DOE/AL/62350-87
REV. 1

UMTRA PROJECT WATER SAMPLING AND ANALYSIS PLAN

DURANGO, COLORADO

September 1995

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Prepared for
U.S. Department of Energy
Environmental Restoration Division
UMTRA Project Team
Albuquerque, New Mexico

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DISCLAIMER

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LIST OF ACRONYMS

Acronym	Definition
BOR	Bureau of Reclamation
CGS	Colorado Geological Survey
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
JEG	Jacobs Engineering Group Inc.
LTSP	Long-Term Surveillance Plant
MCL	maximum concentration limit
MSL	mean sea level
POC	point-of-compliance
RAC	Remedial Action Contractor
RAP	remedial action plan
RRM	residual radioactive material
SOP	standard operating procedures
TAC	Technical Assistance Contractor
TAD	Technical Approach Document
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action
WSAP	water sampling and analysis plan

1.0 INTRODUCTION

1.1 PURPOSE

Planned, routine ground water sampling activities at the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project site in Durango, Colorado, are described in this water sampling and analysis plan (WSAP). The following plan identifies and justifies the sampling locations, analytical parameters, detection limits, and sampling frequency for the routine monitoring stations at the site. The ground water data are used to characterize the site ground water compliance strategies and to monitor contaminants of potential concern identified in the baseline risk assessment (DOE, 1995a).

The regulatory basis for routine ground water monitoring at UMTRA Project sites is derived from the U.S. Environmental Protection Agency (EPA) regulations in 40 CFR Part 192 (1994) and the EPA standards of 1995 (60 FR 2854). Sampling procedures are guided by the UMTRA Project standard operating procedures (SOP) (JEG, n.d.), the Technical Approach Document (TAD) (DOE, 1989), and the most effective technical approach for the site.

1.2 SITE LOCATION

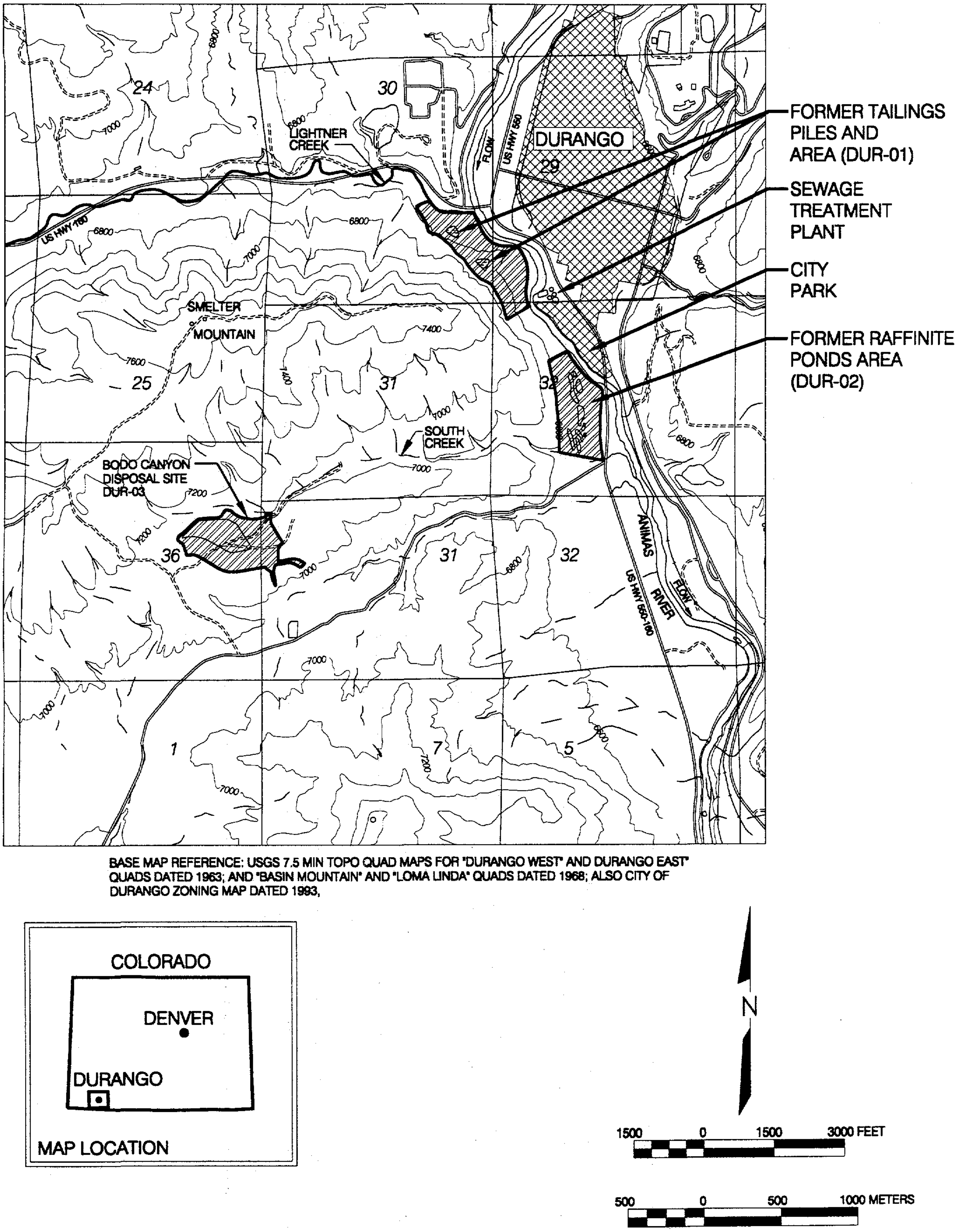
The former Durango uranium ore processing site consists of two geographically contiguous, but hydrogeologically separate, areas: the mill tailings area and the raffinate ponds area. Both areas are located on the west bank of the Animas River immediately southwest of the intersection of Routes 160 and 550, southwest of the city of Durango, in La Plata County, Colorado (Figure 1.1). Contaminated material from the processing site was relocated from 1986 to 1991 to a disposal site located approximately 1.5 miles (mi) (2.4 kilometers [km]) farther to the southwest in a mountain valley near Bodo Canyon.

1.3 SITE HISTORY

A lead smelter, located at the former mill site near the south end of the mill tailings area, operated from 1880 to 1930. Slag from the smelter operation was dumped at the southeast corner of the area along the edge of the Animas River

The mill was constructed in 1941 to produce vanadium. Uranium production later began in 1943. The mill was operated on the same site until 1963. It processed approximately 1.6 million tons (1.4 million metric tons) of ore averaging 0.29 percent uranium oxide and 1.60 percent vanadium oxide. The ore was delivered to the mill from various mines in the Uravan mineral belt.

The milling process involved two separate stages. In the first stage, ores were roasted with sodium chloride, then treated with a sodium carbonate solution to produce an alkaline solution containing both uranium and vanadium. The



BASE MAP REFERENCE: USGS 7.5 MIN TOPO QUAD MAPS FOR "DURANGO WEST" AND DURANGO EAST" QUADS DATED 1963; AND "BASIN MOUNTAIN" AND "LOMA LINDA" QUADS DATED 1968; ALSO CITY OF DURANGO ZONING MAP DATED 1993,

FIGURE 1.1
SITE LOCATION, DURANGO, COLORADO, SITE

PC: H: \USER\SSUNIGA\DUR\WSAP\SITELOC.DWG (XREF: CAD-BASE.DWG) 9-5-95 solution was filtered to separate the solution from the tailings, then treated to remove the uranium and vanadium. The filtrate (alkaline-leach tailings) was washed with water and stored for use in the second stage of processing. Precipitation of uranium and vanadium from the alkaline-leach solution was carried out by adjusting the pH and the oxidation-reduction potential using an acid (sulfuric or hydrochloric acid), a base (sodium hydroxide), and an oxidant (sodium chlorate). The uranium was recovered as uranium dioxide. Soluble vanadium was recycled through the process and precipitated as red cake (Tame et al, 1961; Merritt, 1971).

A second stage of processing used the tailings from the first stage. The tailings were leached using an acid solution containing both hydrochloric and sulfuric acids. The leachate was then separated from the acid-leach tailings and oxidized using potassium permanganate. Finally, the pH was adjusted by adding sodium carbonate. Uranium and vanadium were removed from this solution by solvent extraction using an immiscible organic solvent consisting primarily of tertiary amines, di-2 (ethylhexyl) phosphoric acid, heptadecyl phosphoric acid, and primary decyl alcohol, dissolved in kerosene (Merritt, 1971). The spent solution (raffinate) was disposed of after the uranium and vanadium were removed from the aqueous solution. Uranium and vanadium were stripped and precipitated from the organic solvent using a sodium carbonate solution (Tame et al, 1961). Ultimately the processed waste solution and tailings contained sulfate (SO_4^{2-}), sodium (Na^+), chloride (Cl^-), potassium (K^+), and manganese (Mn^{2+}) derived from processing reagents.

Before 1959, all waste solutions and acid-leach tailings were discharged into the Animas River (Tsivoglou et al, 1960). Beginning in 1959, overflow water from the stored carbonated leach tailings and slurried acid-leach tailings were mixed in a settling pond atop the former large tailings pole adjacent to the mill. Overflow from this pond was treated with barium sulfate and a flocculent and settled in a second pond atop the former small tailings pile at the mill tailings area. Overflow from this pond was discharged into the Animas River at a rate of about 97 gallons (gal) (370 liters[L]) per minute (Tsivoglou et al, 1960). Spent alkaline-leach solutions from the first stage of uranium-vanadium recovery were discharged directly into the Animas River at a rate of about 256 gal (969 L) per minute (Tsivoglou et al, 1960).

Raffinates from the second stage of processing contained most of the radioactivity. This waste solution was pumped to a tank above the mill and, from there, discharged into a 3000-foot (ft) (900-meter [m]) long ditch that carried the waste to the raffinate ponds area. An additional 3000 ft (900 m) of ditch carried the raffinate through a series of ponds on the terraced slope of the raffinate ponds area. The raffinate evaporated and percolated into the underlying alluvium, colluvium, and sandstone bedrock. Raffinates were discharged into the ditch between the mill and the ponds at a rate of about 50 gal (190 L) per minute. However, only about 40 gal (150 L) per minute reached the ponds due to seepage losses within the 6000 ft (2000 m) of ditch (Tsivoglou et al, 1960). Using a value of 50 gal (190 L) per minute of continuous discharge over 3 years, it is estimated that nearly 82 million gal (310 million L) of raffinate were discharged into the ditch and ponds system.

The DOE began relocating the tailing piles, mill debris, and contaminated soils from the mill tailings area and raffinate ponds area to the Bodo Canyon disposal site in November 1986; remedial action was completed in May 1991. 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. After the tailings piles and contaminated soils were removed, the mill tailings and the raffinate ponds surface areas were contoured and planted with grasses.

1.4 SITE STATUS

As mentioned above, remedial action at the Durango site was completed in May 1991. The following is a status list of major documents associated with the Durango site:

- Long-Term Surveillance Plan (LTSP): the document is currently being finalized by the Technical Assistance Contractor (TAC) to the DOE, and it is scheduled to be completed by the end of July 1995.
- Site Completion Report: the TAC is currently reviewing page changes on the final document supplied by the Remedial Action Contractor (RAC) to the DOE, and it is scheduled to be completed by 31 August 1995.
- Baseline Risk Assessment: the draft document was completed by the TAC in February 1995 by the TAC. The final document is scheduled to be completed at the end of September 1995.
- Toe Drain Study: the final document was completed at the end of July 1995.

1.5 SAMPLING PLAN SUMMARY

The current sampling plan for the Durango site for the next 2 years is to collect annual ground water samples and surface water samples from DOE monitor wells at the Bodo Canyon disposal cell site and former processing site and from the Animas River. Table 1.1 lists all proposed sampling locations and constituents to be analyzed over the next 2 years.

Two background wells, a downgradient alluvial aquifer monitoring well, and the three point-of-compliance (POC) wells at the Bodo Canyon disposal cell will be sampled. Analytes selected for analysis include field parameters and major elements indicative of general ground water quality and indicator parameters for detecting ground water contamination derived from the disposal cell. The monitoring wells and analytes selected are in accordance with the Remedial Action Plan (RAP) and LTSP.

Table 1.1 Proposed sampling locations and analytical parameters

Site ID	Sample parameters
Bodo Canyon disposal site	
Dur-03-0605, -0607 -0608, -0612, -0621, and -0623	*Filtered:* Alkalinity, calcium, chloride, iron, magnesium, manganese, molybdenum, pH, potassium, selenium, sodium, sulfate, TDS, uranium, dissolved oxygen, oxidation-reduction potential, specific conductivity, turbidity, and temperature.
Processing site, mill tailings area	
Dur-01-0658, -0629, -0622, -0635, -0634, -0633, -0631, -0617, -0630, and -0612	*Filtered:* Alkalinity, arsenic, antimony, cadmium, calcium, chloride, iron, lead, magnesium, manganese, molybdenum, pH, potassium, selenium, sodium, sulfate, TDS, thallium, uranium, vanadium, dissolved oxygen, oxidation-reduction potential, specific conductivity, turbidity, and temperature.
	Unfiltered: Iron, lead, polonium-210, radium-226, radium-228, thorium-230, uranium.
Processing site, raffinate ponds area	
DUR-02-0592, -0607, -0602, and -0628	*Filtered:* Alkalinity, arsenic, antimony, cadmium, calcium, chloride, iron, lead, magnesium, manganese, molybdenum, pH, potassium, selenium, sodium, sulfate, TDS, thallium, uranium, vanadium, dissolved oxygen, oxidation-reduction potential, specific conductivity, turbidity, and temperature.
	Unfiltered: Iron, lead, polonium-210, radium-226, radium-228, thorium-230, uranium.
Animas River surface water	
DUR-01-0652, -0691, and DUR-02-0654	Uranium, pH, specific conductivity, turbidity, temperature.

TDS – total dissolved solids.

Selected DOE monitoring wells and piezometers will be sampled at the processing site. Analytes selected for analysis include contaminants identified in the Baseline Risk assessment as being of potential concern to human health. The analysis includes a few constituents for which more data are needed to determine whether or not they occur above background levels on site. Data collection objectives are:

1. Monitor trends that may indicate movement, flushing, and attenuation of contaminants in ground water at the processing site. Identify and document these trends to provide information to develop the ground water compliance strategy.

2. Monitor levels of contaminants of human health concern, as identified in the site Baseline Risk Assessment.

3. Expand the data base for levels of constituents in background. Additional background data for certain constituents are needed to determine if levels observed in contaminated ground waters exceed background. In addition, more data are needed for all constituents in background in order to better characterize their statistical range.

Surface water samples will be collected at three locations along the Animas River. Uranium will be analyzed in surface water samples. Uranium is the most sensitive indicator of surface water contamination by ground water discharge. Data collection objectives are to further demonstrate that contaminated ground water discharge to the Animas River is having a negligible impact on surface water quality.

The last sampling event at the site was completed in June, 1994. The next scheduled water quality sampling round will occur in October 1996, and will include the sites listed in Table 1.1. It is recommended that the proposed sampling plan be implemented annually for the next two years. After two years, data collection objectives will be evaluated and the sampling plan for the following three years may be modified to reflect remaining data needs at the processing site. The end point for routine monitoring will occur when the ground water compliance strategy is accepted.

