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UMTRA PROJECT WATER SAMPLING AND ANALYSIS PLAN DURANGO, COLORADO

January 1994

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UMTRA PROJECT WATER SAMPLING AND ANALYSIS PLAN
DURANGO, COLORADO

January 1994

Prepared for
U.S. Department of Energy
UMTRA Project Office
Albuquerque, New Mexico

Prepared by
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Albuquerque, New Mexico

EXECUTIVE SUMMARY

Surface remedial action has been completed at the Uranium Mill Tailings Remedial Action Project site in Durango, Colorado. Contaminated soil and debris have been removed from the former processing site and placed in the Bodo Canyon disposal cell.

Ground water at the former uranium mill/tailings site and raffinate pond area has been contaminated by the former milling operations. The contaminants related to the former uranium milling operations that could be of potential concern for human health and the environment include arsenic, cadmium, chloride, cobalt, copper, lead, manganese, mercury, molybdenum, net gross alpha, nickel, nitrate, radium-226 (Ra-226) and radium-228 (Ra-228), selenium, silver, sodium, sulfate, thallium, uranium, vanadium, and zinc.

The disposal site is located approximately 1.5 miles (0.5 kilometer) from the former processing site. The ground water at the disposal site was not impacted by the former milling operations at the time of the cell's construction.

The following sampling activities are planned for fiscal year 1994:

- Collecting ground water samples from two upgradient monitor wells at the mill/tailings site and three upgradient monitor wells at the raffinate pond area to assess the background water quality.
- Collecting ground water samples from two downgradient monitor wells at the mill/tailings site and three downgradient monitor wells at the raffinate pond area to monitor the contaminant plume.
- Collecting surface water and sediment samples from upstream and downstream locations along Lightner Creek and the Animas River to assess the affects of ground water discharges.
- Collecting ground water samples from one upgradient alluvial well, two upgradient bedrock wells, five downgradient alluvial wells, and five downgradient bedrock wells to identify changes in ground water quality that may indicate leakage from the disposal cell.
- Analyzing the water and sediment samples for selected analytes indicative of background water quality and the contaminant plume associated with the former uranium milling operations.
- Measuring ground water elevations in nine monitor wells and six piezometers at the former processing site to assess ground water flow quantities and directions.
- Measuring surface water elevations at four locations along Lightner Creek and three locations along the Animas River to delineate the ground water/surface water interactions.

- Measuring water level elevations in monitor wells at the Bodo Canyon disposal cell to assess its effectiveness in reducing water infiltration.

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LIST OF ACRONYMS

Acronym	Definition
ac	acre
BLM	U.S. Department of the Interior, Bureau of Land Management
°C	degrees centigrade
cm	centimeters
cm/s	centimeters per second
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
ft	feet
ft/day	feet per day
ft^3/s	cubic feet per second
ft/yr	feet per year
FY	fiscal year
ha	hectare
in	inches
km	kilometer
LTSP	long-term surveillance plan
m	meters
m^3	cubic meters
m^3/s	cubic meters per second
MCL	maximum concentration limit
mg/L	milligrams per liter
mi	mile
MSL	mean sea level
mV	millivolts
m/yr	meters per year
POC	point-of-compliance
QA	quality assurance
QC	quality control
Ra-226	radium-226
Ra-228	radium-228
SOP	standard operating procedures
TAC	Technical Assistance Contractor
TAD	*Technical Approach Document*
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
WSAP	water sampling and analysis plan
yd^3	cubic yards

1.0 INTRODUCTION

1.1 PURPOSE

This water sampling and analysis plan (WSAP) provides the basis for ground water and surface water sampling and identifies and provides justification for the sampling locations, analytical parameters, detection limits, and sampling frequencies for the monitoring stations at the former uranium mill/tailings site (DUR01), the former raffinate (waste solvents) pond area (DUR02), and the Bodo Canyon disposal site (DUR03) in Durango, Colorado. The proposed regulatory requirements for monitoring ground water and surface water at UMTRA sites are published in 52 FR 36000 (1987). Monitoring decisions in this WSAP are based on these regulations, on the Uranium Mill Tailings Remedial Action (UMTRA) standard operating procedures (SOP) (JEG, n.d.), and on the *Technical Approach Document* (TAD) for UMTRA (DOE, 1989).

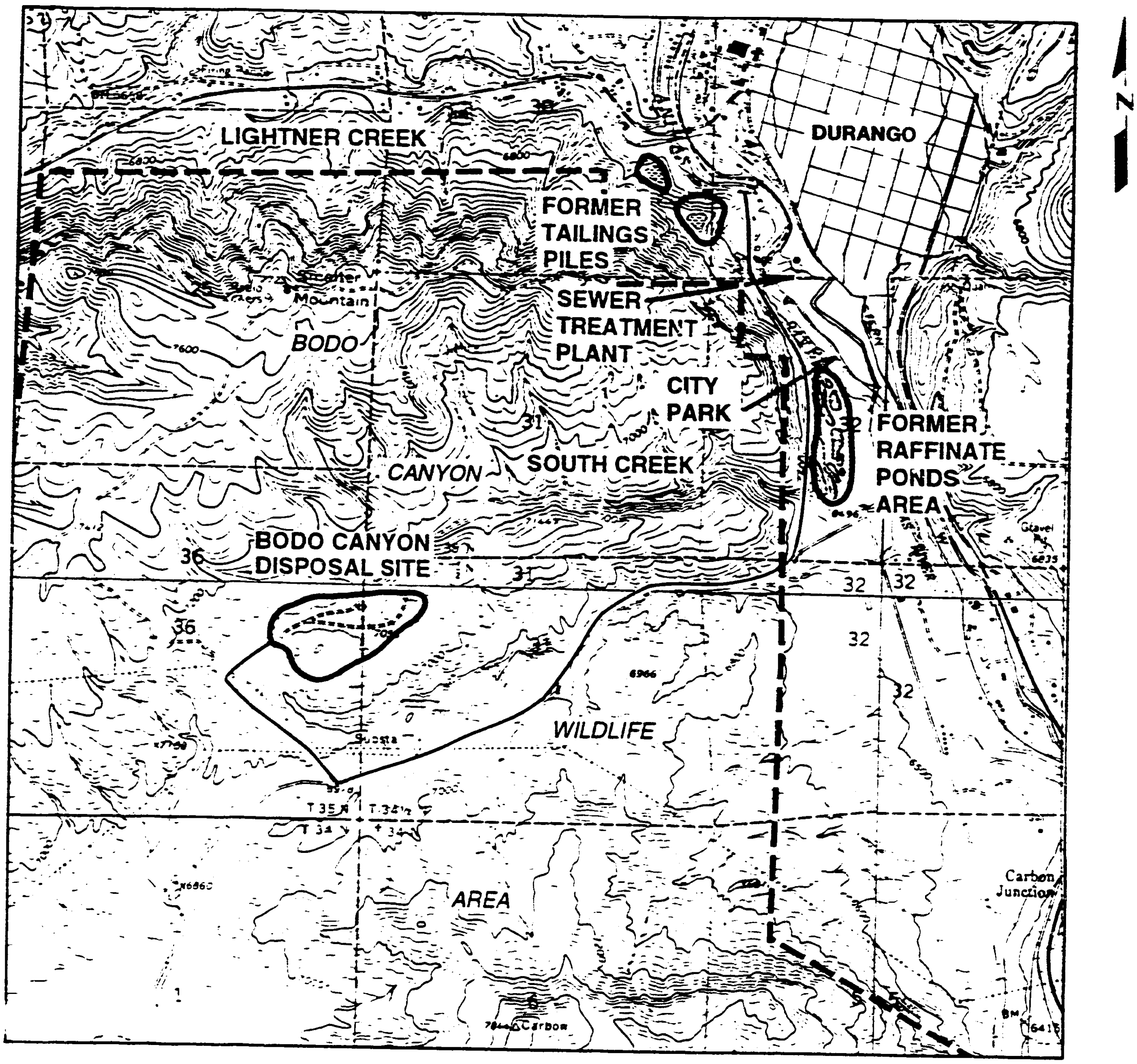
The mill/tailings site and the raffinate pond area are often referred to together as the processing site. Although they are geographically contiguous, they are hydrogeologically separate and will be referred to individually in this WSAP.

Ongoing ground water sampling is conducted at the Durango sites to observe trends in water quality since the processing mill, tailings piles, raffinate ponds, and associated contaminated soils were removed and the disposal cell was constructed. The analytical data will be used to distinguish the constituents found in the background ground water and surface water from those associated with past practices at the mill/tailings site and the raffinate pond area, and to further define the severity and the areal and vertical extent of contamination in those areas. The data also will be used to monitor the effectiveness of the disposal cell in preventing ground water contamination. Finally, the data will be used to evaluate trends in concentrations and to assess the need for continued sampling and analysis of each analyte listed.

Water levels will be measured at all sites; the findings will be used to define the direction and gradient of ground water movements. Surface water samples will be collected to assess impact of ground water discharging into Lightner Creek and the Animas River. This information is needed to facilitate development of the baseline risk assessment.

1.2 SITE LOCATION

The mill/tailings site and raffinate pond area are located on the west bank of the Animas River immediately southwest of the intersection of Routes 160 and 550 (Route 160/150) southwest of the town of Durango, in La Plata County, Colorado (Figure 1.1). The disposal site is located approximately 1.5 miles (mi) (2.4 kilometers [km]) farther to the southwest in a mountain valley near Bodo Canyon.



Base map references: USGS 7-1/2 min topo quad maps for "Durango West" and "Durango East" quads, dated 1963; and "Basin Mountain" and "Loma Linda" quads, dated 1968.

1/2 0 1/2 1
APPROXIMATE SCALE IN MILES

0.6 0 0.6 1.2
APPROXIMATE SCALE IN KILOMETERS

LEGEND

— — BODO CANYON WILDLIFE AREA BOUNDARY

FIGURE 1.1
SITE LOCATIONS AND LAND USE

The mill/tailings site is in Township 35 North, Range 9 West, Section 30SE¼, and Township 35 North, Range 9 West, Section 29SW¼. The range is relative to the New Mexico Principal Meridian. The raffinate pond area is in Township 35 North, Range 9 West, Section 32W½. The Bodo Canyon disposal site is located in Township 35 North, Range 10 West, Section 36E½, and Township 34.5 North, Range 9 West, Section 31W½.

1.2.1 Surrounding land use

Mill/tailings site and raffinate pond area

Lightner Creek runs along the northern edge of the mill/tailings site and Route 160 West parallels the northern bank of the creek (Figure 1.2). A motel and other commercial structures are located on the north side of Route 160 east of the Animas River. The land to the north of Route 160, west of the Animas River, is used for residential and light commercial purposes. A private campground with space for recreational vehicles and semipermanent trailers is adjacent to the northwestern end of the site.

Smelter Mountain rises steeply to the west of the mill/tailings site and the raffinate pond area. The east side of this mountain is characterized by steep, rocky slopes and cliffs with relatively sparse vegetation. The top and much of the western side of Smelter Mountain are within the 8000-acre (ac) (3000-hectare [ha]) Bodo Canyon Wildlife Area and are unoccupied.

The Animas River forms the eastern boundary of both the mill/tailings site and the raffinate pond area. Route 160/550 is located along the eastern edge of the river. The southern end of the city of Durango, including the Durango-Silverton Railroad and station, is east of the road. The municipal sewage treatment plant is located on the eastern bank of the river south of the site and a city park is located south of the sewage treatment plant.

Route 160/550 crosses the Animas River and borders the southern half of the raffinate pond area. The land between Route 160/550 and the Animas River is vacant. County Road 211 leading to Bodo Canyon runs along the southern end of the raffinate pond area. South of this road are a shopping center and several commercial buildings.

Bodo Canyon disposal site

The Bodo Canyon disposal site is located in the northeastern quarter of the Bodo Canyon Wildlife Area (Figure 1.1) owned by the state of Colorado. The land within 1 mi (1.6 km) surrounding the site is uninhabited.

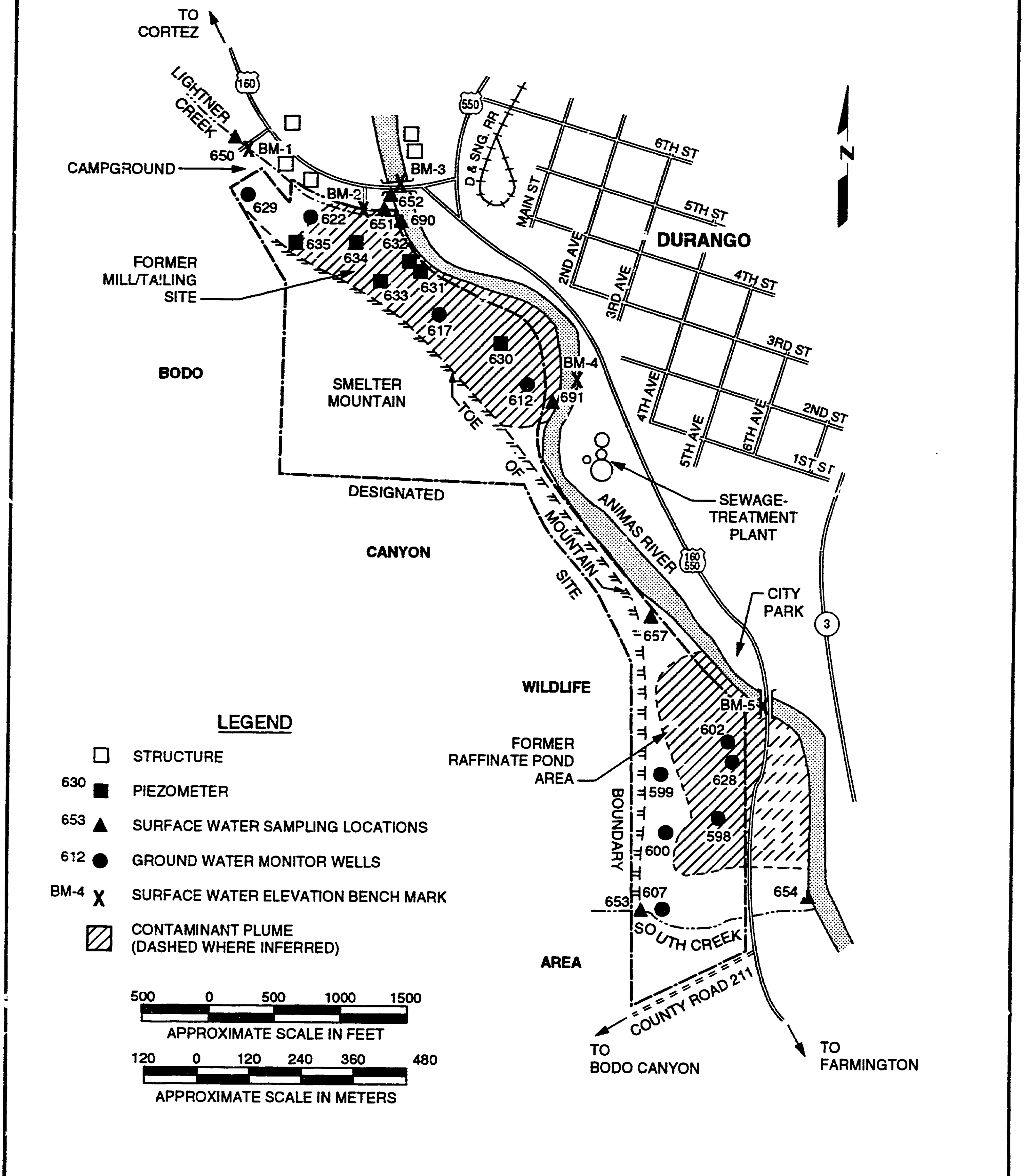


FIGURE 1.2
MONITOR WELL, PIEZOMETER, SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS IN THE MILL/TAILINGS SITE AND RAFFINATE POND AREA DURANGO, COLORADO

MAC: SITE/DUR/WSAP/MONLOCWELL

1.2.2 Surrounding water use

Mill/tailings site and raffinate pond area

The water supply for the city of Durango is withdrawn from gallery collection systems located in the floodplain alluvium of the Animas River upstream of the mill/tailings site and the raffinate pond area. The closest downgradient domestic wells are approximately 2 mi (3.2 km) south and southeast of the site. Ground water contamination at the site and contaminated ground water discharging to the Animas River will probably not affect these wells.

