the ditch samples and background well 292 will be used to determine if onsite samples are statistically similar to background and have met the compliance standard.

Contaminant concentrations in most samples collected from downgradient wells 304, 309, and 310 are below target cleanup goals with the exception of uranium. However, ground water modeling results show that concentrations of Se and V are expected to increase and eventually peak in these wells before declining back to acceptable levels. Based on modeling predictions, monitoring of these wells will continue until concentrations have reached their maximum and subsequently decrease to target goals. As with wells 655 and 656, after a contaminant is at or below its compliance standard for three consecutive years, cleanup will be considered complete and monitoring for that contaminant will be discontinued.

Monitoring will take place on an annual basis for the first 10 years. After that time monitoring will occur every 5 years until the year 2030. At that time the monitoring strategy will be reevaluated and adjusted as appropriate based on previous results. To accommodate the specification of observing concentrations of COCs at or below the compliance standards for 3 consecutive years before discontinuing monitoring for that constituent, an annual monitoring frequency will be imposed as necessary to make this determination. If uranium concentrations decrease as predicted by the modeling, this should occur within the initial 10-year time frame. In the case of selenium and vanadium, the predicted periods for reaching the compliance standards are 50 and 100 years, respectively. Monitoring requirements are summarized in Table 7–2.

Table 7–2. Summary of Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency[a]
RFO–655	Center of plume west side of ditch	Se, U, V	Annual for 10 years; 5 years thereafter
RFO–656	Center of plume east side of ditch	Se, U, V	Annual for 10 years; 5 years thereafter
RFO–304, –309, –310	Most downgradient location; leading edge of plume	Se, U, V	Annual for 10 years; 5 years thereafter
RFO–292	Background ground water quality; upgradient monitor well	Se, U, V	Annual for 10 years; 5 years thereafter
RFO–398	Monitor background U recharging aquifer; on-site ditch	U	Annual for 10 years; 5 years thereafter

[a] Annual monitoring will be initiated when contaminant decreases at or below respective compliance standard. Monitoring will be discontinued after demonstrating the contaminant has remained below compliance levels for 3 consecutive years.

Abandonment of all other monitor wells at the Old Rifle site no longer needed for compliance monitoring will be undertaken in the near future in accordance with UMTRA Project procedures and applicable State of Colorado regulations. This will be accomplished under the LTSM program.

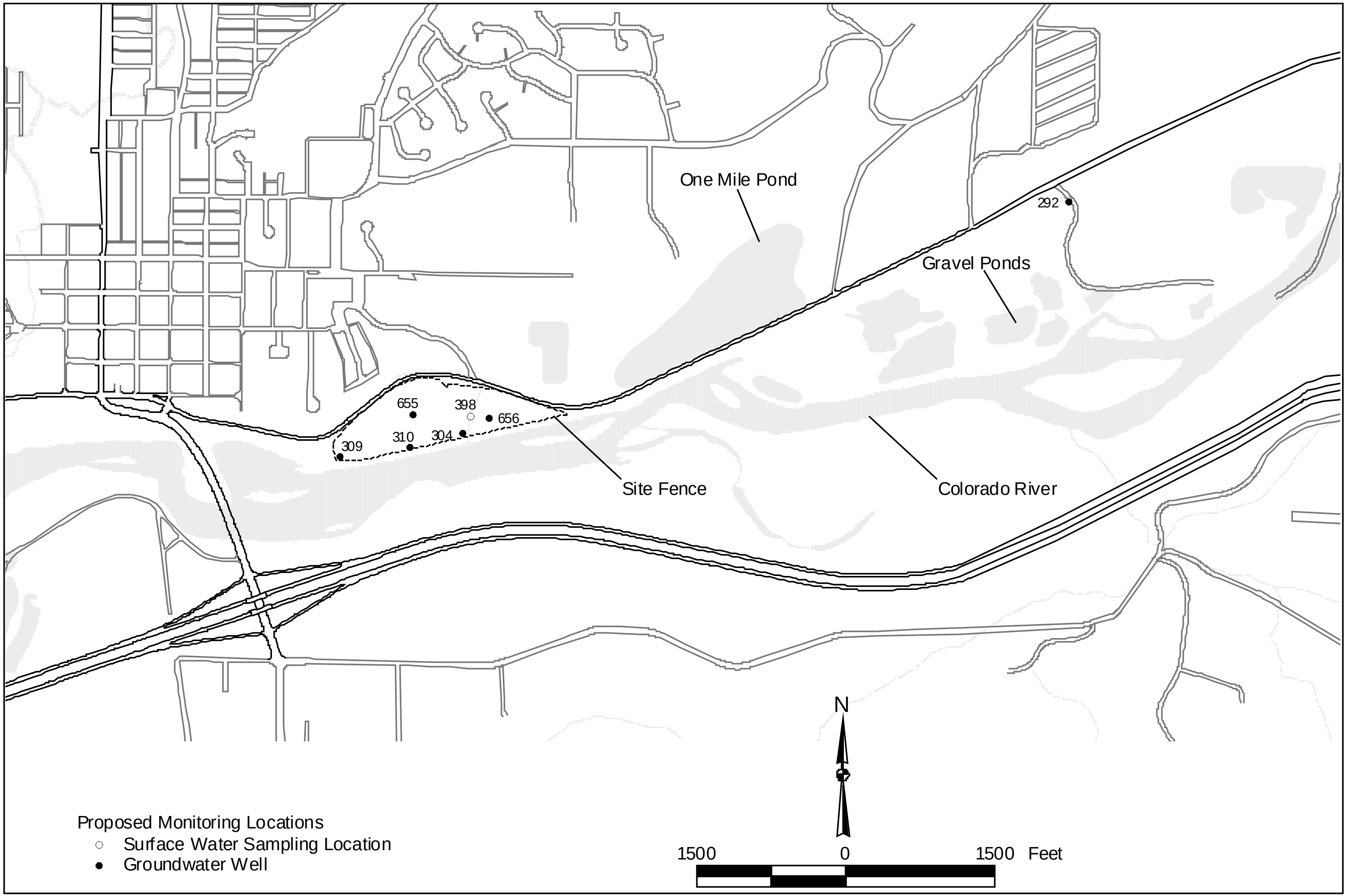


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Figure 7–2. Proposed Monitoring Locations for the Old Rifle Site

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