2.0 SITE CONDITIONS

2.1 SITE BACKGROUND INFORMATION

2.1.1 Surrounding land uses

The region's primary landowner, the federal government, controls the San Juan National Forest to the north of Durango and holds in trust large Indian reservation lands to the south and west of Durango (about 57 percent of the land in La Plata County) (DOE, 1983; DOE, 1985). Privately owned lands are second in extent (about 41 percent), followed by state, county, and municipal lands (about 2 percent, combined). The Durango site is owned by the state of Colorado. Lands in the immediate vicinity of the site are owned by the city of Durango, the Colorado Department of Natural Resources, and private interests. A land use map for the area surrounding the site is provided in Figure 2.1. Land use in the vicinity of the Durango site is primarily commercial, residential (in the city of Durango), and open space. The city operates a nearby sewage treatment plant and a city park on the east side of the Animas River. The Colorado Department of Natural Resources controls the Bodo Canyon Wildlife Area.

Land in downtown Durango, northeast of the site, has been developed since the late 1800s (DOE, 1983; DOE, 1985). The major land use changes near the site have occurred in the Animas River valley. This land has been converted to urban uses by the construction of the sewage treatment plant across the Animas River, south of the site, and the construction of a commercial center, southeast of the site (Figure 2.1). Land use within the Bodo Canyon Wildlife Area, west and southwest of the site, changed from livestock grazing to resource conservation and recreation in the early 1970s.

Other prominent land use areas include transportation (US Highways 160 and 550 and the Durango-Silverton railroad yard), utility (Durango sewage treatment plant), and industrial (Bodo Industrial Park). The Durango site lies outside the city limits, about 0.25 mi (0.4 km) from the central business district of Durango. To the north and northwest of the site (across Highway 160) are residential and commercial/industrial properties. Smelter Mountain is on the western boundary of the site and the Animas River is on the eastern boundary. To the east, across the Animas River and within Durango city limits, are public lands. Farther east, residential and commercial/industrial properties exist. A riverside park is across the river adjacent to the sewage treatment plant. To the southeast are additional residential and commercial properties.

Potential development plans for the former mill tailings area at the site include construction of a visitors' center, parking lots, and a museum or other type of public building (Hoch, 1994). As part of the Animas-La Plata water project, there are draft plans to construct a pumping plant in the former raffinate ponds area of the site. This federal project would supply irrigation water to farmland; drinking water to Durango, Farmington, and Aztec; and water to the Southern

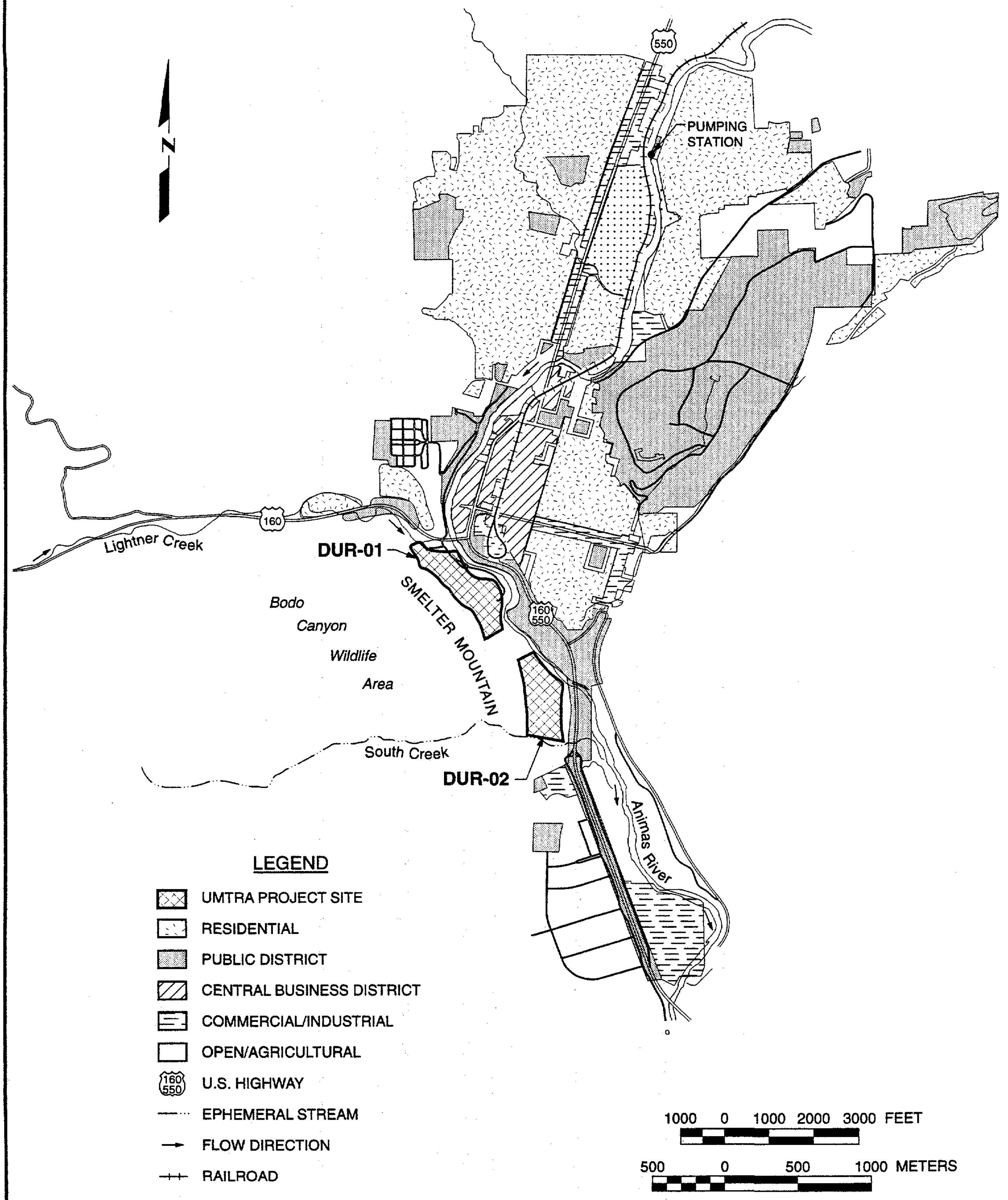


FIGURE 2.1
LAND USE MAP
DURANGO, COLORADO, SITE

MAC: SITE: DUR/WSAP/LANDUSE

Ute and Ute Mountain tribes (Hageman, 1994). Development of additional water resources is a concern because the city's water supply is not sufficient to meet future needs. However, there is public opposition to the project (Hageman, 1994). There are no plans to develop either portion of the site for residential use (Hoch, 1994).

2.1.2 Surrounding water use

Approximately 13,000 people live within the Durango city limits (TAC, 1994a). There are no known wells in use within the city limits. Development and utility policies for the city of Durango prohibit the drilling of private wells within the city limits. However, wells can be drilled on county lands (Hoch, 1994).

The water supply system for the city of Durango is the largest in the county, not only serving city residents, but also selling water to neighboring water districts and companies serving surrounding developed areas. The city's primary water source is the Florida River, with additional water taken from the Animas River during high demand periods (generally during the summer). The water pumping station from the Animas River is approximately 2 mi (3 km) upstream from the northern boundary of the former mill tailings area (Figure 2.1).

The system serves approximately 17,000 people, with approximately 3400 residential and 1100 commercial customers. Its service area extends 2 mi (3 km) to the west and south and 10 mi (16 km) to the north of the city boundaries (Rogers, 1994).

A survey of water use in the area surrounding the Durango site was conducted using information from the Colorado Division of Water Resources database and field investigations (TAC, 1994a). Although the city is considering developing additional water resources to supplement the existing water supply, ground water has not been considered as a water source for the municipal water supply system (Rogers, 1994). Ground water in the area is considered of poor quality with increased levels of hardness, iron, and manganese levels (Rogers, 1994).

Table 2.1 summarizes the information obtained for domestic and commercial wells within a 2-mi (3-km) site radius (Figure 2.2). Some of the listed wells are in use, however, the status of several listed wells is unknown because of a difficulty in determining the current property owners.

The nearest known downgradient well is across US Highway 550, approximately 0.2 mi (0.3 km) southeast of the site, and on the same side of the Animas River (number 10 in Figure 2.2 and Table 2.1). However, this well is located under a building and has never been used because of a black discoloration of the water (TAC, 1994a). Additional wells (numbered 1 through 9 in Figure 2.2) are on the opposite side of the Animas River and are at distances ranging from 0.8 mi (1 km) to 1.5 mi (2 km) from the site. All other wells in Figure 2.2 are north of Lightner Creek. None of these wells would be affected by contaminated ground water from the site. Contaminated ground

Table 2.1 Summary of private wells within a 2-mi (3-km) radius of the Durango, Colorado, site

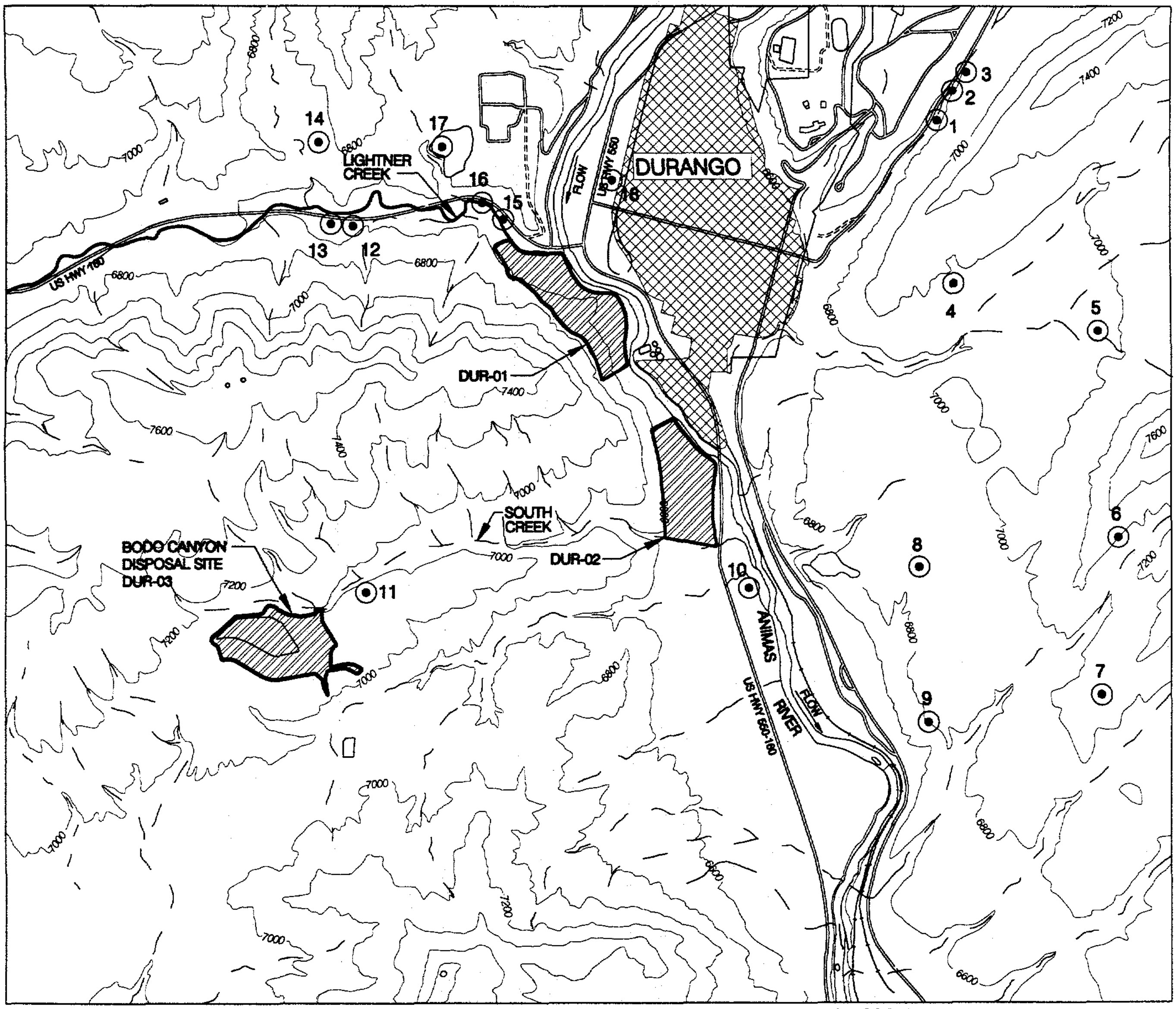
Well[a]	Date installed	Yield (gpm)	Depth (ft bls)	Water level (ft bls)	Water-bearing unit	Current status	Water use/comments
1	1962	7	40 (30-40 perf.)[b]	30	Unknown	NA	Domestic
2	1958	30	38	10	Unknown	NA	Domestic
3	1959	10	85 (70-85 perf.)	75	Shale	NA	Domestic
4	1961	3	100 (60-90 perf.)	32	Shale and slide rock or sandstone	NA	Domestic
5	1977	4.5	351	290	Unknown	NA	Domestic
6	1972	6	500	250	Unknown	In use	Domestic
7	1983	150	480 (400-480 perf.)	114	Fruitland Formation	Currently not in use (future use likely)	Domestic, commercial, industrial, irrigation; used for surface coal mining, wash plant, reclamation irrigation
8	1991	35	155 (125-155 perf.)	96	Cemented gravel	In use	Domestic, commercial, irrigation; very little drawdown
9	1986	6-8	105 (75-105 perf.)	60	Shale	In use	Commercial, domestic, irrigation, stock, fish ponds
10	1963	Unknown	160	Unknown	Unknown	Never used	Unusable water
11	1967	8	101	90	Shale	NA	Domestic/approximate location
12 (2 wells)	1951/1959	30/60	50/52	20/32	Unknown	NA	Domestic/commercial

Table 2.1 Summary of private wells within a 2-mi (3-km) radius of the Durango, Colorado, site (Concluded)

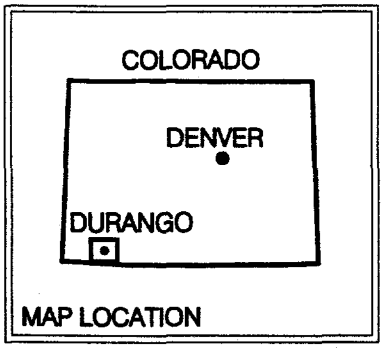
Well[a]	Date installed	Yield (gpm)	Depth (ft bls)	Water level (ft bls)	Water-bearing unit	Current status	Water use/comments
13 (2 wells)	1951/1988	45/30	30/35	Unknown/8	Unknown	NA	Domestic
14	1958	22	90	37	Unknown	In use	Domestic
15	Before 1980	6	30	Unknown	Alluvium	In use	Irrigation, swimming pool
16	1960	10	60 (40-60 perf.)	50	Boulders, shale	NA	Domestic
17	1954	30	12	9	Unknown	NA	Domestic
18	1967	3	305	38	Hard shale	Not in use	Commercial/not in use

[a]Refer to Figure 2.9 for well locations.
[b]Perf. – perforated. Numbers in parentheses indicate that perforations in well casings can be found at this depth.

NA – Information is not available at this time due to difficulty in locating current owner based on records from the Colorado Division of Water Resources.
gpm – gallons per minute.
ft bls – feet below land surface.