Bodo Canyon disposal site

Four registered stock watering and domestic wells are within a 1-mi (1.6-km) radius of the Bodo Canyon disposal site. These wells are all located upgradient or crossgradient of the site and are completed in the Cliff House and Menefee Formations. These wells will not be affected by the Bodo Canyon disposal site.

1.3 SITE HISTORY

1.3.1 Mill/tailings site

A lead smelter located near the south end of the mill/tailings site operated from 1880 to 1930 (Figure 1.2). The old slag dump from the smelter operation is still in the southeast corner of the site along the Animas River and ranges up to 30 feet (ft) (9 meters [m]) thick (BFEC, 1983).

The uranium mill operated on the same site from 1942 to 1963. It processed approximately 1.6 million tons of ore averaging 0.29 percent uranium oxide and 1.60 percent vanadium oxide delivered to the mill from various mines in the Uravan mineral belt. Between 1942 and 1959, the ore was salt roasted using sodium chloride; the calcines were quenched in carbonate solutions such as sodium carbonate. The tailings were acid-leached with sulfuric acid and oxidizers. The acid leach liquor was treated by solvent extraction, involving kerosene and amines to recover vanadium and uranium. The principal wastes from the process included vanadium precipitation liquor, raffinate from the organic solvent extraction process, overflow from alkaline leach tails, iron and aluminum sludge, and acid leach tails.

The waste liquors were discharged directly into the Animas River or Lightner Creek without treatment until 1959. The discharges caused elevated levels of radiological parameters in the Animas River as far downstream as the Farmington, New Mexico, water intake approximately 50 mi (80 km) to the southwest (FBDU, 1981). Tailings were disposed of in two piles to the northwest of the mill (Figure 1.1).

In 1959, the process changed. The acid-leach tails, alkaline leach tails overflow, roaster gas scrubbing sludge, and process water overflow were pumped to a settling pond on the top of the main tailings pile. Some of the liquid in this pond evaporated or percolated into the tailings pile. A flume carried overflow to a small mixing tank where barium sulfate and Separan® were added before the solution flowed to the lower pond on the top of the small tailings pond near the north end of the site, where further settling removed as much of the slimes as possible. Effluent from this pond was discharged to into the Animas River.

Vanadium precipitation liquor remaining in the main plant was diluted with overflow from a process water tank, condensed steam, effluent from the septic tank serving the facility, and miscellaneous plant and process water. The diluted liquor was then discharged to the Animas River.

1.3.2 Raffinate pond area

After 1959, raffinate from the solvent extraction process was pumped to a tank on the flank of Smelter Mountain, behind the mill. From this tank, the raffinate flowed through approximately 300 ft (100 m) of plastic pipe to a small flume, and then down a 3000-ft (1000-m)-long ditch to the raffinate pond area (Figure 1.1). The liner material in the ditch, if any, is unknown. The raffinate emptied into a series of ditches and a system of 10 ponds designed to dispose of the raffinate through evaporation and seepage, with no direct discharge to the river.

The former lead smelting and uranium milling operations potentially added the following constituents to the soils, bedrock, and ground water at the mill/tailings site: arsenic, cadmium, chloride, cobalt, copper, lead, manganese, mercury, molybdenum, net gross alpha, nickel, nitrate, radium-226 (Ra-226) and radium-228 (Ra-228), selenium, silver, sodium, sulfate, thallium, uranium, vanadium, and zinc. Many of these constituents were also pumped to the raffinate ponds and seeped into the soils, bedrock, and ground water in that area.

1.3.3 Bodo Canyon disposal site

Before the disposal cell was constructed, the Bodo Canyon site was used as pasture land and managed by the U.S. Department of the Interior, Bureau of Land Management (BLM). No mining, milling, or other industrial activities occurred in the valley before placement of the cell.

Remedial action to relocate the tailing piles and the contaminated soils from the mill/tailings site and raffinate pond area to the Bodo Canyon disposal site was initiated by the U.S. Department of Energy (DOE) in March 1987 and completed in the fall of 1990. A total of 2.5 million cubic yards (yd^3)

(1.9 million cubic meters [m^3]) of contaminated materials were relocated to the Bodo Canyon disposal cell.

1.4 SITE STATUS

Site specific studies to address the ground water at the mill/tailings site, raffinate pond area, and Bodo Canyon disposal site were initiated in 1976 and continue to the present time. These documents are listed in Section 7.0, References.

The mill/tailings site and the raffinate pond area were contoured and planted in grasses after the tailing piles and contaminated soils were removed.

A baseline risk assessment for the mill/tailings site and raffinate pond area is in preparation and should be complete in the fall of 1994. The draft of the long-term surveillance plan (LTSP) for the Bodo Canyon disposal site is planned for January 1994.

1.5 SAMPLING PLAN SUMMARY

Preparation of a baseline risk assessment at the mill/tailings site and raffinate pond area and compliance monitoring at the Bodo Canyon disposal site will be facilitated by collecting and analyzing water samples and measuring water level elevations at the Durango site. Details of the sampling plan are discussed in Section 5.0. Sampling locations are shown in Figures 1.2 and 1.3.

Both filtered (0.45 microns) and nonfiltered samples will be collected from each well at the mill/tailings site and raffinate pond area to support the risk assessment. Only nonfiltered samples will be collected at the Bodo Canyon site to assess the disposal cell's performance. Standard field parameters, including pH, alkalinity, dissolved oxygen, specific conductivity, temperature, and oxidation/reduction potential, will be measured in each well.

The ground water samples will be analyzed for the constituents listed in Table 1.1. The surface water and sediment samples will be analyzed for the constituents listed on Table 1.2. Constituents to be sampled were identified on the basis of 1) their presence in tailings pore fluids or ground water at concentrations above MCLs or above background for hazardous constituents without MCLs; 2) usefulness as indicator parameters of plume location, movement, and cell performance; and 3) usefulness for overall water chemistry modeling and data validation purposes.

Static water level measurements will be taken in 6 piezometers and 23 monitor wells before purging. Surface water elevations will be measured relative to bench marks located along Lightner Creek and the Animas River. These data will be used to assist in the delineation of the ground water flow direction and gradients and the relationship of the ground water and surface water regimes.

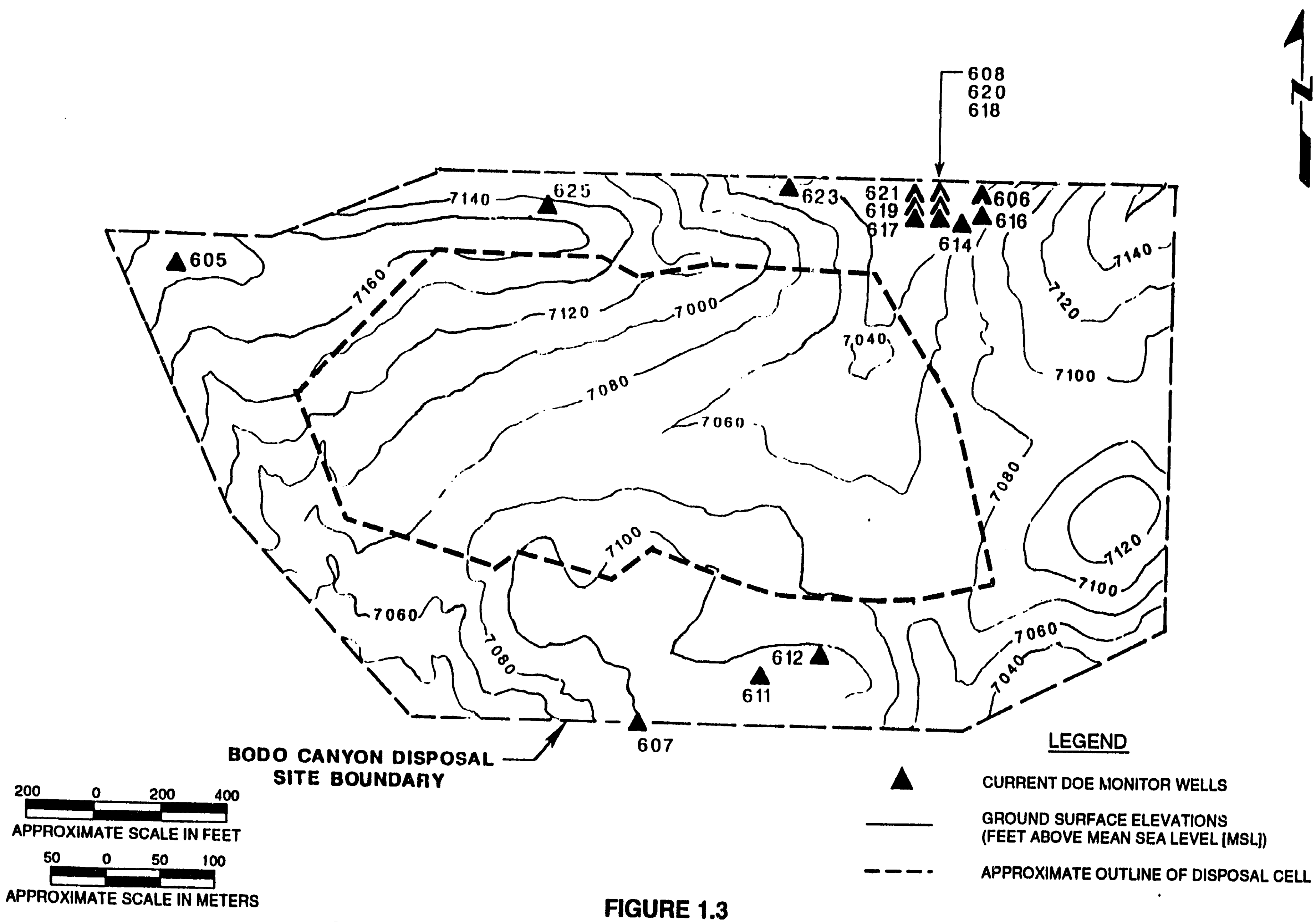


FIGURE 1.3
LOCATIONS OF MONITOR WELLS AND TOPOGRAPHIC MAP
BODO CANYON DISPOSAL SITE, COLORADO

Table 1.1 Ground water sample analyte list

Location	Well	Constituents			
		With MCLs	Without MCLs[a]	Sampled for risk assessment	Sampled for water chemistry modeling/data validation
Mill/tailing site and raffinate pond area	DUR01 612, 617, 622, 629; DUR02 598, 599, 600, 602, 607, 628	As, Cd, Hg, Mo, NO_3, Pb, Ra-226, Ra-228, Se, U, net gross alpha	Tl, V, Zn	Mn, Pb-210, Po-210, Th-230	Ca, Cl, Fe, K, Mg, Na, SiO_2, SO_4, TDS
Bodo Canyon disposal site	DUR03 605, 606, 607, 608, 611, 612, 614, 616, 618, 620, 621, 623, 625	As, Cd, Mo, NO_3, Pb, Ra-226, Ra-228, Se, U	Co, Cu, V, Zn	Mn	Ca, Cl, Fe, K, Mg, Na, S_iO_2, SO_4, TDS

Key

As - arsenic	Mn - manganese	SiO_2 - silica
Ca - calcium	Mo - molybdenum	SO_4 - sulfate
Cd - cadmium	Na - sodium	TDS - total dissolved solids
Cl - chloride	NO_3 - nitrate	Th-230 - thorium-230
Co - cobalt	Pb - lead	Tl - thallium
Cu - copper	Pb-210 - lead-210	U - uranium
Fe - iron	Po-210 - polonium-210	V - vanadium
Hg - mercury	Ra-226 - radium-226	Zn - zinc
K - potassium	Ra-228 - radium-228	
Mg - magnesium	Se - selenium	

[a]Constituents without MCLs listed in Appendix IX, 40 CFR Part 264 (1987).

Table 1.2 Surface water and sediment sample analyte list

Location	Sample point	Analyte
Mill/tailing site		Surface water samples
Lightner Creek	DUR01 650, 651	SO_4, Mg, Ca, NO_3, As, Cd, Fe, Pb, Mn, Hg, Mo, Se, U, Zn
Animas River	DUR01 652, 690, 691	
Raffinate pond area		Sediment samples
Animas River	DUR02 654, 657	SO_4, NO_3, As, Cd, Fe, Pb, Mn, Hg, Mo, Se, U, Zn
South Creek	DUR02 653	

See key to Table 1.1 for definitions.

The rates of drawdown and recovery during well purging will be measured to qualitatively assess aquifer yield.

1.5.1 Mill/tailings site and raffinate pond area

Mill/tailings site

At the mill/tailings site, samples will be collected from the following DUR01 locations shown on Figure 1.2:

- Monitor wells 612 and 617, downgradient of the former mill and tailings sites, to evaluate plume concentrations and plume movement.
- Monitor well 622, to evaluate the quality of the ground water in the alluvium near Lightner Creek.
- Monitor well 629, to measure the background water quality along the interface of the unconsolidated surficial material and the Mancos Shale bedrock upgradient of the site.
- Surface water and sediment sample locations 650, 651, 652, 690, and 691, to assess the impact of ground water discharge to Lightner Creek and the Animas River.
- Monitor well 612, where quality assurance (QA)/quality control (QC) samples will be collected.

Raffinate pond area

At the raffinate pond area, samples will be collected from the following DUR02 locations shown on Figure 1.2:

- Monitor wells 599 and 600 installed by the U.S. Bureau of Reclamation (USBR) (as wells DH114 and DH115, respectively), to measure background water quality in the Point Lookout Sandstone.
- Monitor well 598 (installed by the USBR as well DH110), which is screened within the fault zone, to monitor plume contaminant levels and plume movement.
- Monitor well 607, to measure background water quality in the Menefee Formation.
- Monitor well 628, to measure the ground water quality downgradient of the raffinate ponds.

- Retrofitted monitor well 602, to assess the vertical extent of ground water impacts.

- Surface water and sediment sampling points 657 and 654 at the upstream and downstream ends of the raffinate pond area, to assess the impacts to the Animas River.

- Surface water (if possible) and sediment sampling point 653, in South Creek where it crosses the raffinate pond area fault to assess the impacts on background ground water quality.

No QA/QC samples will be collected at the raffinate pond area.