BASE MAP REFERENCE: USGS 7.5 MIN TOPO QUAD MAPS FOR "DURANGO WEST" AND DURANGO EAST" QUADS DATED 1963; AND "BASIN MOUNTAIN" AND "LOMA LINDA" QUADS DATED 1968; ALSO CITY OF DURANGO ZONING MAP DATED 1993.



LEGEND

- APPROXIMATE GROUND WATER WELL LOCATION
- UMTRA SITE

NOTE: 1 FT = 0.3048 M.

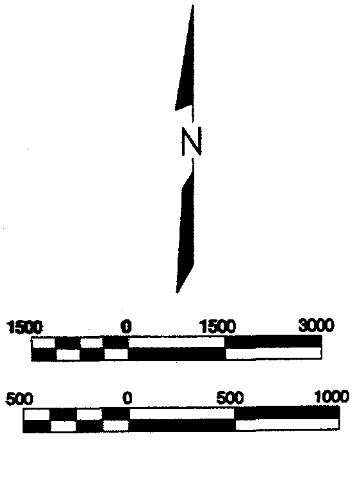


FIGURE 2.2
LOCATIONS OF PRIVATE GROUND WATER WELLS NEAR DURANGO, COLORADO, SITE

PC: H:\USER\SSUNIGA\DUR\BLRA\BASE\PRIVGWW.DWG (XREF: CAD-BASE.DWG) 8-5-95 water discharges into the Animas River, where it is quickly diluted (TAC, 1994b).

2.1.3 Contaminant sources

Salt roasting and carbonate and acid leaching of vanadate ores contributed sodium chloride (NaCl), sodium carbonate (Na_2CO_3), and sodium perchlorate ($NaClO_4$) to the alkaline leach tails and hydrochloric acid (HCl), sulfuric acid (H_2SO_4), and potassium permanganate ($KMnO_4$) to the acid leach tails (DOE, 1995a). Mixing of the overflow from alkaline leach tails with acid tailings in the tailings piles produced solutions that seeped through the tailings and into the ground water system in the mill tailings area. Raffinate was disposed of in ponds and seeped from the ponds into the ground water system in the raffinate ponds area.

Both the seepage from the tailings piles and the raffinate areas contained a similar suite of contaminants (DOE, 1995a). However, the tailings seepage (pH - 4.1) was more diluted and had a higher pH than the raffinate (pH - 0.8). Both sources of contamination contained constituents derived from processing reagents, including sodium, sulfate, chloride, and manganese. Other constituents, derived from the dissolution of the ores, included arsenic, beryllium, copper, fluoride, iron, radium-226, vanadium, and zinc (DOE, 1995a). Dissolved selenium was notably absent in the contaminant sources. However, selenium was reported in the main plant effluent (Tsivoglou et al., 1960) and occurs in contaminated ground water at the site.

2.2 GEOLOGY AND HYDROLOGY

2.2.1 Physical setting

The mill tailings area encompasses approximately 40 acres (ac) (16 hectares [ha]). It is located on a bedrock-supported river terrace between Smelter Mountain to the west, the Animas River to the east, and Lightner Creek to the north (Figure 2.3).

The raffinate ponds area occupies approximately 20 ac (8 ha) on another river terrace approximately 1500 ft (500 m) south of the mill tailings area along the west band of the Animas River. A narrow terrace above the Animas River connects the two areas.

Lightner Creek flows along the north edge of the mill tailings area. The Animas River flows along the eastern sides of the mill tailings and raffinate ponds area. A small, intermittent creek (called South Creek in this study) forms the southern boundary of the raffinate ponds area.

The topography of the processing site was modified during the removal of the tailings and contaminated soils. The property slopes steeply down from Smelter

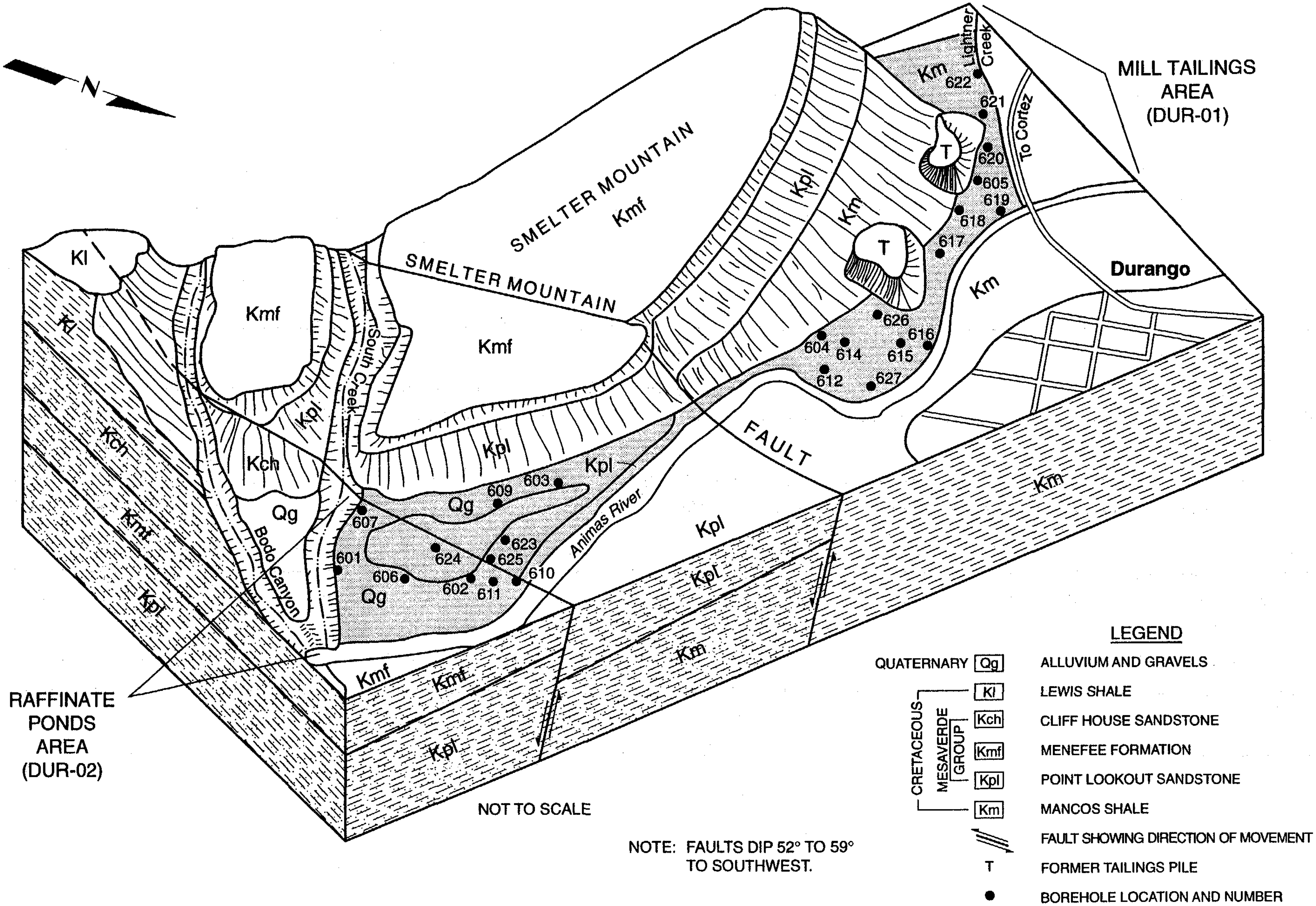


FIGURE 2.3
GENERALIZED GEOLOGY AND BOREHOLE LOCATIONS PRIOR TO REMEDIATION
DURANGO, COLORADO, PROCESSING SITE

FROM BFEC, 1983.

MAC: SITE/DUR/WSAP/GENGEO

Mountain, but becomes relatively level near Lightner Creek and the Animas River.

The Bodo Canyon disposal cell is located in a southwest-to-northeast-trending valley, approximately 1.5 mi (2.4 km) southwest of the processing site. Before installation of the disposal cell, the elevation of the valley ranged from a high of approximately 7190 ft (2190 km) above mean sea level (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 2.4).

2.2.2 Mill tailings area (DUR-01)

Geology

The mill tailings area is underlain by more than 1700 ft (500 m) of dark gray to black Mancos Shale. The Mancos Shale is truncated by the Smelter Mountain fault south of the mill tailings area. The present topography at the mill tailings area is shown in Figure 2.5.

Along the base of Smelter Mountain, the Mancos Shale is directly overlain by up to 25 ft (9 m) of colluvium. The colluvium consists of poorly sorted, silty soil from Smelter Mountain.

Closer to Lightner Creek and the Animas River, up to 15 ft (5 m) of river-laid sand and gravel deposits occur over the shale bedrock and under the colluvium (Figure 2.6). These well-sorted, sands and gravels may represent glacial outwash and/or alluvial river gravels. As much as 25 ft (7.6 m) of the vitreous lead smelter slag remains along the bank of the Animas River near the southeast corner of the mill tailings area.

Hydrology

Ground water. Ground water in the colluvium near the base of Smelter Mountain is recharged primarily by runoff from the mountain and by infiltrating precipitation. The drainage basin upslope of the mill tailings area is small because of a steep cliff along the east side of Smelter Mountain. Therefore, the amount of recharge from this area is relatively small.

Sand and gravel deposits receive recharge from Lightner Creek and the Animas River. During spring runoff when the river stage is high, water flows into the aquifer. When the river stage is lower, the ground water flows from the aquifer back into the Animas River. The ground water flow pattern on 2 June 1994, during high river stages, is shown in Figure 2.5. Some of the ground water may flow down through the colluvium into the underlying Mancos Shale. Ultimately, water from the site that moves through the shale discharges into the Animas River. Because the permeability of the Mancos Shale is very low, only a small quantity of water passes by this route to the river as compared to the route through the more permeable colluvium.

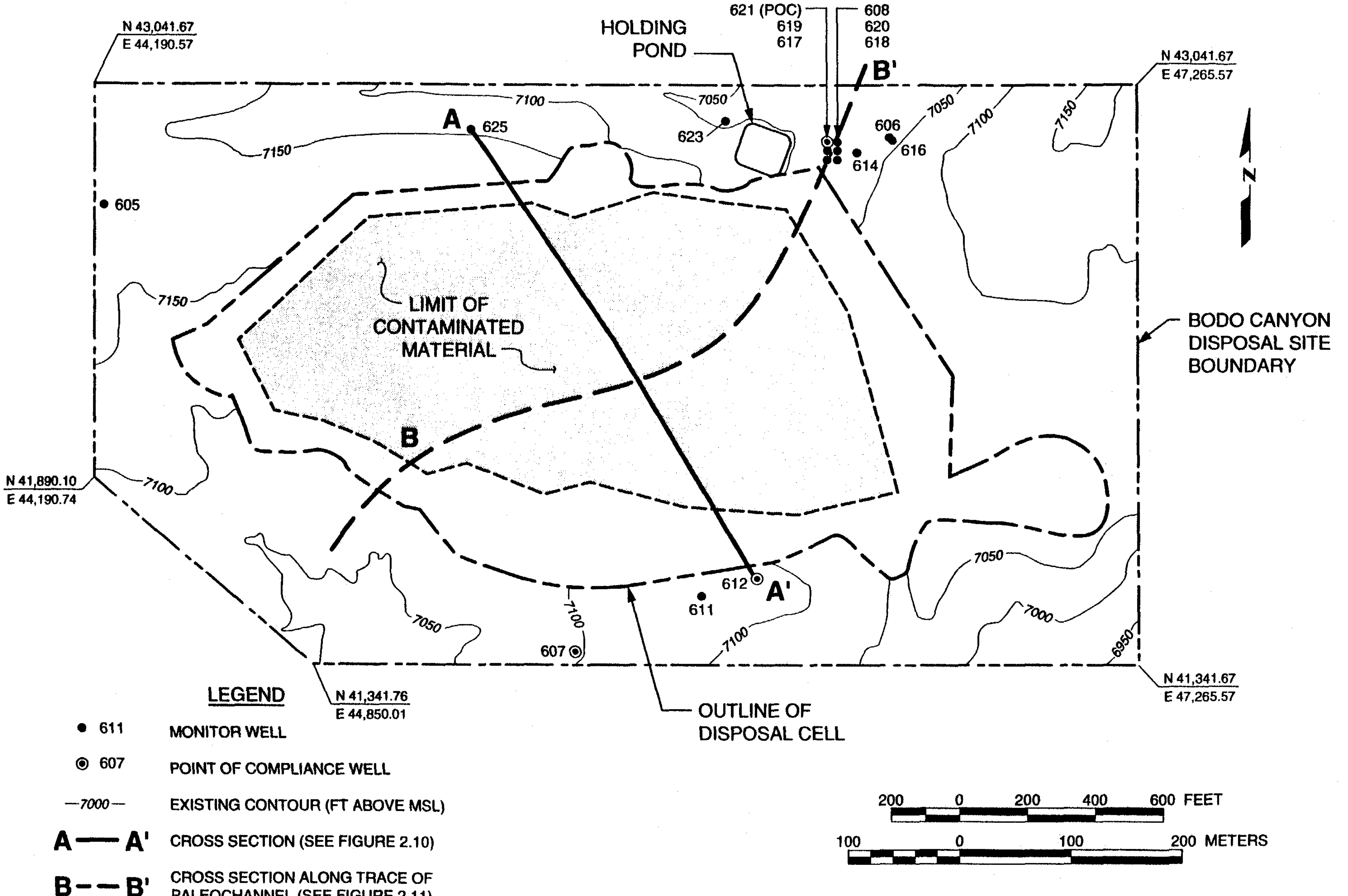


FIGURE 2.4
LOCATIONS OF MONITOR WELLS AND TOPOGRAPHIC MAP (DUR-03)
BODO CANYON DISPOSAL SITE

MAC: SITE/DUR/WSAP/MONWELLLOC

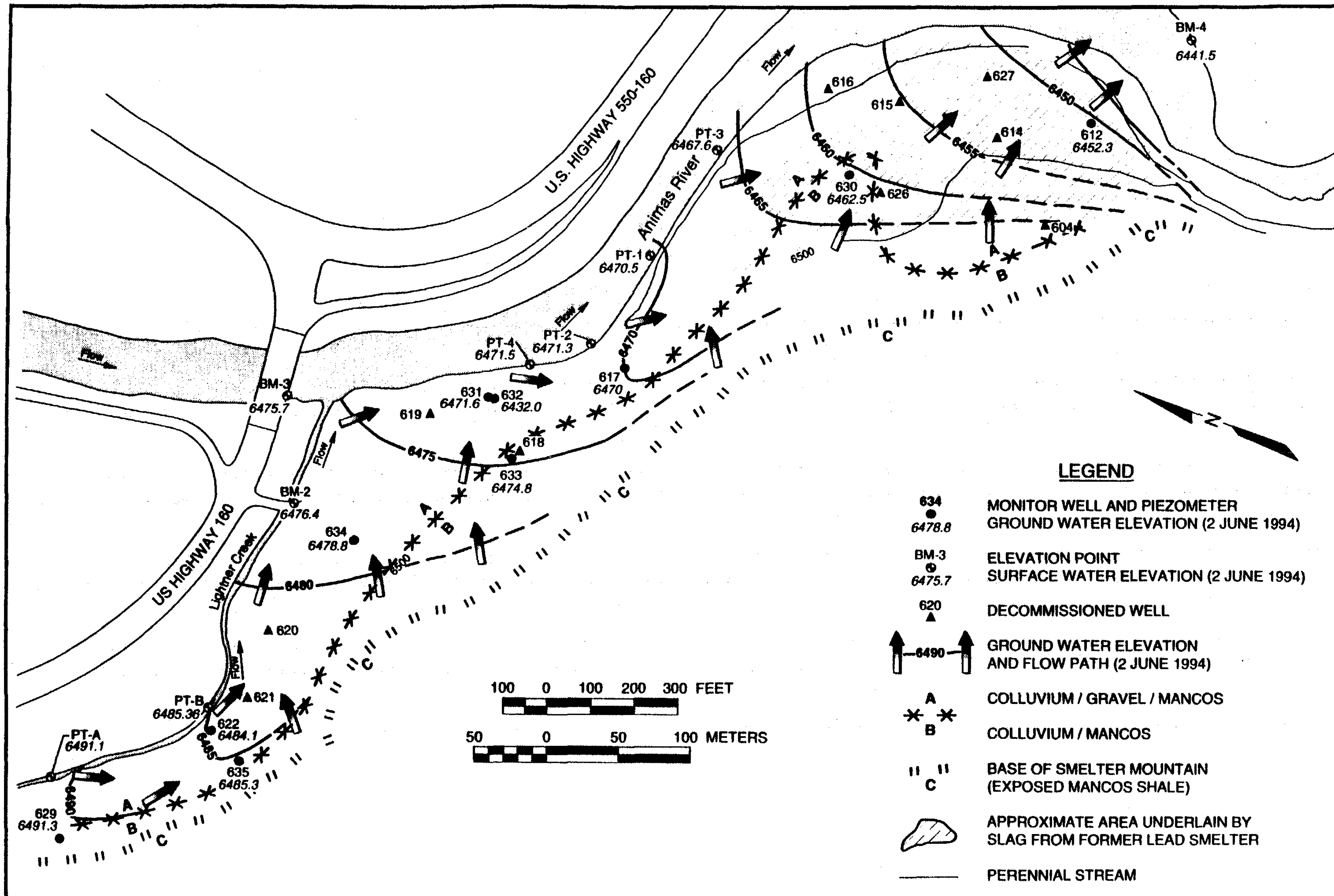


FIGURE 2.5
SURFACE GEOLOGY AT THE MILL TAILINGS AREA (DUR-01)
DURANGO, COLORADO, SITE

MAC: SITE\DUR\WSAP\ BASE-SURFGEO 11-5-94

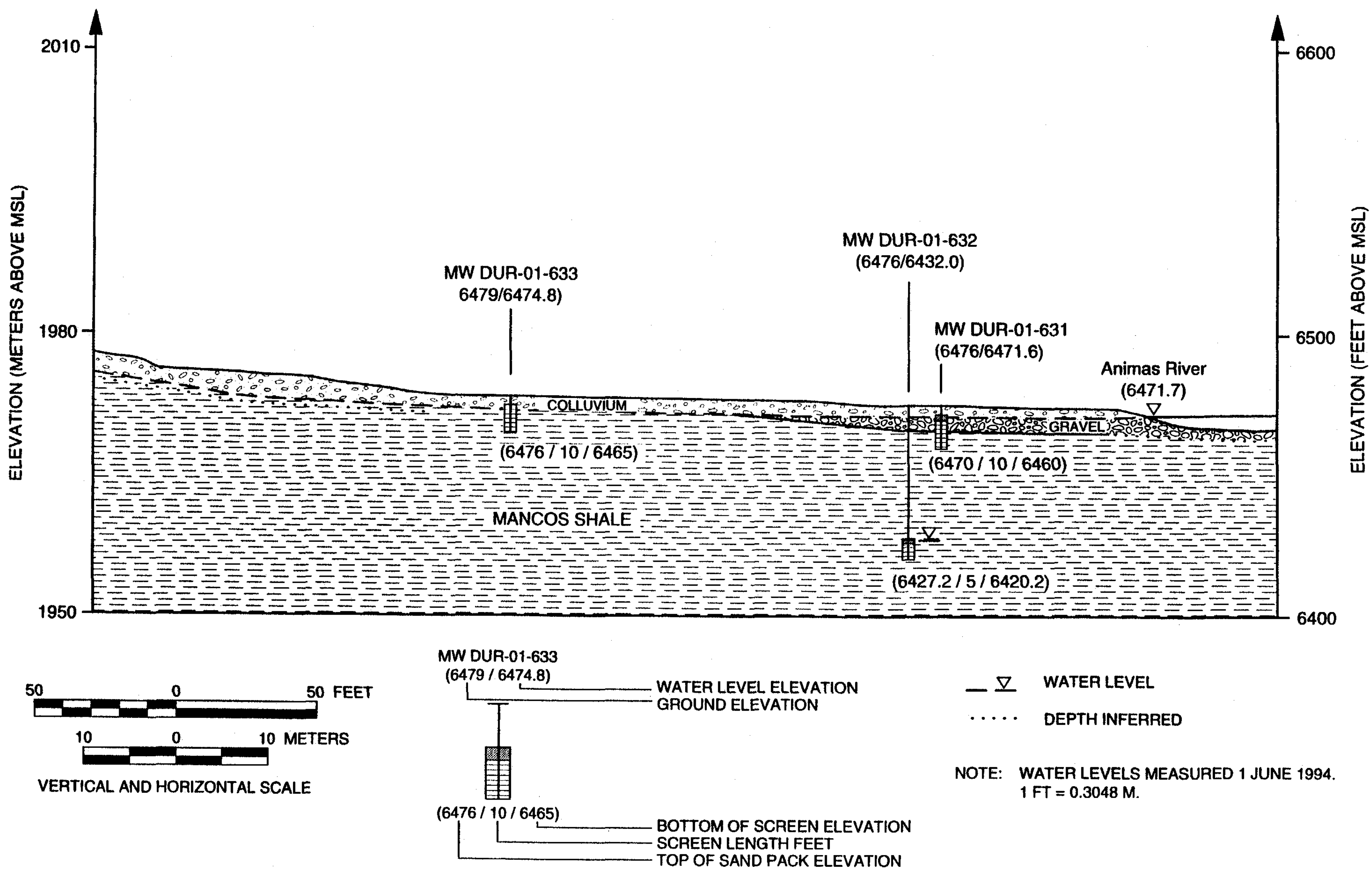


FIGURE 2.6
TYPICAL CROSS SECTION (DUR-01)
MILL TAILINGS AREA, DURANGO, COLORADO, SITE

MAC: SITE/DUR/WSAP/SECTIONS A-D-SECTION C

The high topographic relief and high ground water elevations in wells on the east side of the Animas River (Figure 2.7) indicate that ground water on the east flows toward and discharges into the Animas River. This flow pattern will prevent migration of ground water from one side of the river to the other.

Slug-removal aquifer tests were conducted in monitor wells DUR-01-0612, -0615, -0616, -0619, and -0621 (Figure 2.3) before the tailings piles and contaminated soils were removed (BFEC, 1983). These wells were screened predominantly in the gravels above the bedrock. The hydraulic conductivity calculated from four of these tests is approximately 20 ft per day (7×10^{-3} centimeters [cm] per second), although the tests in well DUR-01-0621 in the terrace gravels near Lightner Creek indicates a hydraulic conductivity of approximately 300 ft per day (1×10^{-1} cm per second).

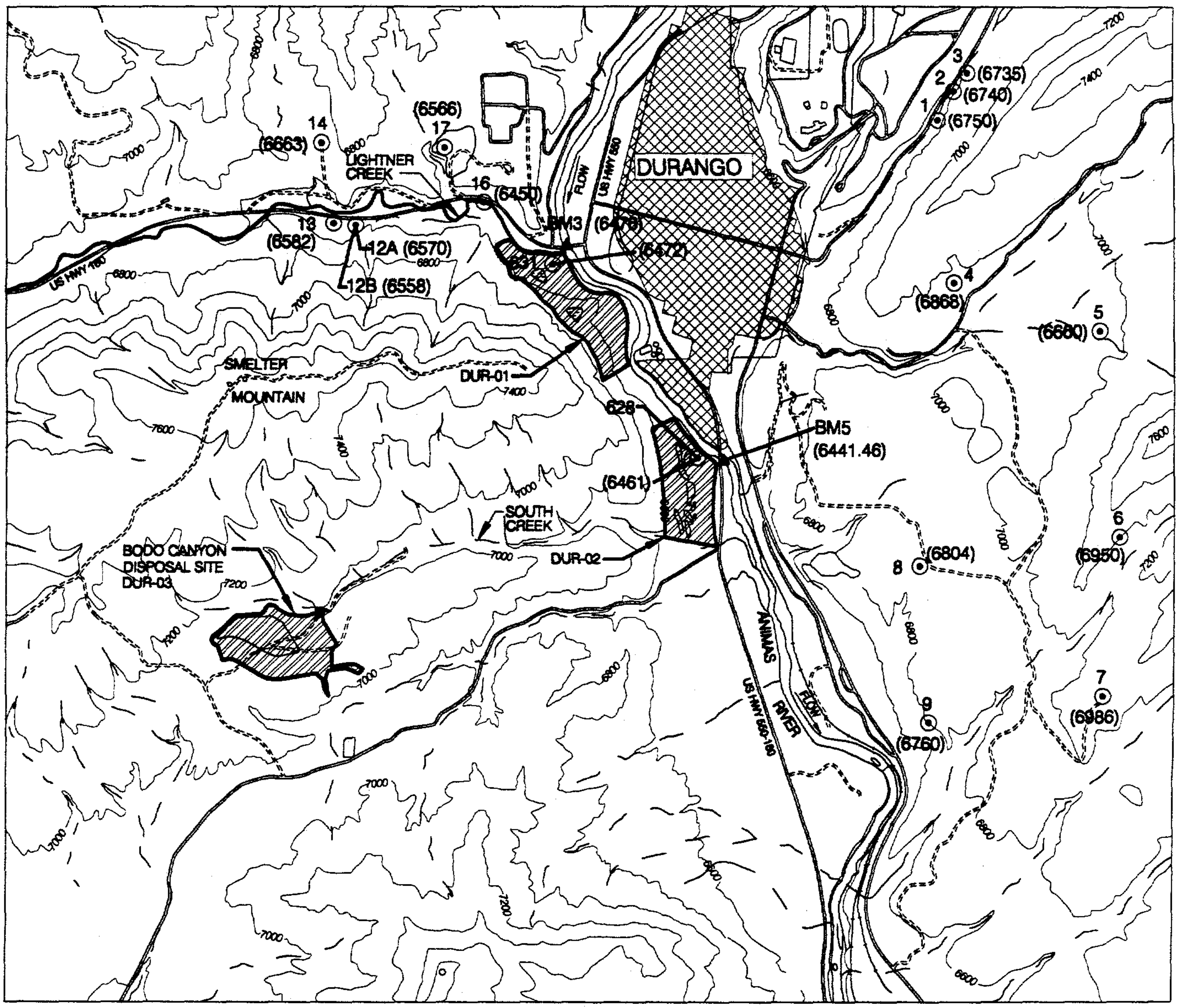
Qualitative aquifer pumping tests were conducted during the summer of 1994 in monitor wells DUR-01-0612 and -0617 and in piezometers DUR-01-0630, -0631, and -0633 (see Figure 2.5) (DOE, 1995a). These tests demonstrate that the part of the site underlain by colluvium over the Mancos Shale has only a limited ability to yield water to wells (piezometers DUR-01-0630 and -0633 in Figure 2.5). By contrast, the sand and gravel deposits encountered in wells DUR-01-0612 and -0617 and in piezometers DUR-01-0631 can yield significant amounts of water and will have a good sustainable yield because of recharge from Lightner Creek and the Animas River.

The bedrock has minimal ground water yield. Piezometer DUR-01-0632 is screened from 39 to 46 ft (14 to 16 m) below the top of the Mancos Shale and at approximately the same depth below the river level (see Figure 2.6).

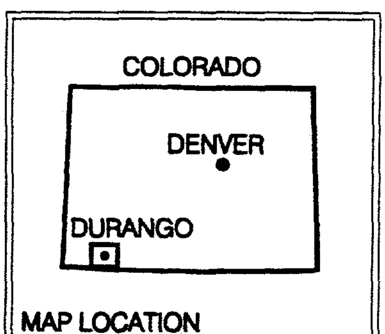
Ground water can be seen seeping from the Smelter Mountain fault south of, and at a higher elevation than, the mill tailings area. This fault forms a hydrologic barrier between the mill tailings and the raffinate ponds areas.

Surface water. Lightner Creek flows along the northern edge of the mill tailings area. Between 1927 and 1949, it's average flow was 22.6 cubic feet (ft^3) per second (0.7 m^3 per second) and minimum daily flows of 1.0 ft^3 per second (0.03 m^3 per second) 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 area. A US Geological Survey gagging 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 per second (24 m^3 per second) and the record 7-day low flow was 100 ft^3 per second (3 m^3 per second) in December 1971.



BASE MAP REFERENCE: USGS 7.5 MIN TOPO QUAD MAPS FOR "DURANGO WEST" AND DURANGO EAST" QUADS DATED 1963; AND "BASIN MOUNTAIN" AND "LOMA LINDA" QUADS DATED 1968; ALSO CITY OF DURANGO ZONING MAP DATED 1993.



LEGEND

1 (6750) — GROUND WATER WELL LOCATION * GROUND WATER ELEVATION (FEET) **

BM3 ▲ (6476) — ELEVATION OF ANIMAS RIVER

UMTRA SITE

* LOCATION ESTIMATED FROM INFORMATION ON WELL LOGS AND INTERVIEWS WITH OWNERS OR OTHERS IN DURANGO.

** WATER LEVEL ELEVATION CALCULATED FROM DEPTH TO WATER REPORTED ON WELL LOG (DOE, 1995). GROUND ELEVATION INTERPOLATED FROM USGS TOPOGRAPHIC MAP.

NOTE: 1 FT = 0.3048 M.

1500 0 1500 3000 FEET

500 0 500 1000 METERS

N

FIGURE 2.7
GROUND WATER ELEVATIONS IN WELLS
DURANGO, COLORADO, SITE

PC: H:\USER\SSUNIGA\DUR\WSAP\GRDWATEL.DWG (XREF: CAD-BASE.DWG) 9-5-95

2.2.3 Raffinate ponds area (DUR-02)

Geology

Two bedrock units, both members of the Mesaverde Group, are below the raffinate ponds area (BOR, 1990). The first one, the Point Lookout Sandstone, underlies the northwestern two-thirds of the area between the Smelter Mountain fault and another fault that cuts through the raffinate ponds area (see Figure 2.3). While the second one, the Menefee Formation, underlies the southeastern one-third of the area, southeast of the fault that cuts across the raffinate ponds area. This fault is a northeast-southwest trending high angle, dipping to the southeast at approximately 55 degrees.

The Point Lookout Sandstone consists of siltstone with interbedded sandstone and minor amounts of shale (BOR, 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 ponds area consisted of colluvium from the slope of Smelter Mountain, glacial outwash, and recent river alluvium (BOR, 1990). The surficial deposits were 20 to 30 ft (6 to 10 m) thick in the area of the ponds (Figure 2.8). As much as 20 ft (6 m) of surficial deposits were removed during site remediation. Most of the remaining surficial material was mixed during remediation activities and now is mixture of clayey sands, gravels, and cobbles. Some gravel beds overlying the bedrock remain.