1.5.2 Bodo Canyon disposal site

At the Bodo Canyon disposal site, samples will be collected at the following DUR03 locations shown on Figure 1.3. All downgradient wells are point of compliance (POC) wells.

- Upgradient bedrock monitor wells 605 and 625, to measure background levels.

- Downgradient bedrock monitor wells 607, 611, and 612 (southeast of the cell), and 616 and 621 (northeast of the cell), to monitor cell performance.

- Upgradient alluvial monitor well 623, to measure background levels.

- Downgradient alluvial wells 606, 608, 614, 618, and 620, to monitor cell performance.

- Monitor well 608, to collect QA/QC samples.

1.6 SUMMARY OF CHANGES TO FISCAL YEAR 1993 SAMPLING PLAN

The DUR01 and DUR02 wells were last sampled in 1992; the DUR03 wells were sampled in both January and May 1993. No surface water or sediment samples were collected in FY1993.

The DUR01, DUR02, and DUR03 wells listed for sampling in fiscal year (FY) 1994 are the same wells that were sampled in 1992 with the addition of a new background well installed at the mill/tailing site (well DUR01 629) and a new shallow well, DUR02 628, at the raffinate pond area. Both wells were installed in October 1993. Also, three wells installed by the USBR in the raffinate pond area (DUR02 598, 599, and 600) will be sampled. Well DUR02 602 in the raffinate pond area has been reconfigured to allow collection of ground water samples and measurements of the piezometric head in the lower screened interval at a depth of 55 to 60 ft (17 to 18 m) below land surface.

Six new piezometers (630 and 635) were installed at the mill/tailings site in October 1993 to facilitate the measurement of ground water elevations (Figure 1.2).

In FY1994, at DUR01 and DUR02, ground water samples will be analyzed for a list of selected constituents similar to the FY1992 list; however, aluminum, barium, chromium, copper, fluoride, gross alpha, gross beta, nickel, silver, and strontium were deleted from the 1994 list and silica and thallium were added. Constituents were deleted either because they were well below their respective maximum concentration limits (MCL) in the last five to eight sampling rounds (i.e., silver, barium, and chromium) because they were near detection limits and in the range of background values (i.e., copper, nickel), or because they are not among constituents generally considered hazardous and do not pose a health threat at the concentrations found at these sites (i.e., aluminum, fluorine, strontium). Silica was added to the list because it is a major constituent needed in mass balance calculations. Thallium was added because it was detected in well DUR02 602 in October 1990 at concentrations significantly above background.

Surface water and sediment samples will be collected in FY1994 and analyzed for the constituents listed on Table 1.2.

The list of constituents selected for analysis in FY1994 at DUR03 is similar to the FY1993 list except that barium, beryllium, chromium, copper, and strontium were deleted and cobalt and silica were added. Constituents were deleted from the list because they were statistically well below their respective MCLs in tailings pore fluids (i.e., barium and chromium); less than 2 times background concentrations and less than 3 times the detection limits (beryllium and copper), or not considered hazardous constituents at concentrations found in the tailings fluids (i.e., strontium). Cobalt is returned to the list because reevaluation of the data indicates that it was detected above background. Silica was added for use in mass balance calculations.

2.0 SITE CHARACTERISTICS

The Durango project area is located on the northern rim of the San Juan Basin of northwestern New Mexico and southwestern Colorado. The San Juan Basin is a near-circular structural basin that developed during Late Cretaceous and early Tertiary (Laramide) time as part of the Colorado Plateau. The project area lies on the northern edge of the Hogback monocline which marks the northern boundary of the San Juan Basin. Strata in the project area dip 8 to 10 degrees southeast into the basin.

The semiarid climate of the Durango area is characterized by severe winters and moderate summers. The mean temperature is 50 degrees Fahrenheit (°F) (10 degrees centigrade [°C]) and varies between 19°F (7°C) in January and 70°F (21°C) in July. Precipitation is predominantly from heavy rainstorms (May through October) and winter snowfall. Precipitation averages approximately 19 inches (in) (48 centimeters [cm]) per year. This combination of temperatures and precipitation creates the potential for evaporation to exceed precipitation by about 30 in (76 cm) annually. However, according to Tsivoglou et al. (1960), during December, January, and February, precipitation is twice the potential evaporation, resulting in ample moisture available for infiltration.

2.1 MILL/TAILINGS SITE

2.1.1 Physiographic setting

The mill/tailings site encompasses approximately 40 ac (16 ha). It is located on a bedrock-supported, river terrace between Smelter Mountain (elevation 7725 ft [2350 m] above mean sea level [MSL]) to the west, the Animas River to the east, and Lightner Creek to the north (Figure 1.1). The terrace pinches to the northwest and to the south where Lightner Creek and the Animas River flow against the side of Smelter Mountain at the south end of the mill/tailings site.

Lightner Creek flows west to east along the northern boundary of the site, dropping in elevation from approximately 6490 ft (1978 m) MSL at the northwest corner of the site to 6475 ft (1973 m) MSL at the confluence with the Animas River. The Animas River drops from approximately 6475 ft (1973 m) MSL at the northeast corner of the mill/tailings site to 6455 ft (1967 m) MSL at the south end of the site.

The topography of the mill/tailings site was modified during the removal of the tailings and contaminated soils. The property slopes steeply down from Smelter Mountain, but becomes relatively level near Lightner Creek and the Animas River. The site is open and is planted in grass. Figure 2.1 shows site conditions before remediation.

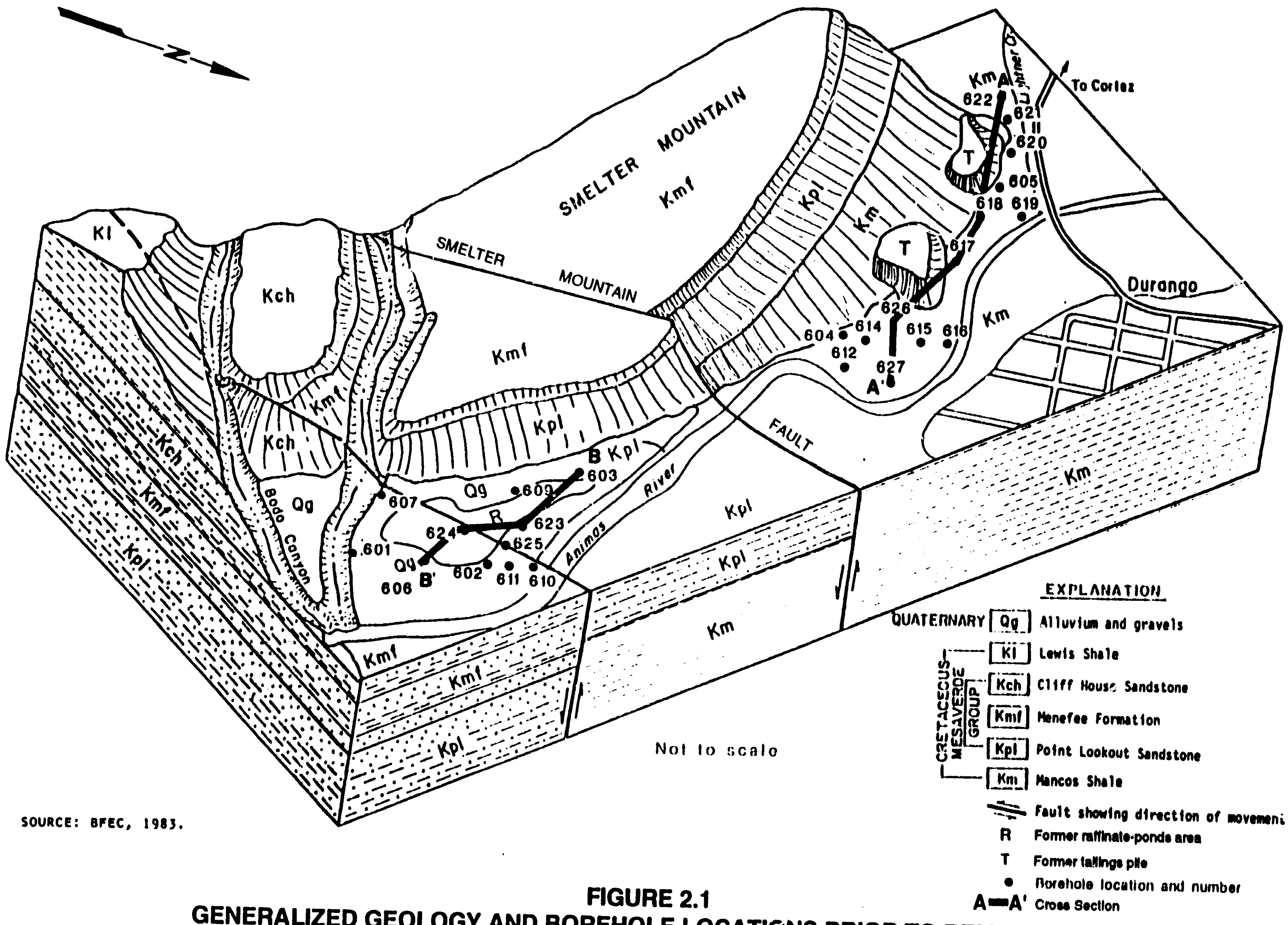


FIGURE 2.1
GENERALIZED GEOLOGY AND BOREHOLE LOCATIONS PRIOR TO REMEDIATION
DURANGO PROCESSING SITE, COLORADO

2.1.2 Geology

The mill/tailings site is underlain by more than 1700 ft (500 m) of dark gray to black Mancos Shale that dips to the southeast at 5 to 10 degrees (Figure 2.1). The Mancos Shale is truncated by the Smelter Mountain fault south of the mill/tailings site.

Before removal of the uranium mill, tailing piles, and contaminated soil, the bedrock terrace was overlain by as much as 60 ft (20 m) of unconsolidated alluvial, colluvial, and man-made fill deposits (Figure 2.2). The depth of overburden remaining above the bedrock after site remediation has not been completely determined but is mostly less than 20 ft (7 m) thick. The lowest layer of this overburden comprises 2 to 15 ft (0.6 to 4.5 m) of Quaternary gravels directly overlying the Mancos Shale. These gravels may represent glacial outwash and/or alluvial river gravels, and are generally water-bearing over the bedrock. Coarse, permeable terrace gravel deposits border Lightner Creek and the northern part of the site along the Animas River. As much as 25 ft (7.6 m) of vitreous smelter slag remains along the bank of the Animas River near the southeast corner of the mill/tailings site.

2.1.3 Hydrology

Ground water

Ground water beneath the mill/tailings site is recharged primarily by infiltrating precipitation. This water moves across the alluvium/Mancos Shale interface toward Lightner Creek and the Animas River. The Mancos Shale has very low permeability, which prevents downward migration.

Ground water can be seen seeping from the Smelter Mountain fault south of, and at a higher elevation than, the mill/tailings site. This fault is a hydrologic barrier between the mill/tailings site and the raffinate pond area to the south.

Slug-removal aquifer tests were conducted in borehole locations (monitor wells) 612, 615, 616, 619, and 622 (Figure 2.1) before the tailings piles and contaminated soils were removed (BFEC, 1983). These wells were screened predominantly in the Quaternary gravels above the bedrock. The hydraulic conductivity calculated from these tests is approximately 20 feet per day (ft/day) (7×10^{-3} centimeters per second [cm/s]). The tests in a well in the terrace gravels near Lightner Creek indicate a hydraulic conductivity of approximately 300 ft/day (1×10^{-1} cm/s).

The absence of a sufficient number of data points has precluded the preparation of a ground water contour map for the site or calculations of the rate of ground water movement. The new piezometers and the monitor well installed in October 1993 should provide the needed data.

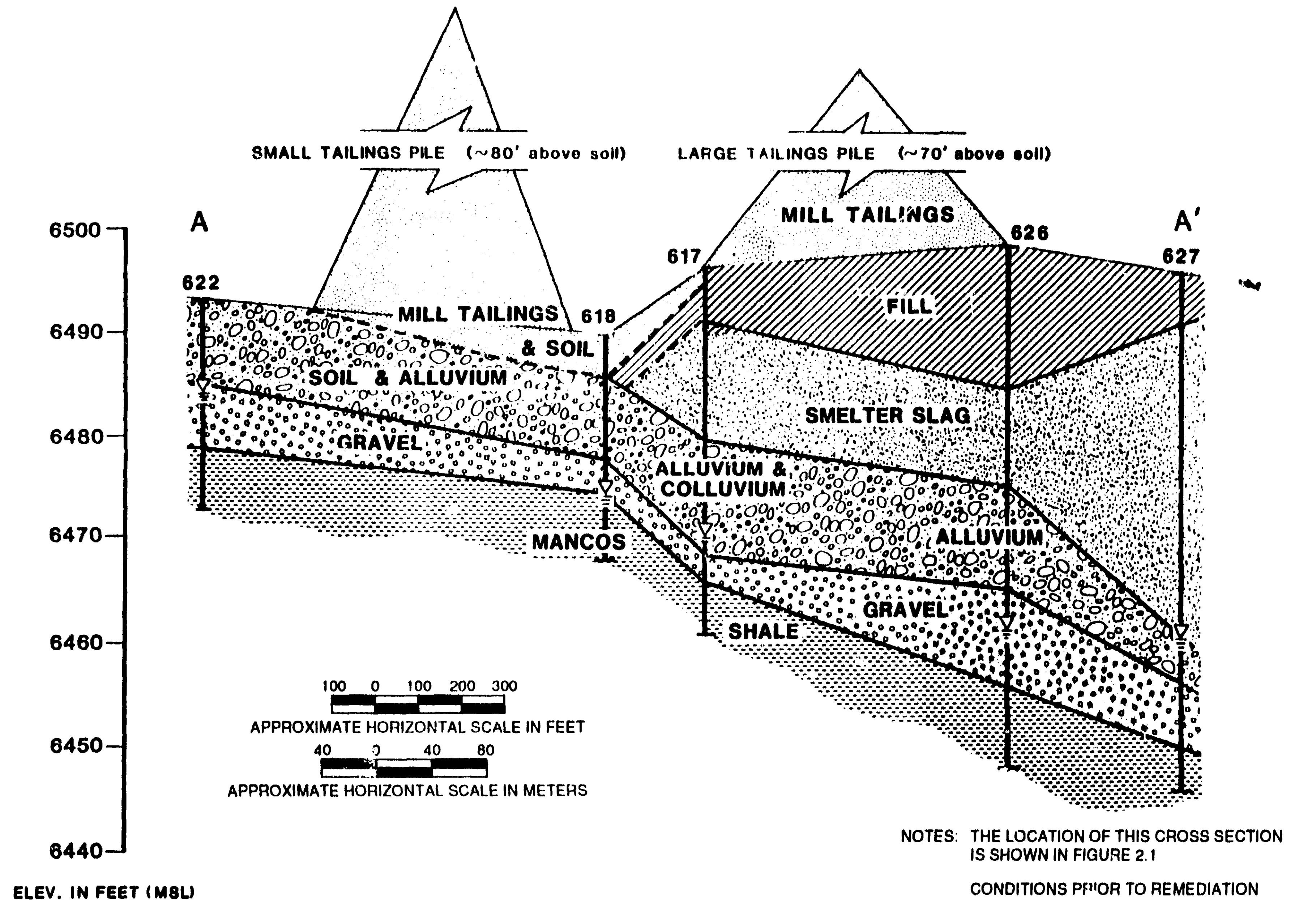


FIGURE 2.2
GEOLOGIC CROSS SECTION (A - A') OF FORMER TAILINGS PILE AREA
DURANGO PROCESSING SITE, COLORADO

Surface water

Lightner Creek flows along the northern edge of the mill/tailings site. Between 1927 and 1949, its average flow was 22.6 cubic feet per second (ft^3/s) (0.7 cubic meters per second [m^3/s]) and minimum daily flows of 1.0 ft^3/s (0.03 m^3/s) or less (USGS, 1993). More recent data are not available on the flow of Lightner Creek, but it was observed to be flowing during the low-flow period in October 1993.