Hydrology

Ground water. Ground water below the raffinate ponds area is recharged by infiltration of precipitation and by ground water moving through the bedrock from the west. The elevations of both the alluvium/bedrock interface and the ground water are higher than the water level in the Animas River. Therefore, unlike the mill tailings area, the river does not recharge the aquifer in this area.

The water table in the eastern part of the raffinate ponds area is above the alluvium/bedrock interface. Farther to the west, all the ground water is within the bedrock and the alluvium is unsaturated. Ground water flow in the Point Lookout Sandstone and Menefee Formation is mostly open bedding planes and joints (BOR, 1990). Ground water also flows through the fault cutting the bedrock (BFEC, 1983).

It 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 DUR-02-0607. Infiltration from South Creek also recharges the fault near monitor well DUR-02-0607 (Figure 2.3).

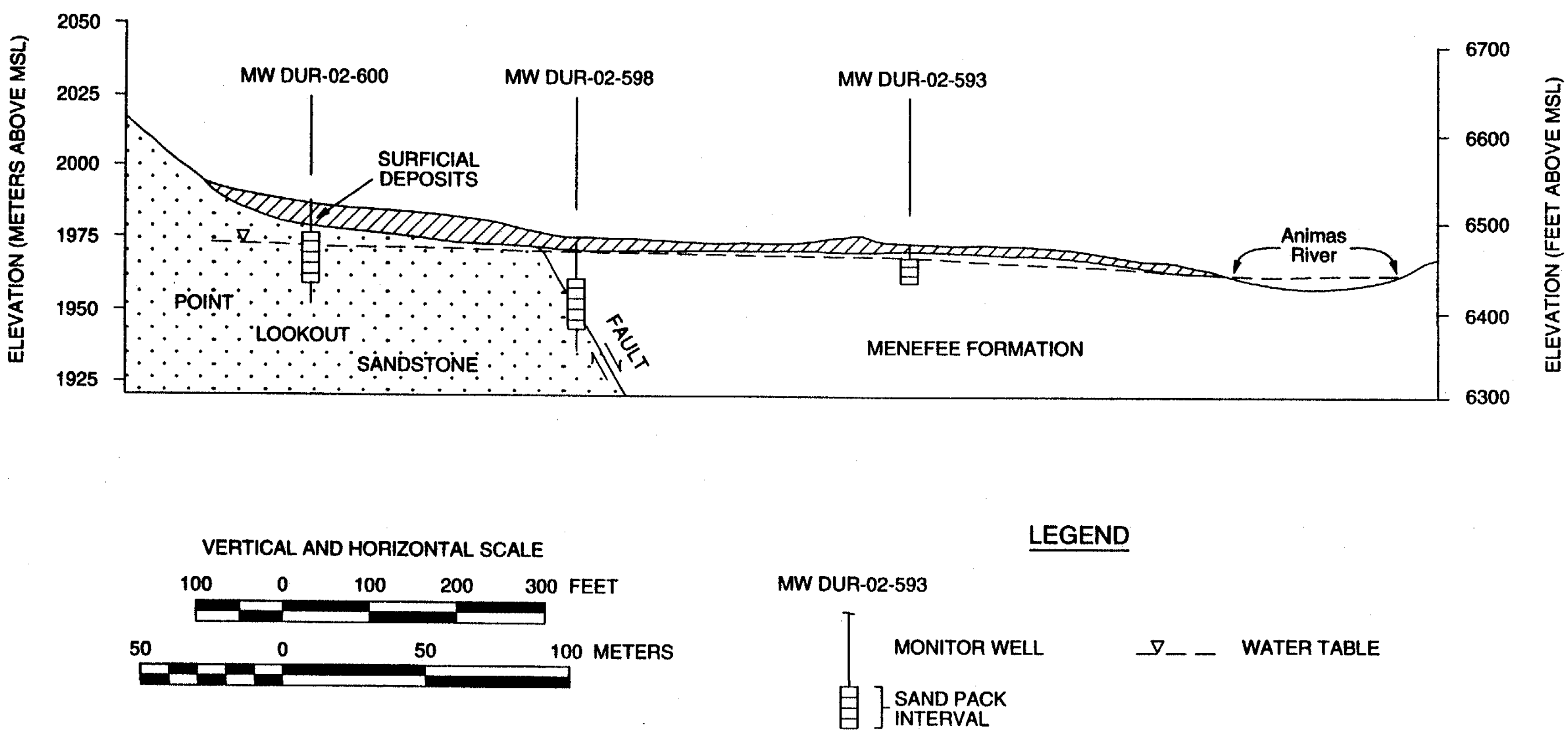


FIGURE 2.8
TYPICAL CROSS SECTION, RAFFINATE PONDS AREA (DUR-02)
DURANGO, COLORADO, SITE

MAC: SITE/DUR/WSAP/TYPXSECT

Ground water flows toward and discharges into the Animas River with an average gradient of approximately 3 percent. An April 1990 ground water contour map is shown in Figure 2.9.

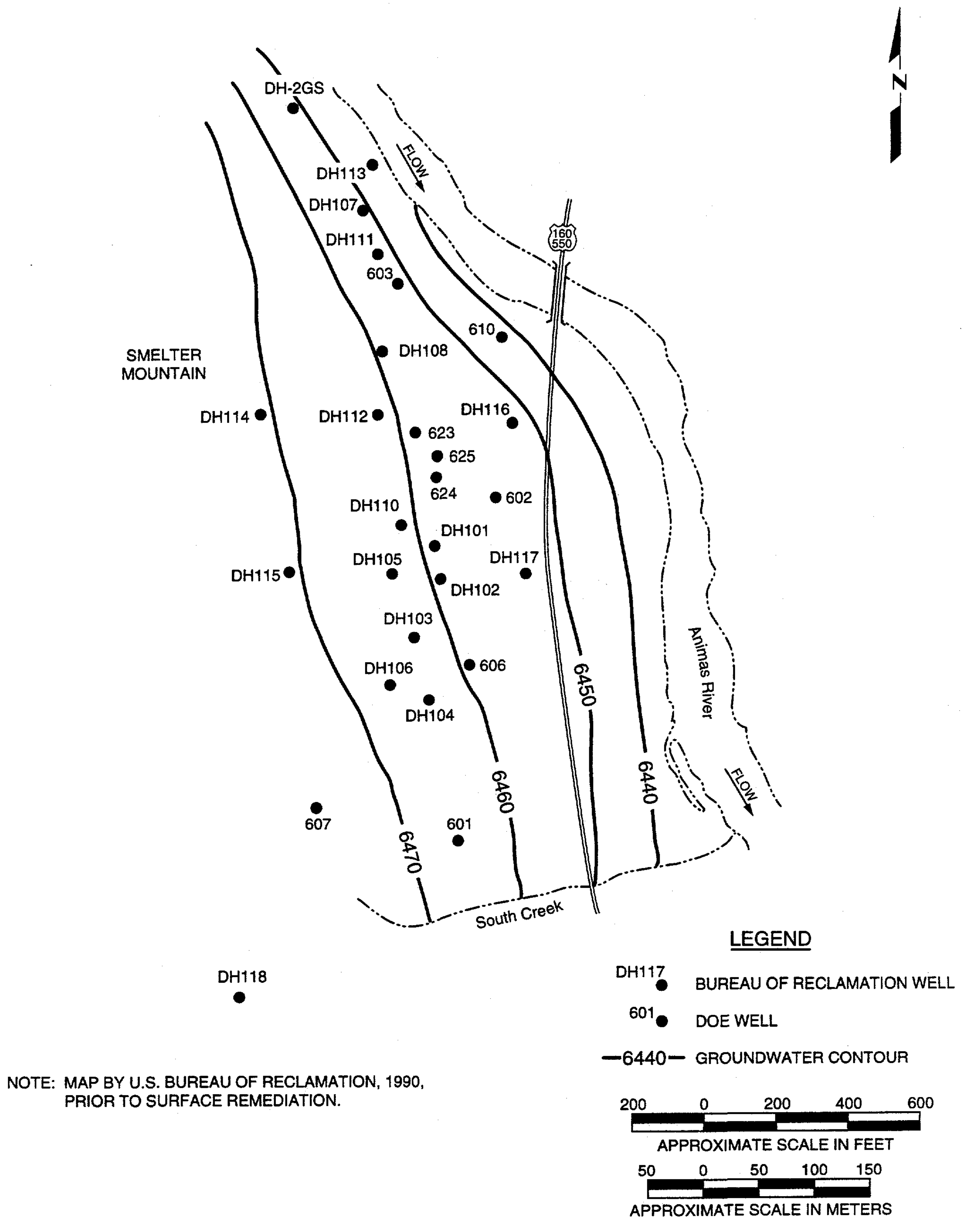
Hydraulic conductivity tests resulted in computed average hydraulic conductivity of 22 ft per day (8 x 10^{-3} cm per second) in the alluvium (DOE, 1991), 0.2 ft per day (8 x 10^{-5} cm per second) in both the Menefee Formation and Point Lookout Sandstone, and 0.8 ft per day (3 x 10^{-4} cm per second) in the faults (BOR, 1990). These permeabilities indicate that wells could produce more than 150 gal (570 L) per day. The yield will be sustained if pumping wells create a sufficient cone of depression to induce recharge from the Animas River.

Based on the gradient calculated from the ground water contours (0.03), an assumed porosity of 15 percent (Freeze and Cherry, 1979), 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 ft (5 m) per year. It will move approximately 45 ft (14 m) per year in the fault, assuming a gradient of 0.021 along the fault calculated from water levels in wells completed within the fault (wells DUR-02-0592 and -0598). Ground water in the alluvium during wet times could move approximately 800 ft (240 m) per year if the bedrock surface has approximately the same slope as the ground water gradient and the porosity is approximately 30 percent.

As with the mill tailings area, the high topographic relief and high ground water elevations (Figure 2.7) demonstrate that ground water on the opposite side of the river also flows toward and discharges into the Animas River. This flow pattern will prevent migration of ground water from one side of the river to the other. Ground water may move down into the fault and the bedrock. Regional hydrogeologic information suggests that the rate and volume of ground water movement in the bedrock are minimal.

Surface water. The Animas River runs along the eastern edge of the northern half of the raffinate ponds area downstream of the mill tailings area. 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 ponds area. This plant discharges approximately 2 million gal per day (8 million L per day).

South Creek, along the southern edge of the raffinate ponds area, is at 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, 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 ponds area.



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

FIGURE 2.9
APRIL 1990 GROUND WATER CONTOUR MAP (DUR-02)
RAFFINATE POND AREA, DURANGO, COLORADO

MAC: SITE/DUR/WSAP/GWCONTOURMAP

2.2.4 Bodo Canyon disposal cell (DUR-03)

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 (Figures 2.4 and 2.10).

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.

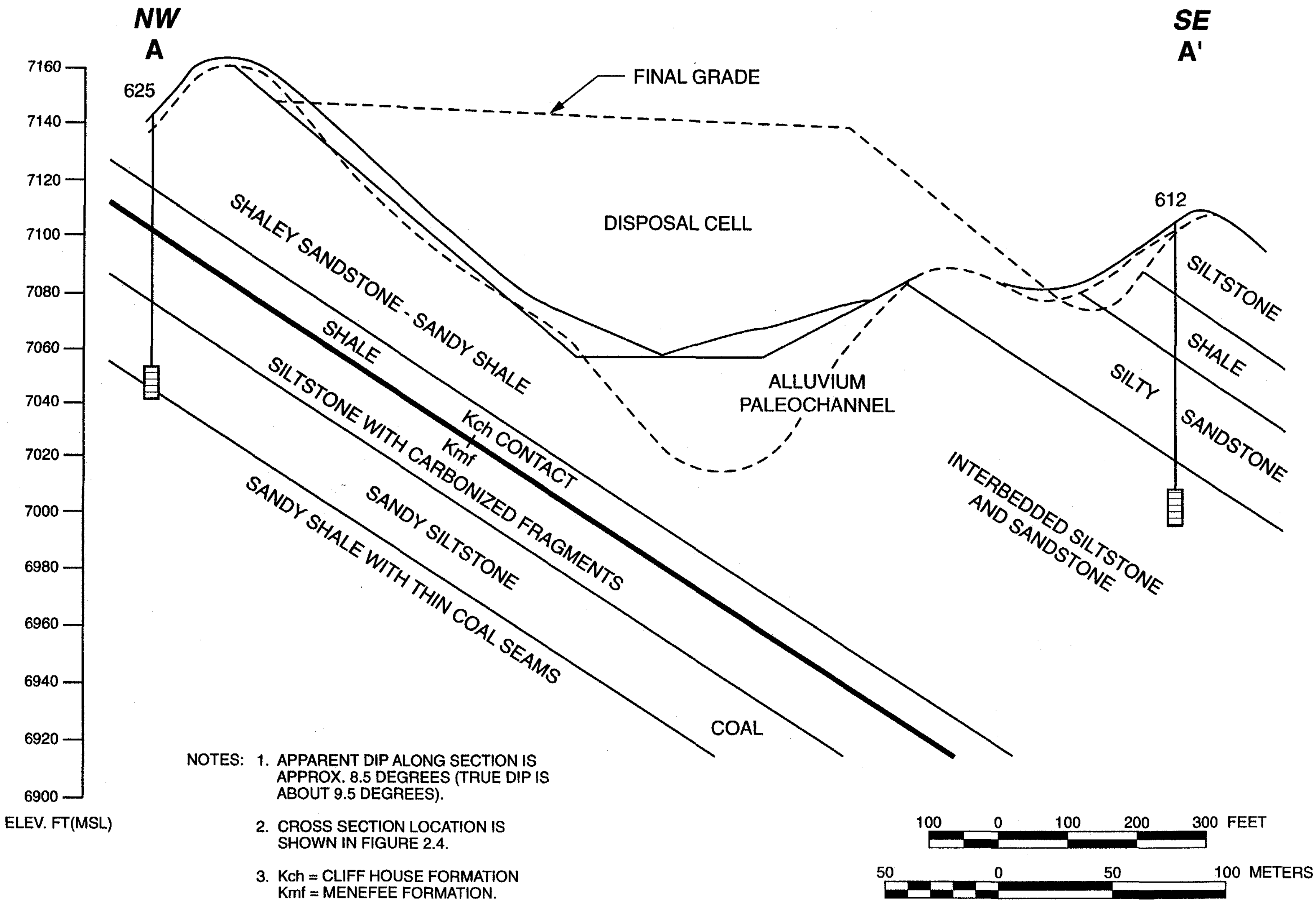
The Cliff House Sandstone is underlain by the Menefee Formation, which is between 250 and 350 ft (90 and 120 m) thick. The Menefee Formation appears at the ground surface only in the arroyo at the extreme northeast corner of the site. Contact between the lower unit of the Cliff House Sandstone and the 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 the valley occupied by the Bodo Canyon disposal cell, from southwest to northeast (Figure 2.4). The paleochannel contains up to about 60 ft (15 m) of alluvium consisting of silty clay, silt, and sand with some sandstone and shale fragments (Figures 2.10 and 2.11). This alluvium thins and is absent along the sides of the ridges north and south of the disposal cell (Figure 2.10). The paleochannel joins the eastward-flowing arroyo north of the disposal cell.