The Animas River forms the eastern and southern boundaries of the mill/tailings site. A U.S. Geological Survey (USGS) gaging station is maintained approximately 4500 ft (1400 m) upstream of the confluence of the Animas River and Lightner Creek. The annual mean flow from 1898 to 1992 was 812 ft^3/s (24 m^3/s) and the record 7-day low flow was 100 ft^3/s (3 m^3/s) in December 1917.

Sections of both Lightner Creek and the Animas River are incised into the bedrock.

2.1.4 Water quality

Background water quality

Before monitor well 629 (Figure 1.2) was installed in October 1993, monitor well 622 most closely represented background water quality in the alluvial aquifer at this site. Monitor well 622 is screened in the terrace gravels along Lightner Creek. Water from the creek is expected to flush through the terrace at varying rates, depending on the stream level. As a result, the water quality is representative of mixtures of ground water seeping beneath the site from the southwest and infiltrating stream water. Water in this well is a calcium bicarbonate type with measured total dissolved solids (TDS) ranging from approximately 450 to 2370 milligrams per liter (mg/L), pH ranging from 6.6 to 7.4, and oxidizing redox potentials.

The high TDS values were obtained in the early sampling events at this well in 1987 and the spring of 1988. Since July 1988, the TDS values have ranged from approximately 500 to 600 mg/L.

Of the constituents with MCLs (see Table 1.1), only molybdenum, selenium, and uranium have exceeded their MCLs since 1987. Molybdenum concentrations exceeded the MCL (0.1 mg/L) only once, in 1987. Selenium concentrations exceeded the MCL (0.01 mg/L) more regularly, ranging up to 0.066 mg/L. Uranium concentrations exceeded the MCL (0.044 mg/L) in the 1987 and April 1988 sampling events, ranging up to 0.115 mg/L.

Potentially hazardous constituents without MCLs were generally at or below detection limits except for sulfide, tin, and vanadium. The sulfide concentration was 0.4 mg/L in one sampling round (July 14, 1990), the tin concentration was 0.014 mg/L in one sampling round (November 16, 1989), and the vanadium concentration was 0.02 mg/L in two sampling rounds (October 28, 1990, and August 7, 1992).

Monitor well 629 was installed in October 1993 farther up the terrace at the base of Smelter Mountain. Samples from this well are expected to be representative of background water moving along the alluvium/bedrock contact.

Contaminant plume

Water quality in downgradient monitor wells 612 and 617 ranges from sodium-sulfate type water in monitor well 612 to calcium-sulfate type water in monitor well 617. TDSs range from approximately 3000 to 6500 mg/L in monitor well 612 and from about 3200 to 3800 mg/L in monitor well 617. The pH ranges from approximately 6.6 to 6.9 in monitor well 612 and from 6.7 to 7.0 in monitor well 617.

Of the potentially hazardous constituents with MCLs, cadmium, molybdenum, selenium, and uranium exceeded their respective MCLs at least once in monitor well 612 since 1987. In monitor well 617, only exceedances of the molybdenum, selenium, and uranium MCLs occurred. The potentially hazardous constituents without MCLs that were above detection limits in monitor well 612 included antimony, copper, nickel, silver, tin, vanadium, and zinc. Of these constituents, only tin was reported above detection limits in background monitor well 622. In monitor well 617, only silver, vanadium, and zinc were reported above detection limits.

The main hazardous constituents of concern at this site are cadmium, molybdenum, net gross alpha, Ra-226 plus Ra-228, uranium, vanadium and zinc. Overall, water quality at this site has improved only slightly since 1987.

Surface water

The DOE collected surface water samples at locations 690 and 691 upstream and downstream of the mill/tailings site in April 1987 and in April and July 1990. No detectable changes in surface water quality attributable to ground water flow from the site were identified. It should be noted, however, that these samples were collected when the river was flowing at a relatively high rate.

Samples were collected during the fall of 1993 during the normal period of lowest stream flow. As a result, the contribution of ground water flow will constitute the highest percentage of stream flow for the hydrologic year and will be indicative of the maximum impact of ground water discharge on Lightner Creek and the Animas River. The USBR has also been collecting samples from

Lightner Creek and the Animas River. Their data have been received and are being reviewed; they will be compared to the DOE analytical results.

2.1.5 Site conceptual model

The soils and ground water at the mill/tailings site have been impacted by constituents from the former lead smelting and from uranium milling operations. The former mill, the tailings piles, and much of the contaminated soil have been removed from the site, but much of the lead slag still remains. No active ground water remediation has been undertaken, although the fresh water is continuously recharging (moving) beneath the site.

Ground water is expected to move beneath the site and discharge into Lightner Creek and the Animas River. Contaminants from the former operations will move with the ground water toward these discharge points. Ground water is not expected to move to the west toward Smelter Mountain or under Lightner Creek or the Animas River to the north, east, or south.

The criteria used for removal of contaminated soils from the site were based on health exposures to wind-borne soils and radon standards for air emissions. The risks associated with the contaminated ground water relate to potential future land uses at the site and the quality and quantity of ground water discharging to Lightner Creek and the Animas River.

2.2 RAFFINATE POND AREA

2.2.1 Physiographic setting

The raffinate pond area occupies part of the river terrace at the foot of Smelter Mountain, south of the Smelter Mountain fault along the west bank of the Animas River. The northern end of the raffinate pond area is located approximately 2000 ft (600 m) south of the southern end of the mill/tailings site. A narrow terrace above the Animas River connects the two areas.

Ten raffinate ponds (FBDU, 1981) were located on the terrace between 6480 ft (1975 m) and 6530 ft (1990 m) above MSL and covered approximately 17 ac (7 ha). The Animas River borders the northeastern half of the site, and Route 160/550 runs along the southeastern half. A small, intermittent creek (called South Creek in this study) forms the southern boundary of the area.

2.2.2 Geology

Two bedrock units underlie the raffinate pond area (USBR, 1990). The Point Lookout Sandstone underlies the northwestern two-thirds of the area between the Smelter Mountain Fault south of the mill/tailings site and another fault that cuts the raffinate pond area (Figure 2.1). The Menefee Formation underlies the southeastern one-third of the area (Figures 2.1 and 2.3). The fault that cuts across the raffinate pond area is a northeast-southwest trending high angle (approximately 55-degree) fault. Both bedrock units dip to the southeast at an average of 9 degrees.

The Point Lookout Sandstone consists of siltstone with interbedded sandstone and minor shale (USBR, 1990). The Menefee Formation consists of massive sandstone and shale, with beds of carbonaceous shale and coal. The fault contains up to 1 ft (0.3 m) of clayey gouge.

Before site remediation, unconsolidated surficial deposits in the raffinate pond area consisted of colluvium from the slope of Smelter Mountain, glacial outwash, and recent river alluvium (USBR, 1990). The surficial deposits were 20 to 30 ft (6 to 10 m) thick in the area of the ponds. As much as 20 ft (6 m) of surficial deposits were removed during site remediation. The remaining surficial material was mixed during remediation activities and now is a mixture of clayey sands, gravels, and cobbles.

2.2.3 Hydrology

Ground water

Ground water below the raffinate pond area is recharged by infiltration of precipitation and by ground water moving through the bedrock from the west. Ground water flow in the Point Lookout Sandstone and Menefee Formation is mostly through open bedding planes and joints (USBR, 1990). The fault cutting the bedrock reportedly is fairly transmissive, with the potential to transmit ground water.

It also is likely that surface water flowing down South Creek during wet times may infiltrate the surficial deposits and recharge the ground water, as evidenced by the large fluctuations of the ground water levels in monitor well 607. Infiltration from South Creek may enter the fault also. The USBR reports that water levels are above the bedrock/surficial deposit contact at some locations during wet times.

Ground water flows toward the Animas River with an average gradient of approximately 3 percent. An April 1990 ground water contour map is shown in Figure 2.4. This map was prepared by the USBR before site remediation. The number of suitable wells limits construction of a current ground water contour map, but flow conditions are expected to be similar.

Hydraulic conductivity tests performed in the surficial deposits, Menefee Formation, Point Lookout Sandstone, and fault zone resulted in computed average hydraulic conductivities of 22 ft/day (8×10^{-3} cm/s) in the alluvium (DOE, 1991), 0.2 ft/day (8×10^{-5} cm/s) in both the Menefee Formation and Point Lookout Sandstone (USBR, 1990), and 0.8 ft/day (0.3×10^{-3} cm/s) in the fault (USBR, 1990).

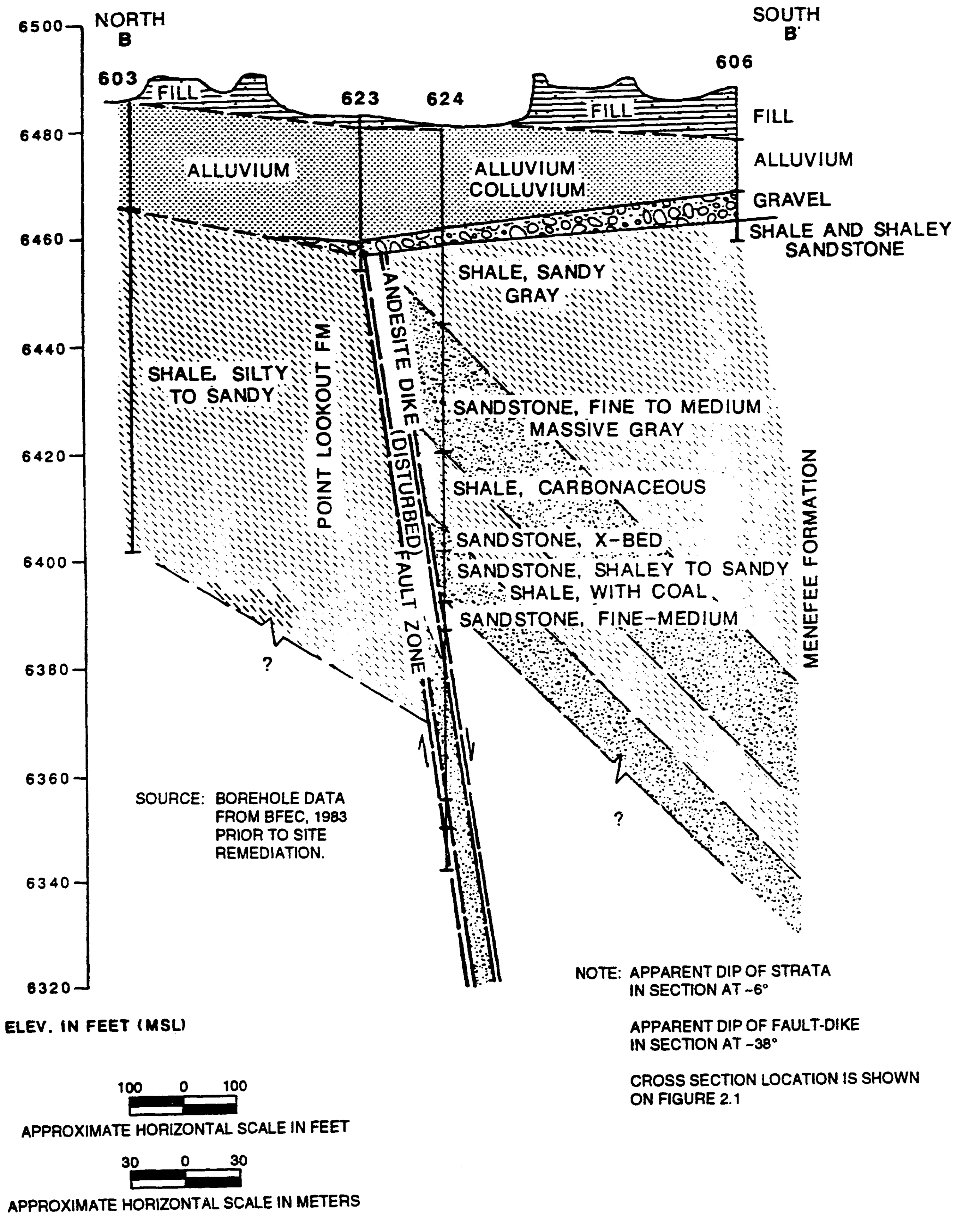
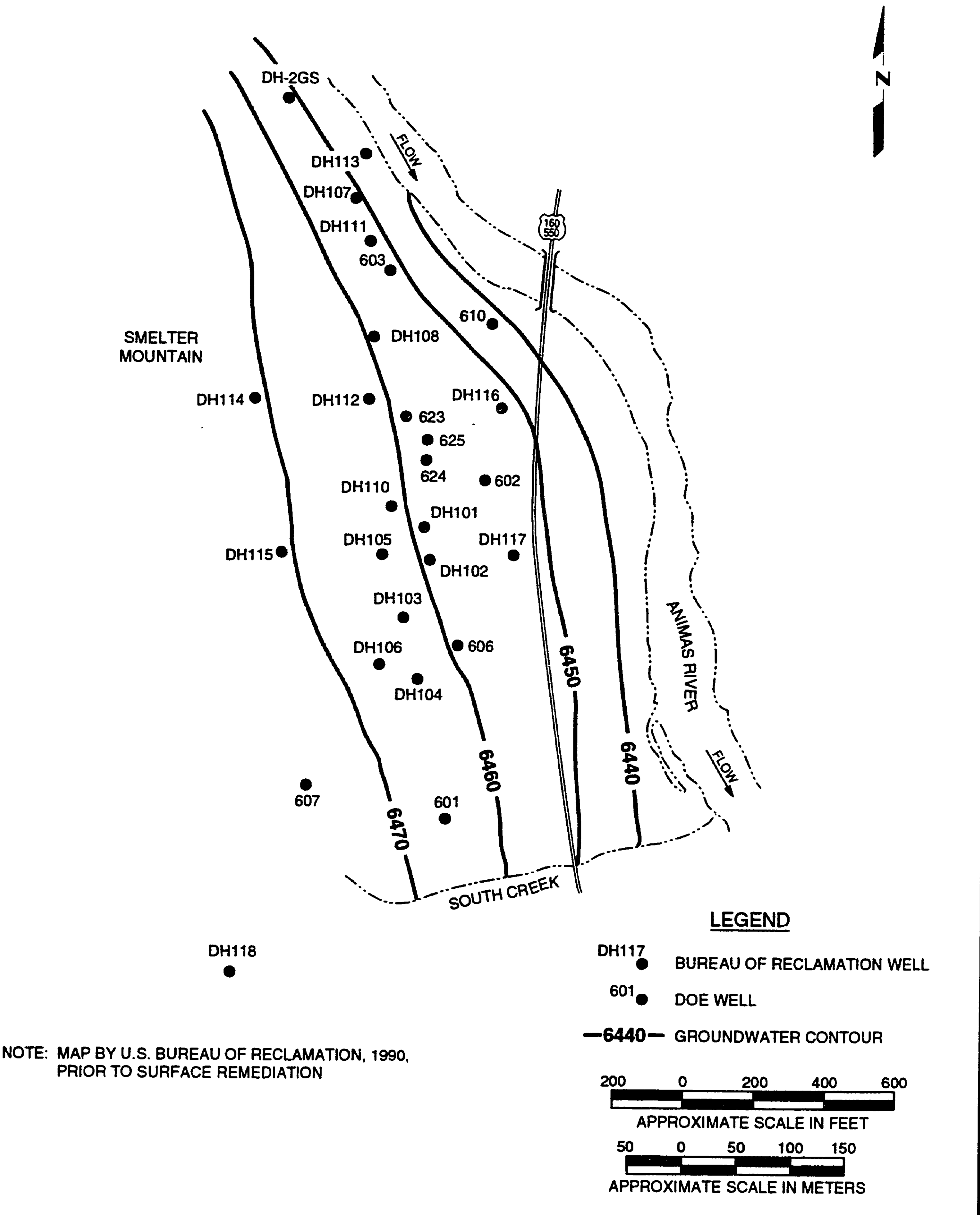


FIGURE 2.3
GEOLOGIC CROSS SECTION (B - B') OF FORMER RAFFINATE POND AREA
DURANGO, COLORADO



NOTE: MAP BY U.S. BUREAU OF RECLAMATION, 1990, PRIOR TO SURFACE REMEDIATION

REF: USBR, 1990

FIGURE 2.4
APRIL 1990 GROUND WATER CONTOUR MAP
RAFFINATE POND AREA, DURANGO, COLORADO

MAC: SITE/DUR/WSAP/GWCONTOURMAP

Based on the gradient calculated from the ground water contours (0.03), an assumed porosity of 15 percent, and the measured hydraulic conductivities of the Menefee Formation and Point Lookout Sandstone, the ground water in the bedrock is estimated to move at a rate of approximately 15 feet per year (ft/yr) (5 meters per year [m/yr]). It will move approximately 75 ft/yr (22 m/yr) in the fault, assuming the same gradient. Ground water in the alluvium during wet times could move approximately 800 ft/yr (240 m/yr) if the bedrock surface has approximately the same slope as the ground water gradient and the porosity is approximately 30 percent.

Surface water

The Animas River runs along the eastern edge of the northern half of the raffinate pond area downstream of the mill/tailings site. No tributaries enter the Animas River between the two sites, but the outfall from the Durango municipal wastewater treatment plant is located at the north end of the raffinate pond area. This plant discharges approximately 2 million gallons per day (8 million liters per day).

South Creek along the southern edge of the raffinate pond area is the lower end of the arroyo along the north side of the Bodo Canyon disposal site. This creek is dry except during heavy rainfall events and wet times and when treated water is released from the toe drain collection pond at the disposal cell. South Creek joins the Animas River approximately 1000 ft (300 m) east of the raffinate pond area.

2.2.4 Water quality

Background water quality

Monitor well 607 (Figure 1.2) is used as a background water quality well in Menefee bedrock at this location. The water in this well is of a mixed sodium-calcium-sulfate type with TDSs ranging from approximately 1800 to 4900 mg/L, pH ranging from 6.6 to 8.3, and a redox potential of approximately 250 millivolts (mV). Of the constituents with MCLs, cadmium, molybdenum, net gross alpha, and selenium exceeded their respective MCLs at least once since 1987, although exceedances for cadmium, chromium, and molybdenum have not occurred since 1988.

Potentially hazardous constituents without MCLs that exceeded detection limits are antimony, barium, mercury, nickel, tin, vanadium, and zinc. For antimony, barium, mercury, nickel, and vanadium, the exceedances are not considered significant because they have not been repeated in additional sampling rounds. Monitor well 607 has shown large fluctuations in water levels, and may receive recharge from South Creek.

The data from two USBR background wells in the Point Lookout Sandstone (monitor wells 599 and 600) have been received and will be reviewed. These wells will also be sampled during FY1994.

Contaminant plume

Of the potentially hazardous constituents with MCLs, arsenic, cadmium, chromium, molybdenum, net gross alpha, selenium, and uranium have exceeded their MCLs in monitor well 602 several times since 1987. Lead exceeded its MCL once.

The potentially hazardous constituents without MCLs that were reported above detection limits include antimony, nickel, silver, sulfide, thallium, tin, vanadium, and zinc. The exceedances for nickel, sulfide, vanadium, and zinc, however, were not supported by the results of additional sampling rounds from these wells.

Several constituents, including antimony, arsenic, cadmium, lead, molybdenum, net gross alpha, Ra-226 plus Ra-228, selenium, sulfate, and uranium, appear to show trends of decreasing concentrations from their maxima that may indicate natural flushing of contaminated water from the system. Figures 2.5 and 2.6 show the concentration plots for sulfate and uranium, respectively.

Surface water samples

The DOE has not collected surface water samples along the Animas River bordering the raffinate pond area. The USBR collected samples upstream of the raffinate pond area and downstream of the outfall from the municipal sewer plant, but not adjacent to or immediately downstream of the raffinate pond area.

Samples have not been collected from South Creek to assess the water quality that may be joining the ground water entering background well 607. However, water that has been periodically discharged from the toe drain along the disposal cell at the Bodo Canyon disposal site since fall 1989 has been analyzed. This water enters South Creek and, if there is sufficient quantity, can reach the raffinate pond area. The water could recharge background well 607. Surface water and sediment samples will be collected during FY1994.

2.2.5 Site conceptual model

Seepage from the former raffinate ponds impacted the soils, bedrock, and ground water in the area. The ponds and much of the contaminated soil have been removed from the site. No active ground water remediation has been undertaken, although fresh water continuously flushes beneath the site.

Ground water is expected to move beneath the site to discharge into the Animas River. Contaminants from the former operations will move with the ground water toward the discharge points.

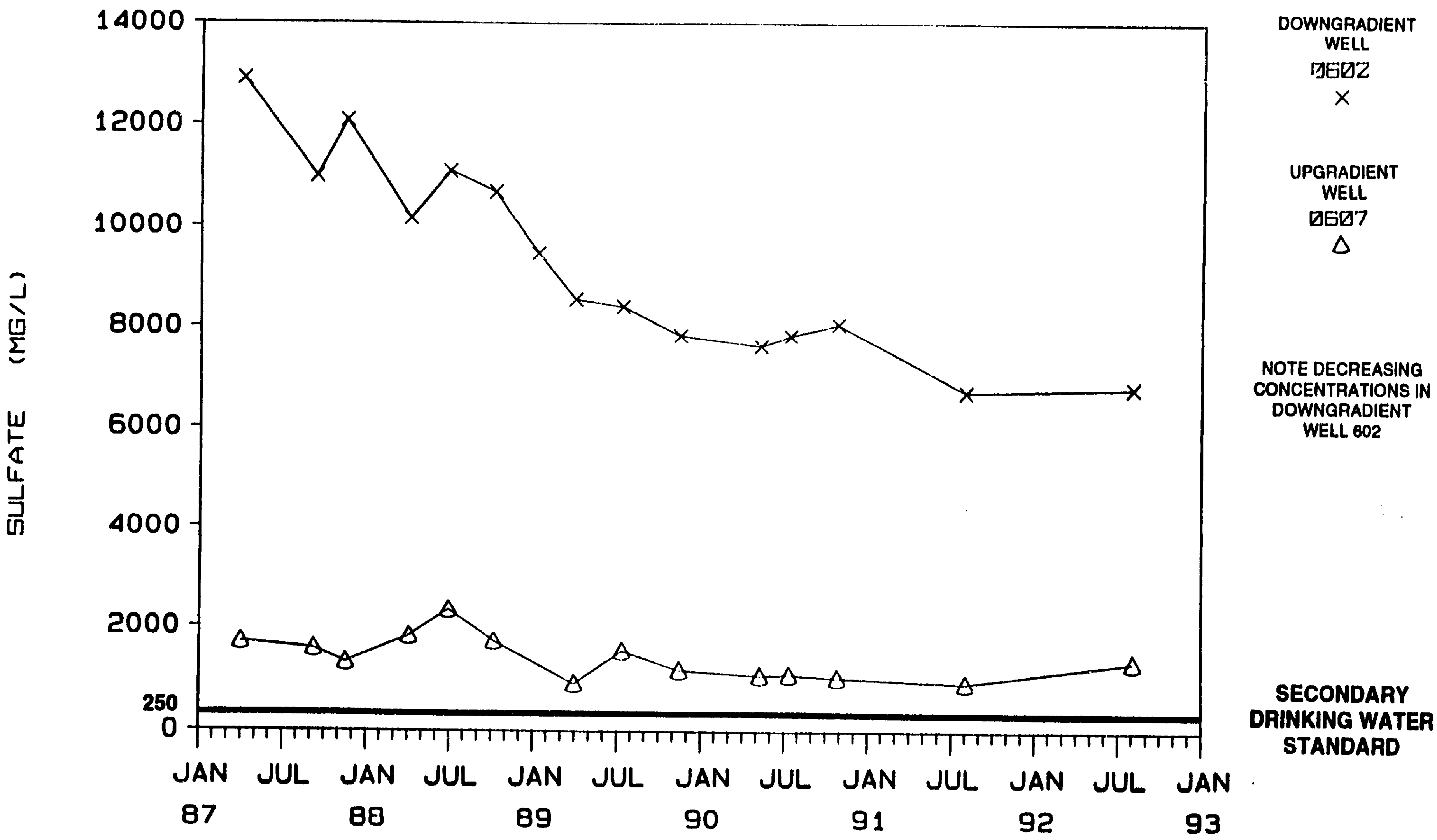


FIGURE 2.5
SULFATE CONCENTRATIONS VERSUS TIME
RAFFINATE POND AREA, DURANGO, COLORADO

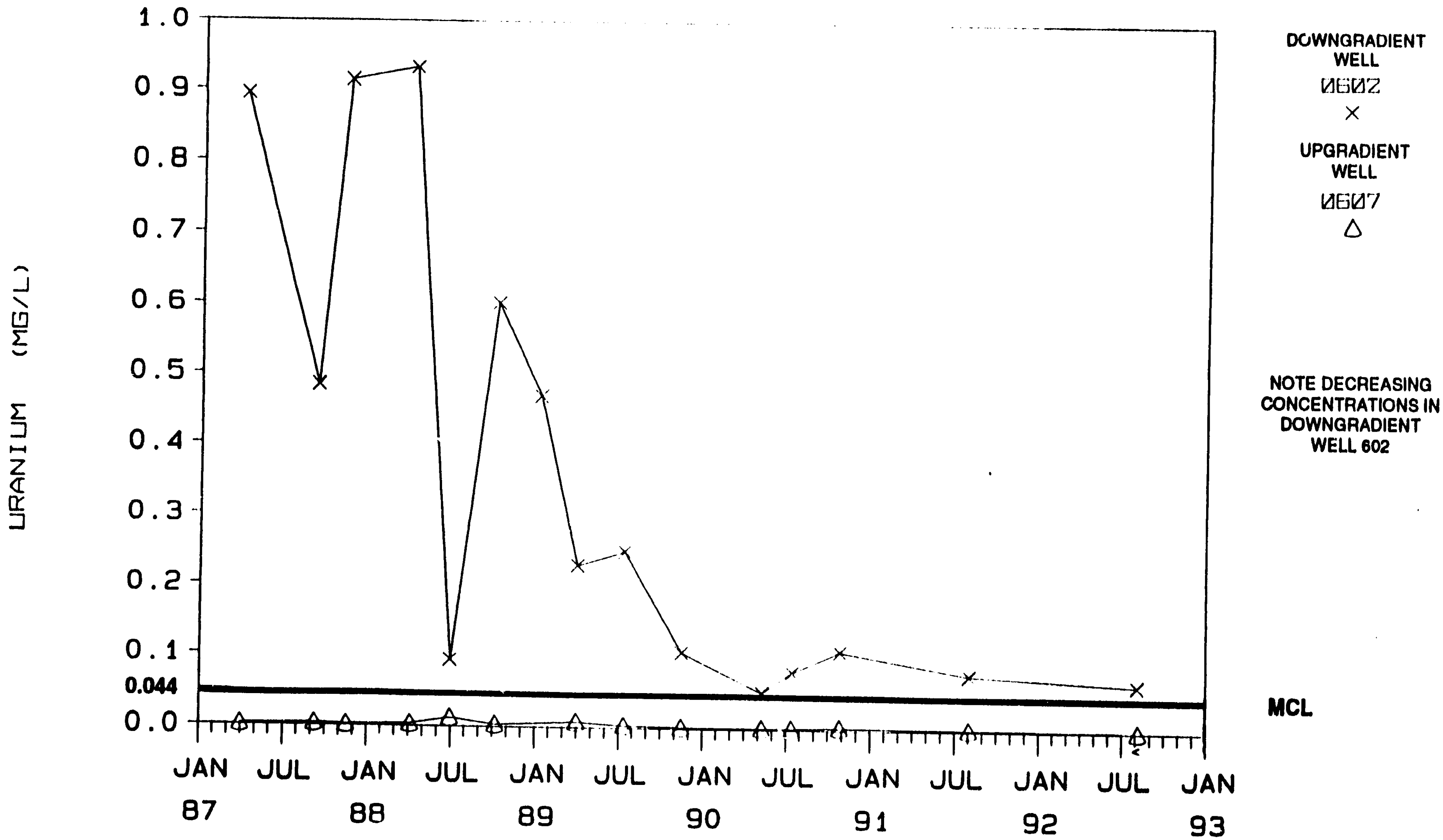


FIGURE 2.6
URANIUM CONCENTRATIONS VERSUS TIME
RAFFINATE POND AREA, DURANGO, COLORADO

The criteria used for removing contaminated soils from the site were based on health exposures to wind-borne soils and radon standards for air emissions. As at the mill/tailings site, the risks associated with contaminated ground water relate to potential future land use and ground water discharge to the Animas River.

2.3 BODO CANYON DISPOSAL SITE

2.3.1 Physiographic setting

The Bodo Canyon disposal cell is located in a southwest-to-northeast trending valley. Before installation of the disposal cell, the elevation of the valley ranged from a high of approximately 7190 ft (2190 m) above MSL near the western end of the property to a low of approximately 7020 ft (2140 m) MSL at the extreme northeastern corner of the site (Figure 2.7). The valley is bordered on both the northern and southern flanks by bedrock-supported ridges Figure 2.8. The northern ridge is more than 7160 ft (2180 m) high, and the southern ridge is more than 7100 ft (2160 m) high. The elevation of the top of the disposal cell is approximately 7145 ft (2175 m) MSL. Eastward-flowing arroyos to the north and south of the two flanking ridges are dry during much of the year.

2.3.2 Geology

The bedrock underlying the Bodo Canyon disposal site and supporting the ridges north and south of the canyon is Cliff House Sandstone (CGS, 1981). The bedrock dips to the southeast at approximately 9.5 degrees.