Hydrology

Ground water - alluvium level. 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 per day (5.0 x 10-6 cm per second) 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 per day (10 m per 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



NOTES:
1. APPARENT DIP ALONG SECTION IS APPROX. 8.5 DEGREES (TRUE DIP IS ABOUT 9.5 DEGREES).
2. CROSS SECTION LOCATION IS SHOWN IN FIGURE 2.4.
3. Kch = CLIFF HOUSE FORMATION
Kmf = MENEFEE FORMATION.

FIGURE 2.10
SCHEMATIC CROSS SECTION A - A' (DUR-03)
BODO CANYON DISPOSAL SITE

MAC: SITE/DUR/WSAP/SCHM-XSEC(A-A')

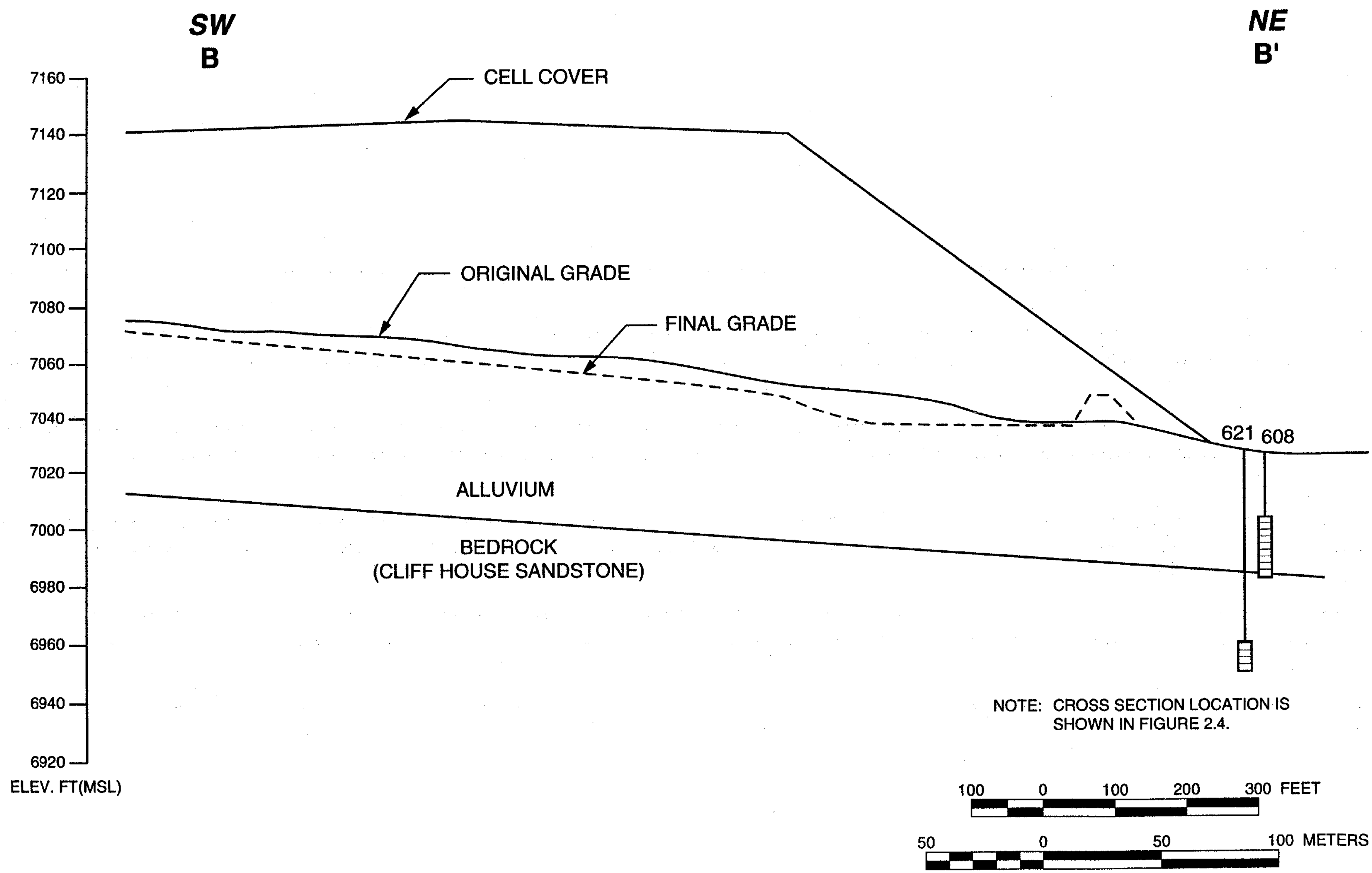


FIGURE 2.11
SCHEMATIC CROSS SECTION B - B' (DUR-03)
BODO CANYON DISPOSAL SITE

MAC: SITE/DUR/WSAP/SCHM-XSEC(B-B')

per year (0.2 m per year) near the middle of the valley to about 140 ft per year (40 m per year) near the northeast end of the valley.

The disposal cell fills more than 85 percent of the original valley (Figure 2.4). 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.

Ground water bedrock level. 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 aerial 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.

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 ponds area. The arroyo north of the disposal cell becomes South Creek in the raffinate ponds 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 WATER QUALITY

2.3.1 Background water quality

Mill tailings area (DUR-01)

Background ground water quality is defined as the quality of water if uranium milling activities had not taken place. Background ground water quality data for conditions at the mill tailings area are available from upgradient monitor well DUR-01-0629, completed in the colluvium overlying the Mancos Shale on Smelter Mountain, and private irrigation well DUR-01-0658, completed in alluvial gravel near Lightner Creek (Table 2.2 and Figure 2.12). Background ground water quality at the site is of two types: ground water occurring in colluvium above the Mancos Shale near the base of Smelter Mountain and ground water occurring in gravel near the streams. Monitor well DUR-01-0629 and private

Table 2.2 Summary of existing wells at the Durango processing and disposal sites

Location ID[a]	BOR ID[b]	Unit screened[c]	Screen interval (ft)	Screen interval (m)	Filter pack interval (ft)	Filter pack interval (m)	Dates sampled	Flow relation
Processing site mill tailings area (DUR-01)								
DUR-01-0612		Qal/Qco/Km	30-50	9-15	23-50	7-15	1982-94	Downgradient
DUR-01-0617		Qal/Km	14-29	4-9	12-32	3.5-10	1982-94	Downgradient
DUR-01-0622		Qal/Km	9-14	2.5-4	7-17.5	2-5.5	1982-94	Downgradient
DUR-01-0629		Qco/Km	9-19	3-6	7-21	2-6.5	1993-94	Upgradient
DUR-01-0630		Qal/Km	30-40	9-12	26-40	8-12	1994	Downgradient
DUR-01-0631		Qal/Km	6-16	2-5	4-16	1-5	1994	Downgradient
DUR-01-0632		Km	51-56	15.5-17	49-56	15-17	Not sampled	Downgradient
DUR-01-0633		Qal/Km	4-14	1-4	3-14	1-4	1994	Downgradient
DUR-01-0634		Qal/Km	8-18	25-5.5	6-18	2-5.5	1994	Downgradient
DUR-01-0635		Qal	6-16	2-5	4-16	1-5	1994-95	Downgradient
DUR-01-0658		Qal	Unknown		Unknown		1994	Upgradient
Raffinate ponds area (DUR-02)								
Quaternary deposits								
DUR-02-0607		Qal/Kmf	35-55	10.5-17	26-58	8-17.5	1982-94	Downgradient
DUR-02-0628		Qal/Kmf	5-32	1.5-10	7-33	2-10	1994	Downgradient
Mesaverde Group (bedrock)								
DUR-02-0599	DH-114	Kpl	35-65	10.5-20	21-69	6.5-21	1990-94	Upgradient
DUR-02-0600	DH-115	Kpl	37-87	11-26.5	33-89	10-27	1990-94	Upgradient
DUR-02-0596	DH-112	Kpl	19-59	6-18	9-64	3-19.5	1990-94	Downgradient
DUR-02-0595	DH-113	Kpl	21-51	6.5-15.5	16-61	5-18.5	1990-94	Downgradient
DUR-02-0597	DH-111	Kpl	18-58	5.5-17.5	18-62	5.5-19	1990-94	Downgradient
DUR-02-0603		Kpl	20-63	6-19	Open hole		1982-89	Downgradient
DUR-02-0594	DH-116	Kmf	9-39	3-12	7-39	2-12	1990-94	Downgradient

Table 2.2 Summary of existing wells at the Durango processing and disposal sites (Concluded)

Location ID[a]	BOR ID[b]	Unit screened[c]	Screen interval (ft)	Screen interval (m)	Filter pack interval (ft)	Filter pack interval (m)	Dates sampled	Flow relation
DUR-02-0602		Kmf	56-61	17-18.5	16-68	5-20.5	1982-94	Downgradient
DUR-02-0593	DH-117	Kmf	19-39	6-12	10-39	3-12	1990-94	Downgradient
DUR-02-0598	DH-110	Kpl/flt/Kmf	66-96	20-29	53-100	16-30	1990-94	Downgradient
DUR-02-0592	DH-118	Kpl/flt/Kmf	80-140	24.5-43	70-198	21-60.5	1990-94	Upgradient
Bodo Canyon disposal cell (DUR-03)								
DUR-03-0606		Qal	16-36	5-11	12-38	4-11.5	1987-94	downgradient
DUR-03-0608		Qal	33-43	10-13	27-43	8-13	1987-94	downgradient
DUR-03-0614		Qal	22-42	7-13	not available		1989-93	downgradient
DUR-03-0618		Qal	30-50	9-15	not available		1990-94	downgradient
DUR-03-0620		Qal	29-49	9-15	not available		1990-94	downgradient
DUR-03-0623		Qal	19-39	6-12	not available		1989-94	upgradient
DUR-03-0605		Kcf	40-60	12-18	32-61	10-19	1987-94	upgradient
DUR-03-0607		Kcf	39-59	12-18	27-62	8-19	1987-94	downgradient
DUR-03-0611		Kcf	108-118	33-36	102-121	31-37	1990-94	downgradient
DUR-03-0612		Kcf	98-108	30-33	88-111	27-34	1989-94	downgradient
DUR-03-0616		Kcf	89-99	27-30	82-101	25-31	1989-94	downgradient
DUR-03-0617		Kcf	80-90	24-27	74-91	22.5-28	not sampled	downgradient
DUR-03-0619		Kcf	79-89	24-27	73-93	22-28	not sampled	downgradient
DUR-03-0621		Kcf	78-88	23-27	73-90	22-27	1990-94	downgradient
DUR-03-0625		Kcf	89-99	27-30	83-101	25-31	1989-94	upgradient

[a]Location identifications in bold type are existing wells used for baseline risk assessment. Locations in plain type are decommissioned wells used to determine the extent of contamination.
[b]Bureau of Reclamation (BOR) wells used in baseline risk assessment.
[c]Qal = alluvium; Qco = colluvium; Kcf = Cliff House Formation; Km = Mancos Shale; Kmf = Menefee Formation; Kpl = Point Lookout Sandstone; flt = fault zone.

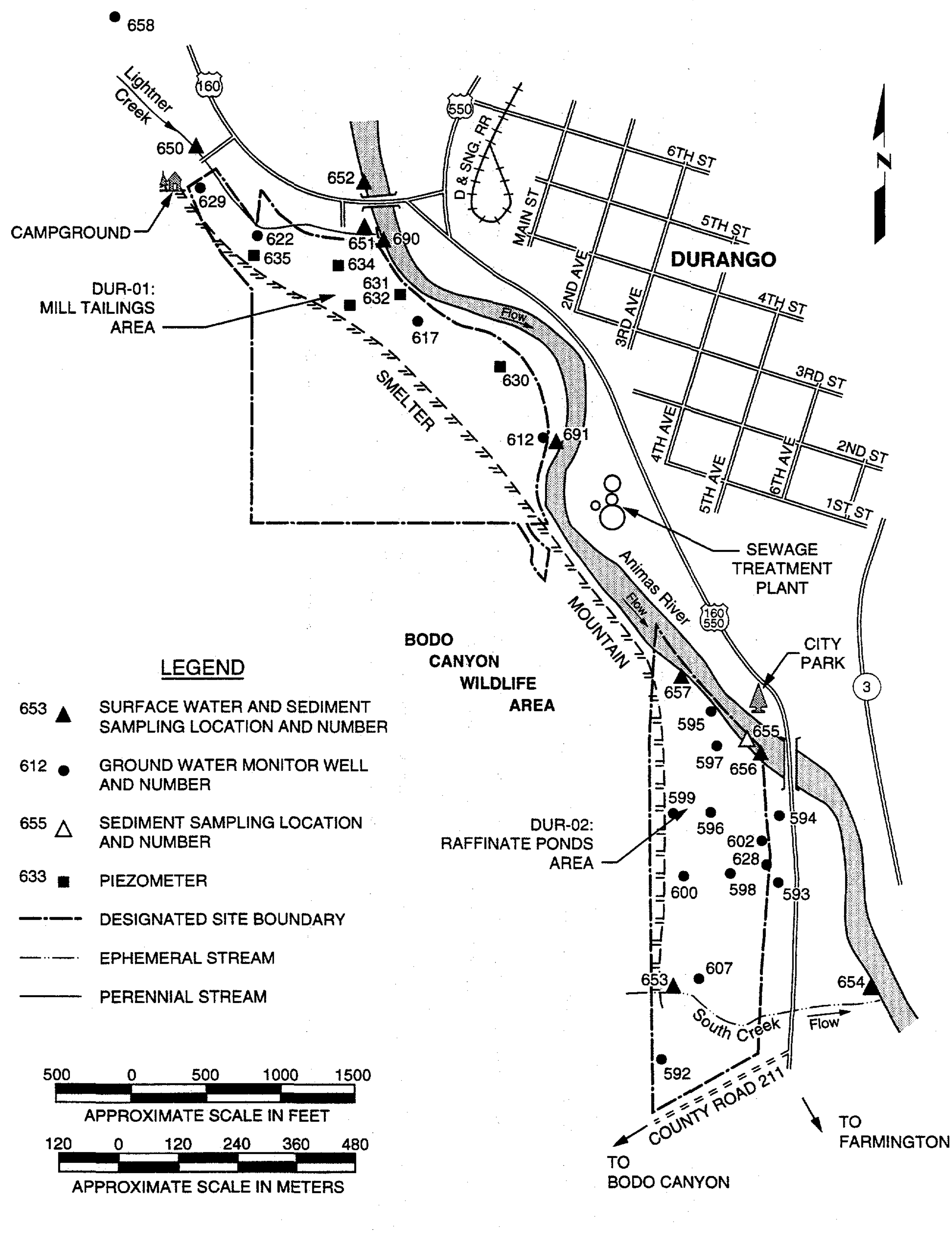


FIGURE 2.12
EXISTING MONITOR WELL, SURFACE WATER, AND SEDIMENT SAMPLING LOCATIONS IN THE FORMER MILL TAILINGS AREA AND RAFFINATE PONDS AREA DURANGO, COLORADO, SITE

MAC: SITE/DUR/WSAP/LOCMONWELL

well DUR-01-0658 represent the two types of background ground water at the site.