The Cliff House Sandstone is approximately 200 ft (60 m) thick and contains two distinct units. The lower unit, which includes about 110 ft (34 m) of interbedded siltstone and sandstone with sandstone beds up to 3 ft (1 m) thick, supports the ridge north of the disposal cell and outcrops in the arroyo south of the south-flanking ridge. The upper unit of the Cliff House sandstone is more shaley and contains fewer and thinner sandstone beds. This unit is approximately 90 ft (30 m) thick and supports the southern ridge.

The Cliff House Sandstone is underlain by the Menefee Formation, which is between 250 and 350 ft (90 and 120 m) thick. The Menefee Formation appears at the ground surface only in the arroyo at the extreme northeast corner of the site. Contact between the lower unit of the Cliff House Sandstone and the Menefee Formation is distinguished primarily by coal and carbonized fragments in the Menefee. Otherwise, the gross lithologies of the two formations are very similar.

A paleochannel in the lower unit of the Cliff House formation runs down the axis of valley occupied by the Bodo Canyon disposal cell, from southwest to northeast (Figure 2.9). The paleochannel contains approximately 50 ft (15 m) of alluvium consisting of silty clay, silt, and sand with some sandstone and

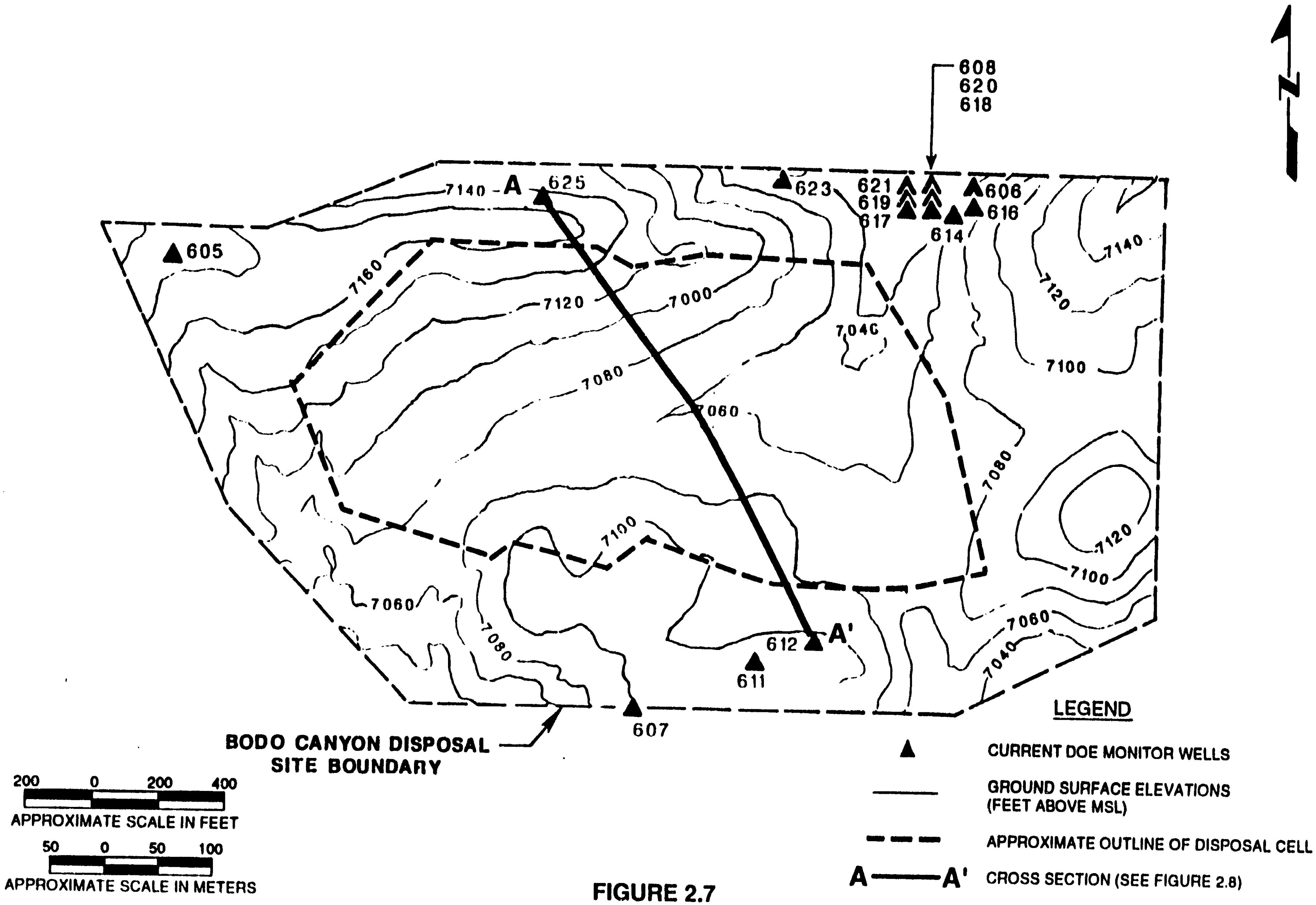
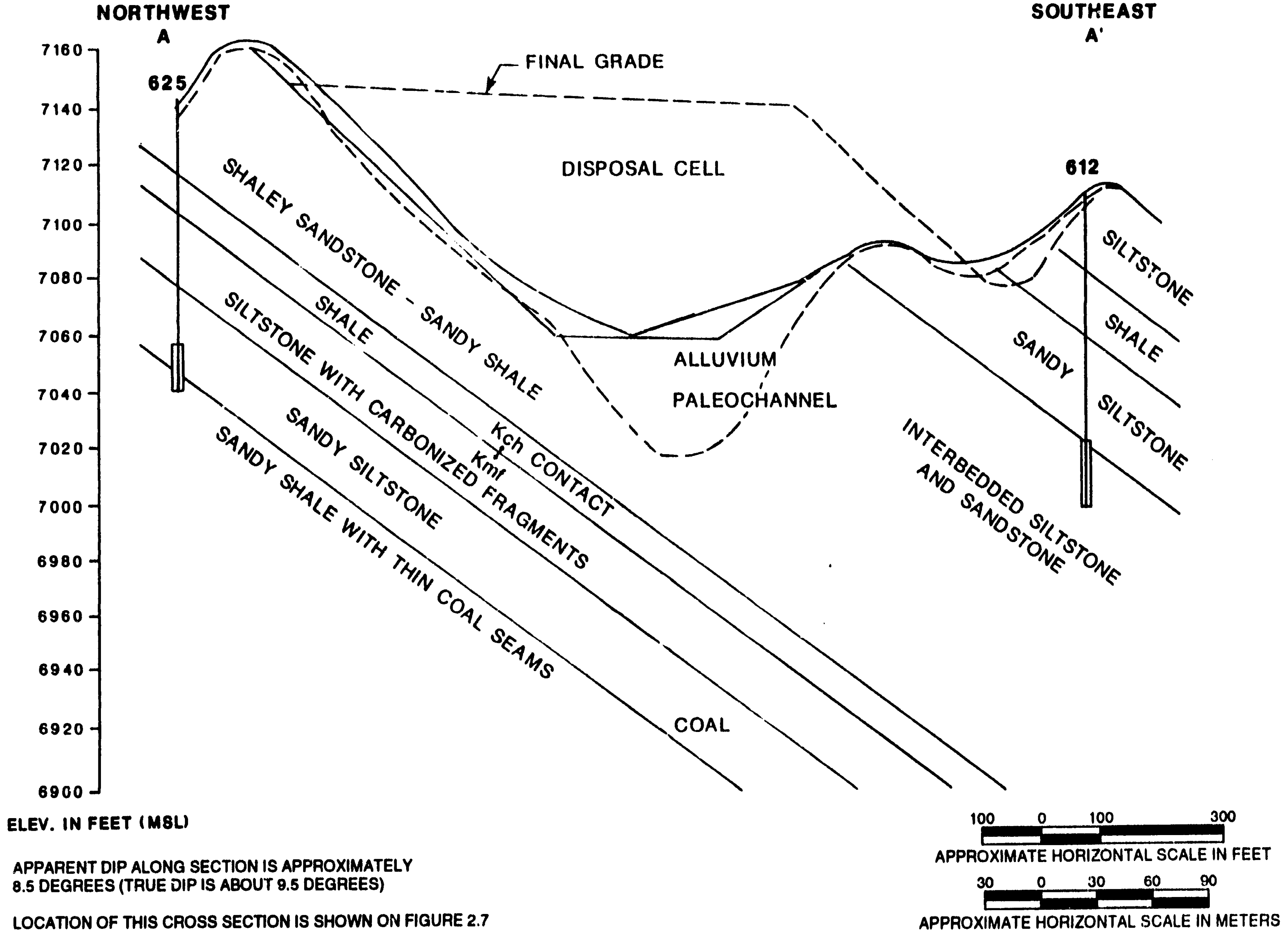


FIGURE 2.7
LOCATIONS OF MONITOR WELLS AND TOPOGRAPHIC MAP
BODO CANYON DISPOSAL SITE, COLORADO



NOTES: APPARENT DIP ALONG SECTION IS APPROXIMATELY 8.5 DEGREES (TRUE DIP IS ABOUT 9.5 DEGREES)

LOCATION OF THIS CROSS SECTION IS SHOWN ON FIGURE 2.7

Kch = CLIFFHOUSE FORMATION
Kmf = MENEFEE FORMATION

FIGURE 2.8
SCHEMATIC CROSS SECTION (A - A')
BODO CANYON DISPOSAL SITE, COLORADO

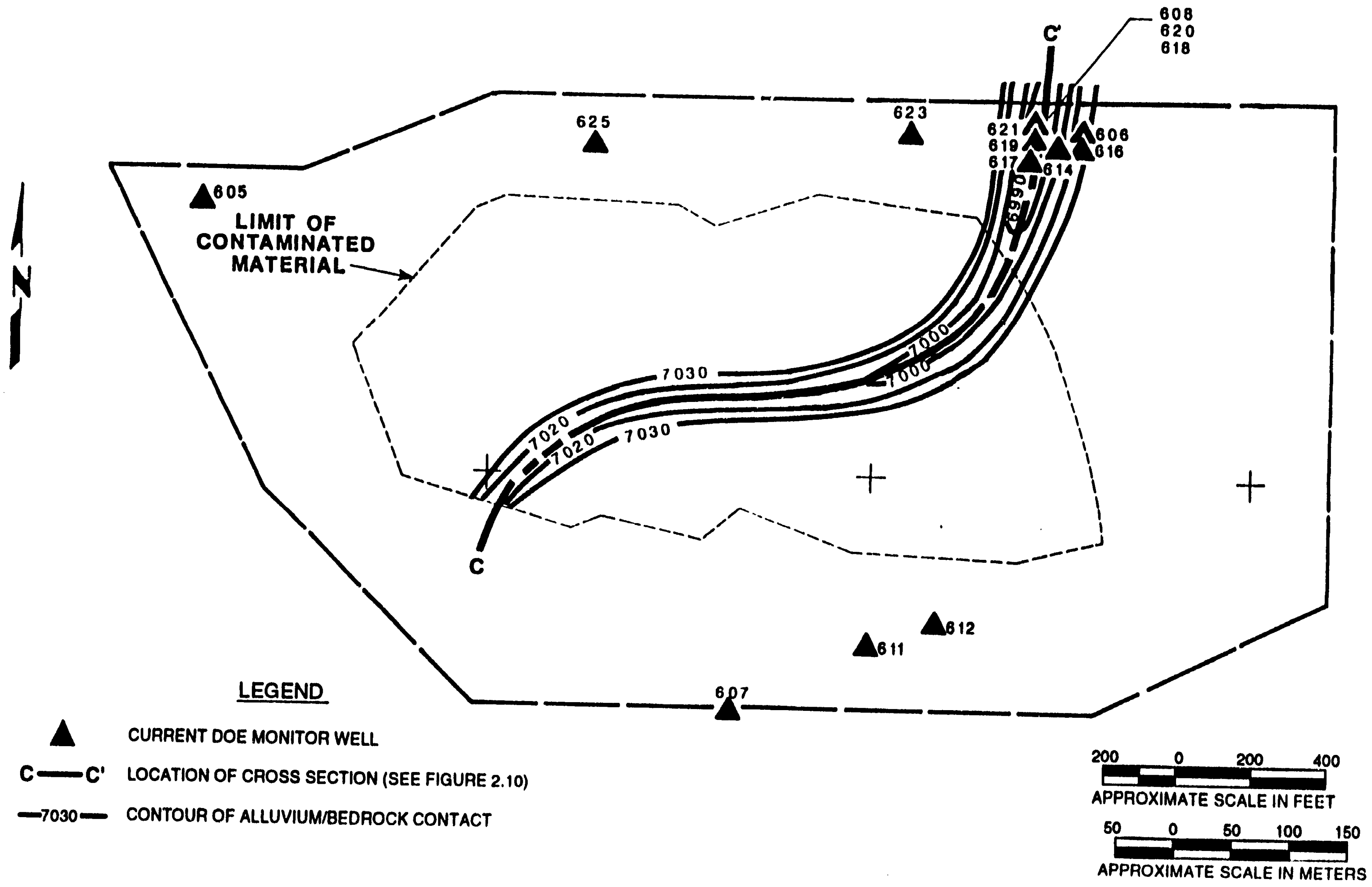


FIGURE 2.9
PALEOCHANNEL ALIGNMENT BELOW CELL AREA, EXISTING DOE MONITOR WELLS, AND LOCATION OF CROSS SECTION (C - C') BODO CANYON DISPOSAL SITE, COLORADO

shale fragments (Figure 2.10). This alluvium thins and is absent along the sides of the ridges north and south of the disposal cell (Figure 2.8). The paleochannel joins the eastward-flowing arroyo north of the disposal cell.

2.3.3 Hydrology

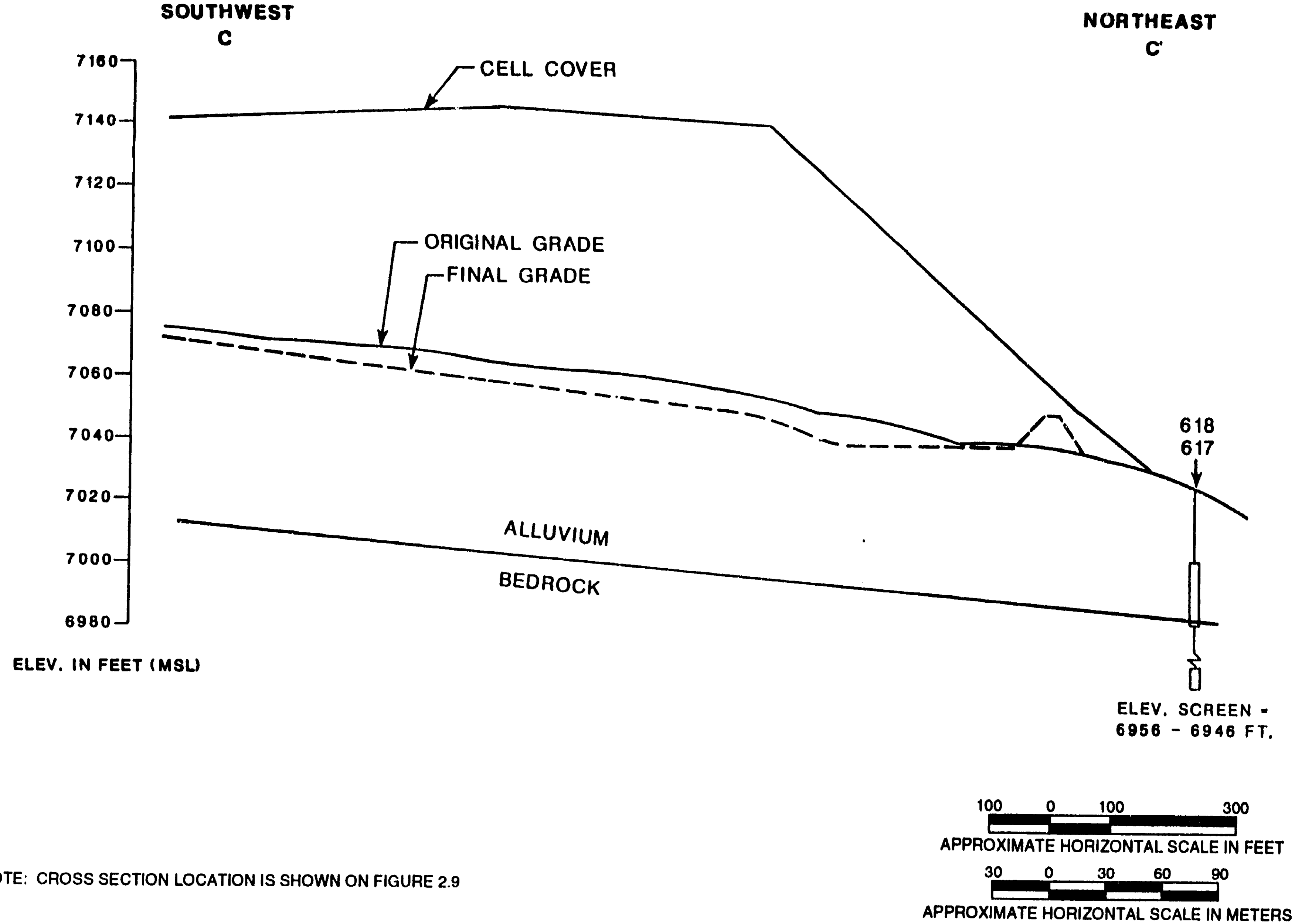
Ground water

Alluvium. Shallow ground water occurs within the alluvium in the bottom of the valley. The depth to ground water before construction of the disposal cell varied seasonally. During the wet season, ground water was at or near the ground surface.

Hydraulic conductivity tests on the shallow alluvium near the middle of the valley averaged approximately 0.13 ft/day (5.0×10^{-5} cm/s) although an aquifer test performed in monitor well 608 near the confluence of the paleochannel and the north arroyo gave a value of 32 ft/day (10 m/day). This test was conducted in a loose, coarser-grained deposit. Assuming a porosity of 0.25 and a gradient of 0.003 down the center of the valley, the rate of ground water movement to the northeast will vary from approximately 0.6 ft/yr (0.2 m/yr) near the middle of the valley to about 140 ft/yr (40 m/yr) near the northeast end of the valley.

The disposal cell fills more than 85 percent of the original valley (Figure 2.7). During disposal cell construction, the alluvium was shaped and compacted with additional imported silty clay and clay soil to form a low-permeability base for the disposal cell to restrict the downward migration of contaminants. This compacted layer, combined with the extremely low permeability radon and infiltration barriers on the top of the cell, will prevent precipitation and snowmelt from percolating through the cell into the subsurface and recharging the ground water. As a result, the alluvium is expected to become dewatered with time.

Bedrock. Ground water elevations measured in monitor wells drilled into the bedrock beneath the cell before its construction and into the bedrock north, south, and east of the cell do not clearly identify a piezometric surface, flow direction, or gradient. Ground water relatively near the land surface (within 100 ft [30 m]) apparently occurs in different layers within the bedrock and these ground water bodies may have limited areal extent. Recharge of the near-surface ground water in the bedrock is probably only from local precipitation and is unrelated to the deeper, regional flow regime. Ground water in the shallow bedrock appears to flow both southeast, downdip of the bedrock, and northeast, down the strike of the valley in the same direction as the ground water in the alluvium.



NOTE: CROSS SECTION LOCATION IS SHOWN ON FIGURE 2.9

FIGURE 2.10
SCHEMATIC CROSS SECTION (C - C')
BODO CANYON DISPOSAL SITE, COLORADO

Surface water

Arroyos are located north and south of the Bodo Canyon disposal site. Both arroyos are dry except after periods of heavy rainfall and during wet times. At those times, both arroyos flow from west to east and empty into the Animas River south of the raffinate pond area. The arroyo north of the disposal cell becomes South Creek in the raffinate pond area. This arroyo also receives periodic discharge from the pond that collects water from the toe drain along the eastern edge of the disposal cell.

2.3.4 Water quality

Background water quality wells

Before construction of the disposal cell, all wells at the disposal site were considered background wells. Analytical data indicate background water quality is different in the alluvium and the bedrock. Variations also occur in the bedrock water quality.

The alluvial aquifer is a calcium-sulfate water quality type as represented by monitor wells 606, 608, and 623. Water quality in the bedrock units ranges from a sodium-calcium, sulfate-bicarbonate water at relatively shallow depths (probably in the Cliff House Formation in such monitor wells as 605 and 607), to a sodium bicarbonate water at intermediate depths (e.g., monitor wells 611, 612, 625, and 621), to a sodium-sulfate type in the deepest well (former monitor well 603).

The TDSs in upgradient alluvial monitor well 623 ranged from approximately 2200 to 2500 mg/L, pH ranged from 7.0 to 7.5, and the redox potential was measured at 186 mV. Of the constituents with MCLs, only molybdenum and Ra-226 plus Ra-228 have exceeded their MCLs. Molybdenum concentrations exceeded the MCL once in 1990 with a concentration of 0.2 mg/L. Ra-226 plus Ra-228 exceeded the MCL once in 1989 with an activity of 35.4 picocuries per liter. Subsequent analyses did not confirm these exceedances. Potentially hazardous constituents without MCLs were generally at or below detection limits except for sulfide, tin, vanadium, and zinc. Tin exceeded detection limits three times. Vanadium and sulfide exceeded detection limits only two times. Zinc exceeded detection limits four times and appears to be generally elevated in background waters at the site.

In upgradient bedrock well 605, TDSs ranged from approximately 1900 to 3600 mg/L, pH ranged from 6.6 to 7.1, and the measured redox potential ranged from 218 to 769 mV. In bedrock well 625, which is also upgradient of the disposal cell, the measured TDSs ranged from approximately 900 to 1300 mg/L, the pH ranged from 7.6 to 8.0, and the redox potential ranged from approximately 150 to 260 mV.

The TDSs in downgradient bedrock wells 607, 611, and 612 to the southeast of the cell ranged from approximately 1000 to 5500 mg/L, pH ranged from 5.5 to 7.8, and the redox potentials ranged from approximately 140 to 440 mV.

Of the constituents with MCLs, selenium and uranium exceeded their MCLs. Selenium exceeded its MCL in upgradient bedrock well 605 three times since 1987, with concentrations up to 0.042 mg/L. Uranium concentrations exceeded the MCL one time in well 625, at a concentration of 0.077 mg/L.

Potentially hazardous constituents without MCLs were generally at or below detection limits except for antimony, sulfide, tin, vanadium, and zinc. Antimony and tin exceeded detection limits one time each, but subsequent analyses did not confirm these exceedances. Vanadium and zinc exceeded their detection limits several times in each well, with concentrations up to 0.04 mg/L for vanadium and 0.11 mg/L for zinc.

Surface water and sediment sampling locations

No surface water or sediment samples have been collected at the Bodo Canyon site, except from the toe drain.

2.3.5 Site conceptual model

The disposal cell is designed to limit the amount of infiltrating precipitation. Transient drainage from the tailings is collected in a toe drain and treated.

The cell has decreased the amount of infiltrating water and, with time, the alluvium will become dewatered. The unsaturated zone will attenuate any seepage from the bottom of the cell, reducing the amount of water moving into the alluvium and underlying bedrock.

Any leachate that does reach the ground water in the bedrock will be mixed with and diluted by the natural ground water moving in the rock below the cell. As a result, no ground water contamination should be detected in the POC wells to the southeast or northeast of the cell.

3.0 DATA COLLECTION OBJECTIVES

3.1 REGULATORY REQUIREMENTS

The Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (42 USC §7901 *et seq.*) establishes the statutory and regulatory framework for the stabilization and control of 24 inactive uranium mill tailings sites (Title I sites). Through UMTRCA, the U.S. Environmental Protection Agency (EPA) is directed to establish general regulations and standards for the cleanup and disposal of contamination at the sites.

In 1987, the EPA published proposed revised ground water regulations (52 FR 36000 [1987]). The proposed regulations and standards call for DOE to demonstrate control of specific constituents in the ground water. These constituents are identified in three sources: 1) Table A from 52 FR 36000 (1987), 2) Table 1 of 40 CFR §264.94 (1987), and 3) Appendix IX of 40 CFR Part 264 (1987). Maximum concentration limits (MCLs) are established for the constituents listed in Table A and Table 1 referenced above. Hazardous constituents listed in these sources identified from the characterization of the tailings materials or associated with the former milling operations were selected as constituents to be analyzed in the ground water samples to show compliance with the proposed standards. These constituents are listed on Tables 1.1 and 5.1.

3.2 COMPLIANCE MONITORING

To achieve compliance with the proposed EPA ground water protection standards (52 FR 36000 [1987]) at the Bodo Canyon disposal site, the DOE proposes meeting background concentrations or the MCLs for hazardous constituents in ground water in the uppermost aquifer at the POC. The DOE will comply with the published proposed standards until the final standards are in effect.

Data collection objectives focus on the early detection of contaminant leakage from the disposal cell through a screening-monitoring program. This program consists of regular sampling at POC wells and a background well for contaminants of concern. The selection of monitor well locations, analytes, and monitoring frequency for cell performance assessment is discussed in detail in Section 5.0, Sampling Plan.

An LTSP is in preparation for the Durango disposal site. Compliance monitoring will be addressed further in that report.

The ground water monitoring program will be implemented and carried out over a specified period of time that is adequate to demonstrate that the performance of the disposal cell complies with the design requirements.

3.3 SITE CHARACTERIZATION

3.3.1 Mill/tailings site and raffinate pond area

Ground water monitoring will continue at the mill/tailings site and raffinate pond area and water levels will be measured. The objectives are 1) to characterize background water quality and distinguish the contaminants related to site activities from the naturally occurring constituents and concentrations, and 2) to calculate the rate of discharge of contaminated ground water into Lightner Creek and the Animas River. Site characterization will provide information needed to evaluate the potential risks to human health and the environment and to evaluate remedial alternatives.

3.3.2 Bodo Canyon disposal site

Site characterization at the Bodo Canyon disposal site is complete.

3.4 RISK ASSESSMENT CONSIDERATIONS

3.4.1 Mill/tailings site and raffinate pond area

The primary concerns for health and environmental risks at the former Durango mill/tailing site and raffinate pond area are associated with the potential for discharge of contaminated ground water to Lightner Creek and the Animas River. The Animas River is heavily used for recreational purposes. A city park is located across the river from the raffinate pond area, and the full length of this stretch of the river is frequently used for whitewater kayaking and rafting during the spring and early summer.

In addition to recreational usage, the USBR is considering the feasibility of locating the intake and pump station for the Animas/La Plata irrigation project in the vicinity of the raffinate pond area. Water and sediment samples taken along the courses of Lightner Creek and the Animas River will be compared to water and sediment quality from upriver samples to assess the impacts of ground water discharges and resulting potential risks to human health or the river ecosystem.

In addition to evaluating the potential risks to surface waters, the health and environmental risks associated with future possible ground water use at the mill/tailings site and the raffinate pond area must be evaluated. More data were acquired to establish background water quality by sampling additional wells drilled in the fall of 1993 and by reviewing data from USBR site assessment related to the Animas/La Plata project. The USBR has analyzed data from surface samples and fish tissue samples. If these data are consistent with data collected under UMTRA SOPs, the combined data base should allow high confidence in the assessment of this site.

Finally, although USBR and Technical Assistance Contractor (TAC) data on ground water movement indicate contaminated ground water should not cross the Animas River, businesses adjoining the site will be surveyed to verify their source of water. If any domestic use of ground water occurs, sampling those wells may be necessary.

3.4.2 Bodo Canyon disposal site

The disposal cell is designed to protect human health and the environment. As a result, risk assessment is not an applicable data collection objective.

4.0 DATA QUALITY OBJECTIVES

Data quality objectives (DQO) define the manner in which samples are collected, handled, and analyzed, including defining analytical support levels; following standard procedures for water sampling, preservation, transport, and other field procedures; performing DQOs in accordance with QA and QC protocols; and validating analytical data. DQOs that will be followed during data collection and evaluation activities are listed in the WSAP guidance document (DOE, 1993), the UMTRA QA implementation plan, and the applicable SOPs (JEG, n.d.) listed below.

- 14.5.1 "Procedures for Handling and Shipping of Geotechnical Samples"
- 16.1.6 "Soil-Water Sampler Installation and Sample Collection"
- 16.1.10 "Field Measurements for Temperature, Conductivity, pH, Alkalinity, and Total Acid"
- 16.1.11 "Sample Collection for Organic Substances"
- 16.1.13 "Field Determination of dissolved Oxygen in Water Samples"
- 16.1.14 "Field Determination of Dissolved Oxygen in Water Samples"
- 16.1.16 "Alternate Method For Determination of Dissolved Oxygen"
- 16.1.21 "Measurement of Water Turbidity"
- 16.2.1 "Sample Collection, Preservation, and Shipment of Water Samples"
- 16.2.2 "Water Sampling for Tritium Analysis"
- 16.2.4 "Sampling Radon in Water"
- 16.2.5 "Monitor Well Sampling With an Electric Submersible Pump"
- 16.2.6 "Monitor Well Sampling With a Bladder Pump"
- 16.2.7 "Monitor Well Sampling With a Peristaltic Pump"
- 16.2.8 "Quality Control Samples for Water Sampling"
- 16.2.9 "Monitor Well Sampling With a Bailer"
- 16.3.1 "Inventory and Documentation of Damage and Repair of UMTRA Project Wells"

The sequence in which water quality samples will be collected is prioritized so the least contaminated samples are collected first and the most contaminated samples are collected last. Sampling locations and sequences are discussed in Section 5.0, Sampling Plan.

5.0 SAMPLING PLAN

5.1 SAMPLING LOCATIONS

5.1.1 Mill/tailings site

Ground water samples

Filtered and nonfiltered ground water samples will be collected from existing DOE monitor wells DUR01 612, 617, 622, and 629 (Figure 1.2). Monitor wells 612 and 617 are downgradient of the former mill site and the tailings piles. Well 629 is a newly installed background well at the north end of the terrace along the south side of Lightner Creek. The sample from this well will indicate the background ground water quality along the interface of the unconsolidated surficial material and the bedrock. Well 622 is in the terrace gravels along Lightner Creek downgradient of one of the tailings piles. The water in this well may contain some constituents from past activities at the site, but it also will be indicative of the water from Lightner Creek that enters the alluvium.