There are two rounds of data: one from monitor well DUR-01-0629 and one from private well DUR-01-0658 (Table 2.2). Because monitor well DUR-01-0629 is completed in clay-rich colluvial materials, it contains very little water and tends to pump dry during sampling events. Each time the well is pumped dry, the possibility of disturbance to the aquifer matrix exists and unfiltered sample results will not be representative of ground water conditions in the well. Private well DUR-01-0658, which is completed in alluvial gravel, has been in place for several years, is pumped regularly, and has much higher yields. Thus, private well DUR-01-0658 has been extensively developed and the aquifer matrix has stabilized. It is therefore reasonable to compare filtered data from monitor well DUR-01-0629 with unfiltered data from private well DUR-01-0658.

Background ground water quality data clearly show the two distinctly different water types and sources that contribute to the ground water in the colluvium and gravel material in the Durango mill tailings area (Table 2.3). Ground water in the colluvium close to the toe of Smelter Mountain represented by background monitor well DUR-01-0629, is a sodium-sulfate type (containing significant concentrations of calcium and magnesium) with relatively high total dissolved solids (TDS) (3500 milligrams per liter [mg/L]). By contrast, ground water in the gravely alluvium closer to the river, represented by background private well DUR-01-0658, is a calcium-bicarbonate type with low TDS (not species measured). The pH of ground water in both well is close to neutral (7.0 in well DUR-01-0629 and 7.08 in well DUR-01-0658). The difference in water chemistry between these two wells is likely related to equilibration of ground water in monitor well DUR-01-0629 with gypsum and clay minerals known to be present in colluvial materials.

<u>Raffinate ponds area (DUR-02)</u>

Before remediation, ground water in the area of the raffinate ponds was present in both the surficial deposits and the bedrock. At present, ground water in the raffinate ponds area occurs primarily in the bedrock units located beneath surficial deposits. Regional ground water quality data for the Mesaverde Group (Butler, 1986) are summarized in Table 2.4. These data are from an area of about 600 square miles (mi^2) (1550 square kilometers [km^2]) surrounding Durango and includes 35 ground water sampling locations. The regional data indicate that water quality is variable in the Mesaverde Group. For example, sulfate concentrations vary from 0.5 to 2000 mg/L and chloride concentrations vary from 1 to 93 mg/L. Several trace elements are present, including iron (averaging 0.89 mg/L), lead (averaging 0.033 mg/L), manganese (averaging 0.08 mg/L), and molybdenum (averaging 0.014 mg/L) (Table 2.4).

Near the site, background water quality data for the raffinate ponds area are available from one monitor well located in the far southwest corner of the site and upgradient of the raffinate ponds area (monitor well DUR-02-0592). This

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted)

		Filtered samples				Unfiltered samples	
Constituent[a]	Well ID	Frequency of detection[b]	Minimum (mg/L)	Median[c] (mg/L)	Maximum (mg/L)	Frequency of detection[b]	Maximum observed value (mg/L)
Inorganics							
Aluminum	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	1220.0005	<0.05	<0.10	NA	NA
	Plume 612	0/3	<0.05	<0.05	<0.10	NA	NA
	Plume 617	0/3	<0.05	<0.05	<0.10	NA	NA
Ammonium	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	1/2	<0.10	<0.15	<0.20	NA	NA
	Plume 617	1/2	<0.10	<0.15	<0.20	NA	NA
Antimony	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	1/4	<0.003	<0.007	0.022	1/1	0.025
	Plume 617	1/4	<0.003	<0.007	0.018	1/1	0.017
Arsenic	Bkg 629	0/1	NA	<0.005	NA	0/1	<0.005
	Bkg 658	NA	NA	NA	NA	0/1	<0.003
	Plume 612	0/7	<0.005	<0.01	<0.05	0/3	<0.01
	Plume 617	0/7	<0.005	<0.01	<0.05	0/3	<0.01
Barium	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	3/5	0.01	<0.03	<0.10	0/1	<0.10
	Plume 617	2/5	<0.01	<0.02	<0.10	0/1	<0.10

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

Constituent[a]	Well ID	Filtered samples: Frequency of detection[b]	Filtered samples: Minimum (mg/L)	Filtered samples: Median[c] (mg/L)	Filtered samples: Maximum (mg/L)	Unfiltered samples: Frequency of detection[b]	Unfiltered samples: Maximum observed value (mg/L)
Inorganics							
Beryllium	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/3	<0.005	<0.01	<0.01	0/1	<0.01
	Plume 617	0/3	<0.005	<0.01	<0.01	0/1	<0.01
Cadmium	Bkg 629	0/1	NA	<0.001	NA	0/1	<0.001
	Bkg 658	NA	NA	NA	NA	0/1	<0.001
	Plume 612	6/7	<0.001	0.038	0.070	3/3	<0.05
	Plume 617	1/7	<0.001	<0.001	0.003	0/3	<0.001
Calcium	Bkg 629	1/1	NA	278	NA	1/1	273
	Bkg 658	NA	NA	NA	NA	1/1	85
	Plume 612	7/7	226	424	477	3/3	451
	Plume 617	7/7	466	481	499	3/3	496
Chloride	Bkg 629	1/1	NA	23.9	NA	1/1	25.6
	Bkg 658	1/1	NA	NA	NA	1/1	8.2
	Plume 612	6/6	308	697	795	3/3	952
	Plume 617	6/6	50	67	75	3/3	66
Chromium	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/5	<0.01	<0.01	<0.01	0/1	<0.05
	Plume 617	0/5	<0.01	<0.01	<0.01	0/1	<0.05

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

		Filtered samples				Unfiltered samples	
Constituent[a]	Well ID	Frequency of detection[b]	Minimum (mg/L)	Median[c] (mg/L)	Maximum (mg/L)	Frequency of detection[b]	Maximum observed value (mg/L)
Inorganics							
Cobalt	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/3	<0.03	<0.05	<0.05	0/1	<0.05
	Plume 617	0/3	<0.03	<0.05	<0.05	0/1	<0.05
Copper	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/5	<0.01	<0.01	<0.02	0/1	<0.02
	Plume 617	0/5	<0.01	<0.01	<0.02	0/1	<0.02
Cyanide	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/3	<0.01	<0.01	<0.01	NA	NA
	Plume 617	0/3	<0.01	<0.01	<0.01	NA	NA
Fluoride	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	5/5	1.3	1.4	1.6	1/1	1.2
	Plume 617	5/5	0.6	0.8	0.8	1/1	0.6
Iron	Bkg 629	1/1	NA	0.28	NA	1/1	3.12
	Bkg 658	NA	NA	NA	NA	1/1	0.20
	Plume 612	2/7	<0.03	<0.03	0.12	2/3	1.3
	Plume 617	3/7	<0.03	<0.03	0.15	3/3	5.2

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

		Filtered samples				Unfiltered samples	
Constituent[a]	Well ID	Frequency of detection[b]	Minimum (mg/L)	Median[c] (mg/L)	Maximum (mg/L)	Frequency of detection[b]	Maximum observed value (mg/L)
Inorganics							
Lead	Bkg 629	0/1	NA	<0.003	NA	0/1	<0.003
	Bkg 658	NA	NA	NA	NA	0/1	<0.003
	Plume 612	1/7	<0.003	<0.01	0.02	1/3	0.012
	Plume 617	0/7	<0.003	<0.01	<0.03	1/3	0.042
Magnesium	Bkg 629	1/1	NA	215	NA	1/1	205
	Bkg 658	NA	NA	NA	NA	1/1	20
	Plume 612	7/7	139	279	309	3/3	301
	Plume 617	7/7	209	224	278	3/3	241
Manganese	Bkg 629	1/1	NA	0.16	NA	1/1	0.26
	Bkg 658	NA	NA	NA	NA	0/1	<0.01
	Plume 612	7/7	1.8	5.5	6.7	3/3	6.2
	Plume 617	5/7	<0.01	0.02	0.04	3/3	0.11
Mercury	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/6	<0.0002	<0.0002	<0.0002	0/2	<0.0002
	Plume 617	0/6	<0.0002	<0.0002	<0.0002	0/2	<0.0002
Molybdenum	Bkg 629	1/1	NA	0.01	NA	0/1	<0.01
	Bkg 658	NA	NA	NA	NA	0/1	<0.01
	Plume 612	7/7	0.13	0.13	0.21	3/3	0.13
	Plume 617	2/7	<0.01	<0.01	0.05	0/3	<0.01

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

		Filtered samples				Unfiltered samples	
Constituent[a]	Well ID	Frequency of detection[b]	Minimum (mg/L)	Median[c] (mg/L)	Maximum (mg/L)	Frequency of detection[b]	Maximum observed value (mg/L)
Inorganics							
Nitrate	Bkg 629	0/1	NA	NA	NA	0/1	<1.0
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	5/5	2.0	5.0	12	2/2	7.0
	Plume 617	5/5	1.0	4.4	28	2/2	8.4
Nickel	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/5	<0.04	<0.04	<0.04	0/1	<0.04
	Plume 617	0/5	<0.04	<0.04	<0.04	0/1	<0.04
Potassium	Bkg 629	1/1	NA	4.57	NA	1/1	4.78
	Bkg 658	1/1	NA	NA	NA	1/1	2.3
	Plume 612	7/7	16	30	34	3/3	33
	Plume 617	7/7	17	19	22	3/3	22
Selenium	Bkg 629	0/1	NA	<0.005	NA	0/1	<0.005
	Bkg 658	0/1	NA	NA	NA	0/1	<0.005
	Plume 612	5/7	0.008	0.034	0.09	3/3	0.08
	Plume 617	7/7	0.007	0.087	0.16	3/3	0.08
Silica	Bkg 629	1/1	NA	9.7	NA	1/1	13.8
	Bkg 658	1/1	NA	NA	NA	1/1	7.1
	Plume 612	2/2	22	23	23	2/2	23
	Plume 617	2/2	14	14	15	2/2	29

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

		Filtered samples				Unfiltered samples	
Constituent[a]	Well ID	Frequency of detection[b]	Minimum (mg/L)	Median[c] (mg/L)	Maximum (mg/L)	Frequency of detection[b]	Maximum observed value (mg/L)
Inorganics							
Silver	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	1/5	<0.01	<0.01	0.01	0/1	<0.01
	Plume 617	0/5	<0.01	<0.01	<0.01	0/1	<0.01
Sodium	Bkg 629	1/1	NA	473	NA	1/1	478
	Bkg 658	NA	NA	NA	NA	1/1	25
	Plume 612	7/7	516	1120	1200	3/3	1190
	Plume 617	7/7	231	271	288	3/3	287
Strontium	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	3/3	3.3	3.4	3.7	NA	NA
	Plume 617	3/3	3.3	3.4	3.6	NA	NA
Sulfate	Bkg 629	1/1	NA	1860	NA	1/1	1830
	Bkg 658	NA	NA	NA	NA	1/1	83
	Plume 612	6/6	1540	3110	3290	3/3	NA
	Plume 617	6/6	2080	2160	2230	3/3	2250
Sulfide	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/3	<0.1	<0.1	<0.1	NA	NA
	Plume 617	0/3	<0.1	<0.1	<0.1	NA	NA

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

		Filtered samples				Unfiltered samples	
Constituent[a]	Well ID	Frequency of detection[b]	Minimum (mg/L)	Median[c] (mg/L)	Maximum (mg/L)	Frequency of detection[b]	Maximum observed value (mg/L)
Inorganics							
Thallium	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	0/4	<0.01	<0.01	<0.03	0/3	<0.01
	Plume 617	0/4	<0.005	<0.01	<0.03	0/2	<0.01
Tin	Bkg 629	NA	NA	NA	NA	NA	NA
	Bkg 658	NA	NA	NA	NA	NA	NA
	Plume 612	1/3	<0.005	<0.015	0.015	1/1	0.015
	Plume 617	1/3	<0.005	<0.007	0.007	1/1	0.006
Uranium	Bkg 629	1/1	NA	0.002	NA	1/1	0.002
	Bkg 658	NA	NA	NA	NA	1/1	0.002
	Plume 612	6/6	1.5	3.0	3.8	3/3	4.0
	Plume 617	7/7	0.12	0.25	0.28	3/3	0.29
Vanadium	Bkg 629	0/1	NA	<0.01	NA	1/1	<0.01
	Bkg 658	NA	NA	NA	NA	0/1	<0.01
	Plume 612	7/7	0.31	0.47	0.53	3/3	0.52
	Plume 617	1/7	<0.01	<0.01	0.01	0/3	<0.01
Zinc	Bkg 629	0/1	NA	<0.05	NA	1/1	0.08
	Bkg 658	NA	NA	NA	NA	1/1	0.11
	Plume 612	7/7	0.88	2.6	3.3	3/3	3.2
	Plume 617	7/7	0.060	0.085	0.15	3/3	0.20

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Continued)

Constituent[a]	Well ID	Number of samples	Minimum (pCi/L)	Median[c] (pCi/L)	Maximum (pCi/L)
Radionuclides[d]					
Lead-210	Bkg 629	1	NA	3.6	NA
	Bkg 658	0	NA	NA	NA
	Plume 612	2	0.4	2.4	4.4
	Plume 617	2	0.6	1.8	3.0
Polonium-210	Bkg 629	1	NA	0.1	NA
	Bkg 658	0	NA	NA	NA
	Plume 612	2	0.1	0.1	0.1
	Plume 617	2	0.0	0.1	0.2
Radium-226	Bkg 629	1	NA	1.0	NA
	Bkg 658	1	NA	0.1	NA
	Plume 612	3	0.0	0.1	1.2
	Plume 617	3	0.0	0.2	0.2
Radium-228[e]	Bkg 629	1	NA	0.0	NA
	Bkg 658	1	NA	0.0	NA
	Plume 612	3	0.0	0.7	1.1
	Plume 617	3	0.0	0.4	1.0

Table 2.3 Summary of ground water quality data at the mill tailings area (DUR-01) at Durango, Colorado, May 1990 - June 1994 (filtered samples, except as noted) (Concluded)

Constituent[a]	Well ID	Number of samples	Minimum (pCi/L)	Median[c] (pCi/L)	Maximum (pCi/L)
Radionuclides[d]					
Thorium-230	Bkg 629	1	NA	1.8	NA
	Bkg 658	0	NA	NA	NA
	Plume 612	2	0.4	0.6	0.8
	Plume 617	2	0.7	1.3	1.8

[a]Water quality data from unfiltered water samples are presented for all constituents for domestic well DUR-01-0658 and for radionuclides in all wells. One to three analyses of unfiltered water samples from wells DUR-01-0629, -0612, and -0617 are available for some, but not all, constituents.

[b]Frequency of detection = number of samples with reported concentrations at or above the detection limit/total number of samples.

[c]The median is the 50th percentile of the data. When only two data are available, the reported median is the arithmetic mean of the two values. For parameters having only one round of sampling data, the single reported value is listed in the median column.

[d]Samples for radionuclides are unfiltered.

[e]A statistical comparison between background and plume data was not done because of the small number of samples and potentially large counting errors.

Bkg – background.
NA – no data available.
mg/L – milligrams per liter.
pCi/L – picocuries per liter.