Based on existing water quality data, these wells should be sampled in the following order, from least contaminated to most contaminated: 629, 622, 617, and 612.

QA/QC samples will include a duplicate, a field blank, and an equipment blank taken at monitor well 612.

Surface water and sediment samples

Surface water and sediment samples will be collected at five locations at the mill/tailings site (Figure 1.2):

- Two locations on Lightner Creek. One upstream of the northwest corner of the property (656) and the other just upstream of the confluence with the Animas River (651); these samples will be compared to measure impacts to the creek from the discharge of ground water beneath the former tailings piles.

- One location on the Animas River just upstream of the confluence with Lightner Creek (694), to measure the water quality upstream of the UMTRA site.

- One location on the Animas River just downstream of the confluence with Lightner Creek (695), to measure the quality of the Animas River, including flow from Lightner Creek, at the upstream end of the site.

- One location on the Animas River at the downstream end of the mill/tailings site (696), to measure changes in river quality from the upstream end to the downstream end of the site.

5.1.2 Raffinate pond area

Ground water

Filtered and nonfiltered ground water samples will be collected from monitor wells DUR02 602, 607, and 628. In addition to the DOE wells, three USBR monitor wells (DH110, DH114, and DH115) will be sampled and numbered DUR02 598, 599, and 600, respectively. Monitor well 607 is a background well screened in the Menefee Formation. Well 628 is downgradient of the former pond area. Monitor well 602 is downgradient of the former pond area near well 628. It has been retrofitted with a packer to allow sample collection from the lower screen.

Wells 599 and 600 (DH114 and DH115) are background wells in the Point Lookout Sandstone. Monitor well 598 (DH110) is screened within the fault zone and is the most contaminated well.

The USBR has sampled their wells approximately quarterly since May 1990 and have collected a substantial amount of data. Sampling these wells will permit comparison with USBR analyses to determine if their data can be incorporated into the site assessment.

The wells will be sampled in order of anticipated increasing contamination: 607, 599, 600, 602, 628, and 598.

No QA/QC samples are needed from the raffinate pond area because these samples will be collected during the same sampling round as those at the mill/tailings site and are therefore within the 20 QA/QC sample requirements.

Surface water and sediments

Filtered and nonfiltered surface water samples and sediment samples will be collected at three locations in the raffinate pond area (Figure 1.2).

- One location (657) on the Animas River at the upstream end of the raffinate pond area and downstream of the sewer treatment plant will be sampled to measure the change in water quality between the mill/tailings site and the beginning of the raffinate pond area.
- One location on the Animas River downstream of the raffinate pond area and immediately upstream of the confluence with South Creek, flowing from the west along the south end of the raffinate pond area (654), will be sampled to measure changes in water quality along the stretch of the river bordering the raffinate pond area.

- One location in South Creek (653) will be sampled if there is sufficient water. Water from this creek seeps into the ground and could affect the water quality in monitor well 607 that is used as the upgradient, background water quality well for the raffinate pond area (water levels in monitor well 607 fluctuated by as much as 12 ft [4 m], far more than the other wells) and/or into the fault that transects the raffinate pond area and could reach monitor well 598 (DH110). If this creek is dry in October 1993, attempts will be made to collect a water sample later in FY1994.

5.1.3 Bodo Canyon disposal site

Ground water samples

Filtered ground water samples will be collected from monitor wells DUR03 605, 606, 607, 608, 611, 612, 614, 618, 620, 621, 623, and 625 (Figure 1.3); samples will be collected first from upgradient monitor wells 605, 625, and 623.

QA/QC samples, including a duplicate sample, a field blank, and an equipment blank, will be collected from monitor well 608.

Surface water and sediment samples

Surface water and sediment samples will not be collected at the Bodo Canyon disposal site.

Seepage from disposal cell

Seepage thought to be from the disposal cell was seen in the bottom of Ditch No. 1 along the cell toe. This water does not discharge from the end of the ditch, but appears to seep back into the ground. Water also was seen in the north arroyo at the northeast corner of the site. This water may be the seepage reappearing.

This water may be coming from the drainage layer above the radon barrier on top of the cell. To determine the source of this water, small catchments will be dug in the bottom of the ditch and the arroyo to collect water samples. Both filtered and nonfiltered samples will be collected and analyzed.

5.2 CONSTITUENT SELECTION

5.2.1 Ground water

Constituents to be sampled were identified on the basis of 1) their presence in tailings pore fluids or ground water at concentrations above MCLs or above background for hazardous constituents without MCLs; 2) usefulness as indicator parameters of plume location, movement, and cell performance; and

3) usefulness for overall water chemistry modeling, and data validation purposes. These constituents are listed in Table 5.1.

Standard field parameters, including pH, alkalinity, dissolved oxygen, specific conductivity, temperature, and oxidation/reduction potential will be measured in each monitor well.

Ground water samples from the mill/tailings site, the raffinate pond area, and the disposal site will be analyzed for the analytes listed in Table 5.1.

5.2.2 Surface water and sediments

Filtered and nonfiltered surface water samples and sediment samples will be analyzed for the analytes listed in Table 5.2.

5.3 WATER LEVEL MEASUREMENTS

Ground water levels will be measured in each well before purging, periodically during purging (at 1- to 5-minute intervals depending on rate of drawdown), and periodically as water levels recover after purging. Purging the wells with a submersible pump will be attempted. The pumping rate will be measured in a graduated container. If a well is pumped dry, the rate of recovery will be measured.

Water level elevations will be measured in the six piezometers at the mill/tailings site (monitor wells 630 to 636). The surface elevations of Lightner Creek and the Animas River will be measured at bench marks located along Lightner Creek (BM-1 and BM-2) and the Animas River (BM-3, BM-4, and BM-5) shown on Figure 1.2. Water surface elevations will be calculated by measuring the distance from the bench marks to the water surface and subtracting this distance from the bench mark elevation.

Water elevation data will be used to assist in delineating the ground water flow directions and gradients and the relationship between the ground water and surface water regimes. These data will be useful in evaluating whether significant quantities of contaminated ground water are discharging into Lightner Creek and the Animas River.

Comparison of the water elevations in nested piezometers 631 and 632, and the elevation of the piezometric surface below the packer in monitor well 602, will indicate the magnitude of any vertical hydraulic gradients between the deep bedrock and shallow aquifer and their relation to the surface water in the Animas River.

Water levels will be measured in each of the wells at the Bodo Canyon disposal site before, during, and after purging. Water elevations will be calculated. Wells that do not recover or seem to have anomalous water elevations should be noted.

Table 5.1 Ground water sample analyte list

Location	Well	Constituents: With MCLs	Constituents: Without MCLs[a]	Constituents: Sampled for risk assessment	Constituents: Sampled for water chemistry modeling/data validation
Mill/tailing site and raffinate pond area	DUR01 612, 617, 622, 629; DUR02 598, 599, 600, 602, 607, 628	As, Cd, Hg, Mo, NO_3, Pb, Ra-226, Ra-228, Se, U, net gross alpha	Tl, V, Zn	Mn, Pb-210, Po-210, Th-230	Ca, Cl, Fe, K, Mg, Na, SiO_2, SO_4, TDS
Bodo Canyon disposal site	DUR03 605, 606, 607, 608, 611, 612, 614, 616, 618, 620, 621, 623, 625	As, Cd, Mo, NO_3, Pb, Ra-226, Ra-228, Se, U	Co, Cu, V, Zn	Mn	Ca, Cl, Fe, K, Mg, Na, S_iO_2, SO_4, TDS

Key

As - arsenic	Mn - manganese	SiO_2 - silica
Ca - calcium	Mo - molybdenum	SO_4 - sulfate
Cd - cadmium	Na - sodium	TDS - total dissolved solids
Cl - chloride	NO_3 - nitrate	Th-230 - thorium-230
Co - cobalt	Pb - lead	Tl - thallium
Cu - copper	Pb-210 - lead-210	U - uranium
Fe - iron	Po-210 - polonium-210	V - vanadium
Hg - mercury	Ra-226 - radium-226	Zn - zinc
K - potassium	Ra-228 - radium-228	
Mg - magnesium	Se - selenium	

[a]Constituents without MCLs listed in Appendix IX, 40 CFR Part 264 (1987).

Table 5.2 Surface water and sediment sample analyte list

Location	Sample point	Analyte
Mill/tailing site		Surface water samples
Lightner Creek Animas River	DUR01 650, 651 DUR01 652, 690, 691	SO_4, Mg, Ca, NO_3, As, Cd, Fe, Pb, Mn, Hg, Mo, Se, U, Zn
Raffinate pond area		Sediment samples
Animas River South Creek	DUR02 654, 657 DUR02 653	SO_4, NO_3, As, Cd, Fe, Pb, Mn, Hg, Mo, Se, U, Zn

Note: See key to Table 1.1 for definitions.

5.4 SAMPLING FREQUENCY

The frequency with which ground water, surface water, and sediment samples must be taken at the mill/tailings site and the raffinate pond area should be determined by the rate of ground water flow and seasonal variations in the flow of Lightner Creek, the Animas River, and South Creek. Sampling frequency at the Bodo Canyon site is dictated by the LTSP for that site.

5.4.1 Mill/tailings site

Before installation of the additional wells and piezometers planned for the fall of 1993, data on the hydraulic gradient at the mill/tailings site was insufficient to predict the rate of ground water movement. Data collected during the October sampling round will provide the water level information to calculate ground water flow velocities during periods of low water levels. A second set of water level readings will be taken in the spring of 1994 when water levels are expected to be higher. These measurements will also be used to calculate the rate of ground water movement.

Similarly, infiltrating precipitation and snowmelt during the year may result in changes in water quality. Therefore, ground water samples will be collected during the spring of 1994.

5.4.2 Raffinate pond area

The predicted rate of ground water movement through the alluvium and the bedrock are approximately 800 ft/yr (240 m/yr) and 15 ft/yr (3 m/yr), respectively. To assess the effectiveness of natural flushing by this ground water movement and because of the need to develop a water quality data base for the new shallow well and reconfigured monitor well 602, the wells in this area were sampled in the fall of 1993 and will be sampled again in the spring of 1994.

5.4.3 Surface water and sediment samples

The most conservative assessments of the potential impacts of contaminated ground water on surface water quality will come from surface water and sediment samples collected during periods when the greatest percentage of stream flow can be attributed to ground water discharge. Therefore, these samples will be collected annually in the fall. If the surface water and sediment samples collected in October 1993 show contamination by ground water discharge, samples will be collected during times of higher stream flow to evaluate the significance of this impact. At this time, only one surface water and sediment sampling event is scheduled for FY1994.

5.4.4 Bodo Canyon disposal site

The draft LTSP for the disposal site describes a ground water monitoring program. This program will be conducted by the UMTRA Project Office until the disposal cell license takes effect. Ground water samples were collected in October 1993 and will be collected again in May 1994.

5.5 DATA INTERPRETATION METHODS

Interpretation of the FY 1994 data will include comparing background water quality with the contaminated water and identifying water quality trends and variations in water level elevations.

The trends in water quality at the mill/tailings site and raffinate pond area will be used to evaluate the potential for effective natural flushing at the site, the existence of remaining sources of contamination, strategies for remedial action, if needed, and the potential for risks to human health and the environment. The trends in water quality in downgradient wells at the disposal site will be used to identify the effects of water seepage from the disposal cell. Changes in the upgradient, background water quality may indicate regional water quality trends.

Water elevation data collected at the mill/tailings site and raffinate pond area will be contoured to better interpret surface and ground water interactions and the direction and rate of contaminant movement. Water level data from disposal site monitor wells will be used to assess the site ground water flow regime and to evaluate the cell cover's effectiveness in reducing infiltration into the alluvial aquifer.

5.6 RESPONSE TO ANOMALOUS DATA

If large increases or decreases in contaminant concentration are detected, several activities will be conducted to determine whether the increase indicates a significant change in water quality. Apparent increases in analyte concentrations can result from sample collection and laboratory analysis or documentation procedures, changes in background water quality, and changes in the environment that are unrelated to the former uranium processing activities or disposal cell. Activities to determine the nature and extent of an increase in concentration may include reanalysis, resampling, comparison to other geochemical parameters, and trend analysis, in accordance with SOPs 16.3.2, "Validation of Chemical Analysis Data," and 16.3.3, "Data Management." When an increase is significant and is perceived as a health threat, the TAC and DOE will consult to evaluate potential action.

6.0 LIST OF CONTRIBUTORS

The following individuals contributed to the preparation of this report.

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7.0 REFERENCES

BFEC (Bendix Field Engineering Corporation), 1983. *Preliminary Hydrogeochemical Characterization of the Durango, Colorado, Tailings and Raffinate Ponds Areas*, GJ-03(83), prepared by BFEC, Grand Junction, Colorado, for the U.S. Department of Energy, Grand Junction, Colorado.

CGS (Colorado Geological Survey), 1981. *Preliminary Report on Potential Sites Suitable for Relocation and/or Reprocessing of the Durango Uranium Mill Tailings Pile*, Open-File Report 81-1, prepared by the Colorado Geological Survey, Denver, Colorado, with assistance from Robert M. Kirkham and the Four Corners Environmental Research Institute.

DOE (U.S. Department of Energy), 1993. *Guidance Document for Preparing Water Sampling and Analysis Plans for UMTRA Sites*, final, UMTRA-DOE/AL/62350-70F, DOE UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1991. "Attachment 3, Groundwater Hydrology Report," *Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Durango, Colorado*, DOE UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1989. *Technical Approach Document*, UMTRA-DOE/AL-050425.0002, DOE UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1985. *Disposal Site Characterization Report for the Alternate Uranium Mill Tailings Disposal Site in Bodo Canyon near Durango, Colorado*, final, UMTRA-DOE/AL-050103.0001, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

FBDU (Ford, Bacon & Davis Utah Inc.), 1981. *Engineering Assessment of Inactive Uranium Mill Tailings, Durango Site, Durango, Colorado*, DOE/UMT-0103, prepared for U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

JEG (Jacobs Engineering Group Inc.), n.d. *Albuquerque Operations Manual*, standard operating procedures, prepared by Jacobs Engineering Group Inc., Albuquerque, New Mexico, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Tsivoglou et al. (E. C. Tsivoglou, S. D. Shearer, and J. D. Jones), 1960. *Survey of Interstate Pollution of the Animas River, Colorado/New Mexico*, U.S. Department of Health, Education, and Welfare, Bureau of State Services.

USBR (United States Bureau of Reclamation), 1990. *Durango Pumping Plant—Animas La Plata Project Hydrogeochemical Site Characterization*, USBR Durango Projects Office, Durango, Colorado.

USGS (U.S. Geological Survey), 1993. *Water Resources Data for Colorado Water, 1992*, Vol. 2, *Colorado River Basin*, National Technical Information Service, Springfield, Virginia.

CODE OF FEDERAL REGULATIONS

40 CFR Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," U.S. Environmental Protection Agency (1987).

FEDERAL REGISTER

52 FR 36000, "Standards for Remedial Actions at Inactive Uranium Processing Sites; Proposed Rule," September 24, 1987.

UNITED STATES CODES

42 USC §7901 *et seq.*, *Uranium Mill Tailings Radiation Control Act*, November 8, 1978.

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