Table 2.4 Comparison of regional ground water quality data for the Mesaverde Group to background water quality data from the raffinate ponds area[a]

	Mesaverde Group[b]			Raffinate ponds area Background well DUR-02-592		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Depth (feet)	57	426	158	80	140	110
Depth (meters)	17	130	48	24	43	34
Parameter						
Alkalinity	102	1010	515	740	820	773
Arsenic	<0.001	0.003	<0.001	<0.005	<0.005	<0.005
Boron	0.02	0.42	0.18	NA	NA	NA
Calcium	0.6	340	63	110	120	115
Cadmium	<0.001	0.004	<0.002	<0.0001	<0.005	<0.003
Chloride	1.2	93	15	62	69	66
Copper	<0.001	0.017	0.003	<0.005	<0.005	<0.005
Fluoride	0.1	4.3	1.3	NA	NA	NA
Iron	<0.01	20	0.89	0.02	0.02	0.02
Lead	<0.001	0.160	0.033	<0.001	<0.005	<0.005
Magnesium	<0.1	280	37	150	160	155
Manganese	<0.01	1.1	0.08	0.05	0.07	0.06
Mercury	<0.0001	0.002	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	<0.001	0.025	0.014	<0.01	<0.01	<0.01
Nickel	<0.001	0.025	0.004	<0.001	<0.02	<0.02
Nitrate	0.09	7.1	0.7	<0.2	<0.2	.3
pH	6.3	8.7	7.5	7.6	8.0	8.0
Potassium	0.6	23	3.3	5.7	6.6	6.2
Silica	7	22	12	8.5	9.0	9
Sodium	8	670	238	240	250	245
Sulfate	0.5	2000	293	560	680	650
TDS	130	3300	976	1700	1700	1700

[a]All data in milligrams per liter except for pH (standard units).
[b]Mesaverde Group data from Butler, 1986.

NA – not analyzed.

monitor well is separated from the site by South Creek, which would have acted as a barrier to any contaminant migration caused by development of a ground water mound during operations at the raffinate ponds area. Also, the monitor well is located in an area unaffected by surface operations associated with former uranium processing and surface remediation. Monitor well DUR-02-0592 is screened across a fault contact between the Menefee and Point Lookout Sandstone and thus produces ground water from both units and the intervening fault zone. A comparison of the water quality from this well to regional ground water quality in the Mesaverde Group indicates that ground water from DUR-02-0592 is within the range of regional ground water quality for all measured constituents (Tables 2.4 and 2.5).

Trace elements and heavy metals are generally not present at levels above detection limits in the background well (Tables 2.4 and 2.5). The pH of the water is above neutral (about 8 pH), and the TDS is about 1700 mg/L.

<u>Bodo Canyon disposal cell (DUR-03)</u>

Before construction of the disposal cell, all wells at the disposal site were considered background wells. Since then, there has been no evidence of contamination of ground water in any well at the disposal site, and thus, all data collected from 1987 through 1994 have been used to further characterize background water quality (DOE, 1995a). Analytical data indicate background water quality is different in the alluvium and the bedrock. Variations also occur in bedrock water quality.

The alluvial aquifer is a calcium-magnesium-sulfate water quality type as represented by monitor wells DUR-03-0606, -0608, and -0623. 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 DUR-03-0605 and -0607), to a sodium-bicarbonate water at intermediate depths (monitor wells DUR-03-0611, -0612, -0625 and -0621), to a sodium-sulfate type in the deepest well (former monitor well DUR-03-0603).

The median TDS in alluvial monitor wells ranges from approximately 1500 to 2300 mg/L, median pH ranges from 6.9 to 7.1, and the redox potentials range from 135 to 380 millivolts (mV). Of the constituents with maximum concentration limits (MCL), only lead, selenium and radium-226 plus radium-228 have exceeded their MCLs. These exceedances have generally occurred only once, and subsequent analyses have not confirmed these exceedances. Trace elements and heavy metals are generally not present at levels above detection limits in the downgradient monitor wells (TAC, 1994a).

Background water quality in the bedrock aquifer is summarized in Table 2.6. Overall, in bedrock (Cliff House Formation) wells, TDS ranges from approximately 932 to 5080 mg/L, while pH ranges from 4.7 to 11.1, and the measured redox potential ranges from 218 to 769 mV. In bedrock well DUR-03-0625, which is also upgradient of the disposal cell, the measured TDS

Table 2.5 Summary of ground water quality data at the raffinate ponds area (DUR-02) at Durango, Colorado, May 1990 - June 1994

Constituent	Well ID[c]	Filtered samples: Frequency of detection[d]	Filtered samples: Minimum (mg/L)	Filtered samples: Median[a] (mg/L)	Filtered samples: Maximum[b] (mg/L)	Unfiltered samples: Frequency of detection[d]	Unfiltered samples: Maximum observed value (mg/L)
Inorganics							
Aluminum	Bkg 592	0/4	<0.1	<0.1	<0.1	NA	NA
	Plume	0/11	<0.05	<0.1	<1.0	NA	NA
Ammonium[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	2/2	3.1	3.2	3.3	NA	NA
Antimony[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	1/4	<0.003	<0.025	0.166	1/1	0.196
Arsenic	Bkg 592	0/4	<0.005	<0.005	<0.005	NA	NA
	Plume	1/17	<0.005	<0.01	0.04	1/4	0.04
Barium	Bkg 592	1/4	<0.05	<0.05	0.06	NA	NA
	Plume	1/13	<0.01	<0.05	0.05	1/1	<0.10
Beryllium[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	0/3	<0.005	<0.01	<0.01	0/1	<0.01
Cadmium	Bkg 592	0/4	<0.0001	<0.003	<0.005	NA	NA
	Plume	3/17	<0.0001	f	0.0009	0/4	<0.001
Calcium	Bkg 592	4/4	110	115	120	NA	NA
	Plume	17/17	339	416	491	4/4	475
Chloride	Bkg 592	4/4	62	66	69	NA	NA
	Plume	15/15	1100	2000	2400	5/5	2380

Table 2.5 Summary of ground water quality data at the raffinate ponds area (DUR-02) at Durango, Colorado, May 1990 - June 1994 (Continued)

Constituent	Well ID[c]	Filtered samples: Frequency of detection[d]	Filtered samples: Minimum (mg/L)	Filtered samples: Median[a] (mg/L)	Filtered samples: Maximum[b] (mg/L)	Unfiltered samples: Frequency of detection[d]	Unfiltered samples: Maximum observed value (mg/L)
Inorganics							
Chromium	Bkg 592	0/4	<0.005	<0.005	<0.005	NA	NA
	Plume	2/13	<0.005	f	0.006	0/1	<0.01
Cobalt	Bkg 592	0/4	<0.005	<0.005	<0.005	NA	NA
	Plume	1/11	<0.005	<0.005	0.005	0/1	0.05
Copper	Bkg 592	0/4	<0.005	<0.005	<0.005	NA	NA
	Plume	2/13	<0.005	<0.01	0.011	0/1	<0.02
Cyanide[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	0/3	<0.01	<0.01	<0.01	NA	NA
Fluoride[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	5/5	<0.1	0.2	0.4	1/1	0.2
Iron[g]	Bkg 592	4/4	0.02	0.02	0.02	NA	NA
	Plume (598)	6/6	1.8	2.4	2.5	5/5	2.96
Lead	Bkg 592	0/4	<0.001	<0.005	<0.005	NA	NA
	Plume	2/17	<0.002	<0.021	0.070	0/4	<0.01
Magnesium[g]	Bkg 592	4/4	150	155	160	NA	NA
	Plume (598, 602)	13/13	481	590	724	4/4	644
Manganese[g]	Bkg 592	4/4	0.052	0.057	0.070	NA	NA
	Plume (593)	4/4	4.7	6.6	7.3	4/4	2.5

Table 2.5 Summary of ground water quality data at the raffinate ponds area (DUR-02) at Durango, Colorado, May 1990 - June 1994 (Continued)

Constituent	Well ID[c]	Filtered samples: Frequency of detection[d]	Filtered samples: Minimum (mg/L)	Filtered samples: Median[a] (mg/L)	Filtered samples: Maximum[b] (mg/L)	Unfiltered samples: Frequency of detection[d]	Unfiltered samples: Maximum observed value (mg/L)
Inorganics							
Mercury	Bkg 592	0/4	<0.0001	<0.0001	<0.0001	0/4	<0.0001
	Plume	0/17	<0.0001	<0.0001	<0.0002	1/12	<0.0002
Molybdenum	Bkg 592	0/4	<0.01	<0.01	<0.01	NA	NA
	Plume	3/17	<0.01	<0.01	0.10	0/4	<0.01
Nitrate[g]	Bkg 592	1/2	<0.22	<0.38	0.53	NA	NA
	Plume (602)	3/5	<1.0	1.8	13.7	0/3	<1.0
Nickel	Bkg 592	0/4	<0.001	<0.013	<0.02	NA	NA
	Plume	4/13	0.005	<0.02	0.025	0/1	<0.04
Potassium	Bkg 592	4/4	5.8	6.2	6.6	NA	NA
	Plume	17/17	5.1	49	82	4/4	68
Selenium	Bkg 592	0/4	<0.005	<0.028	<0.05	NA	NA
	Plume	4/7	<0.005	<0.05	0.08	2/4	0.07
Silica[e]	Bkg 592	4/4	8.5	8.6	9.0	NA	NA
	Plume (602)	2/2	23.1	24.0	24.9	4/4	22.8
Silver[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	0/5	<0.01	<0.01	<0.01	0/1	<0.01
Sodium[g]	Bkg 592	4/4	240	245	250	NA	NA
	Plume (593)	4/4	3500	4200	4600	4/4	3370

Table 2.5 Summary of ground water quality data at the raffinate ponds area (DUR-02) at Durango, Colorado, May 1990 - June 1994 (Continued)

		Filtered samples				Unfiltered samples	
Constituent	Well ID[c]	Frequency of detection[d]	Minimum (mg/L)	Median[a] (mg/L)	Maximum[b] (mg/L)	Frequency of detection[d]	Maximum observed value (mg/L)
Inorganics							
Strontium[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	3/3	7.0	10	11	NA	NA
Sulfate[g]	Bkg 592	4/4	560	680	680	NA	NA
	Plume (593, 598)	9/9	7310	8600	10,000	4/4	7740
Sulfide[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	1/3	<0.1	<0.1	0.3	NA	NA
Thallium[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (598, 602)	2/5	<0.005	<0.025	0.06	0/3	<0.01
Tin[e]	Bkg 592	NA	NA	NA	NA	NA	NA
	Plume (602)	2/3	0.007	<0.05	0.089	1/1	0.133
Uranium[g,h] (Total)	Bkg 592	1/4	0.0004	<0.005	<0.005	1/4	NA
	Plume (598)	2/2	0.22	<0.29	0.35	6/6	0.57
Vanadium	Bkg 592	0/4	<0.005	<0.005	<0.005	NA	NA
	Plume	5/17	<0.005	<0.01	0.06	0/4	<0.01
Zinc[g]	Bkg 592	2/4	<0.005	<0.006	0.028	NA	NA
	Plume (593, 598)	8/10	<0.044	0.073	0.25	3/4	0.11

Table 2.5 Summary of ground water quality data at the raffinate ponds area (DUR-02) at Durango, Colorado, May 1990 - June 1994 (Concluded)

Constituent	Well ID[c]	Number of samples	Minimum (pCi/L)	Median[a] (pCi/L)	Maximum[b] (pCi/L)
Radionuclides[i]					
Lead-210[e]	Bkg 592	NA	NA	NA	NA
	Plume (598, 602)	4	0.0	0.0	2.1
Polonium-210[e]	Bkg 592	NA	NA	NA	NA
	Plume (598, 602)	4	0.0	0.1	0.1
Radium-226	Bkg 592	4	0.1	0.3	0.6
	Plume	13	0.0	0.2	0.8
Radium-228[e,j]	Bkg 592	4	0.1	0.4	0.7
	Plume (593)	4	0.6	1.2	3.4
Thorium-230	Bkg 592	4	0.0	0.0	0.4
	Plume	12	0.0	0.5	4.5

[a]The median is the 50th percentile of the data.
[b]The reported maximum is the largest concentration above detection limits.
[c]Background well is BOR monitor well DUR-02-0592. Plume well results combine data from BOR monitor wells DUR-02-0593 and -0598 and DOE monitor well DUR-02-0602 unless otherwise specified.
[d]Frequency of detection = number of samples with reported concentration at or above the detection limit/total number of samples.
[e]Plume wells specified are the only wells for which chemical analysis data are available.
[f]Due to a large number of analyses conducted with high detection limits, the median of the data cannot be reliably estimated.
[g]Plume well(s) specified have significantly higher concentrations than the other plume wells.
[h]Unfiltered water samples were used to evaluate uranium concentrations. The reported minimum and median values for unfiltered uranium in background ground water are 0.004 and <0.005 mg/L, respectively. For unfiltered uranium samples in the plume (well DUR-02-0598), minimum and median values are 0.20 and 0.31 mg/L, respectively.
[i]Radionuclide samples are unfiltered.
[j]A statistical comparison between background and plume data was not done because of the small number of samples and potentially large counting errors.

Note: Water quality data from unfiltered water samples are presented for radiochemical constituents (uranium, polonium-210, lead-210, radium-226, and thorium-230). One to three analyses of unfiltered water samples for inorganic constituents from wells DUR-02-0598 and/or -0602 are available for some, but not all, constituents.

mg/L – milligrams per liter.
NA – no data available.
pCi/L – picocuries per liter.

Table 2.6 Summary of water quality data for tailings solutions, background ground water, and toe drain effluent (DUR-03), Bodo Canyon disposal site, Durango, Colorado

Parameter	Frequency of detection	Minimum	Median	Maximum
MAJOR ELEMENTS AND FIELD PARAMETERS				
Alkalinity				
Tailings	15/15	303	590	770
Background	94/94	2	694	2032
Toe drain	1/1	--	593	--
Calcium				
Tailings	15/15	513	583	609
Background	83/88	2	161	545
Toe drain	1/1	--	--	--
Chloride				
Tailings	15/15	59	75	210
Background	85/85	6	36	428
Toe drain	1/1	--	70	--
Iron				
Tailings	15/15	0.09	0.14	0.63
Background	80/88	0.02	0.33	452
Toe drain	1/1	--	0.13	--
Magnesium				
Tailings	15/15	41	69	166
Background	88/88	1.2	143	458
Toe drain	1/1	--	62	--
Manganese				
Tailings	15/15	3.0	6.0	8.6
Background	84/92	<0.01	0.06	6.0
Toe drain	1/1	--	4.5	--
pH				
Tailings	15/15	6.29	6.63	7.57
Background	97/97	4.72	6.88	11.14
Toe drain	1/1	--	7.65	--
Oxydation-reduction potential				
Tailings	0/0	-	NA	--
Background	43/43	353	204	768
Toe drain	0/0	--	NA	--
Potassium				
Tailings	15/15	13	17	31
Background	88/88	3.4	7.2	40
Toe drain	1/1	--	18	--

Table 2.6 Summary of water quality data for tailings solutions, background ground water, and toe drain effluent (DUR-03), Bodo Canyon disposal site, Durango, Colorado (Continued)

Parameter	Frequency of detection	Minimum	Median	Maximum
Sodium				
Tailings	15/15	122	228	727
Background	88/88	105	326	1370
Toe drain	1/1	--	238	--
Sulfate				
Tailings	15/15	1540	1710	2800
Background	79/79	23	925	4000
Toe drain	1/1	--	1770	--
Total dissolved solids				
Tailings	15/15	2790	3250	5080
Background	79/79	932	2750	7440
Toe drain	1/1	--	3200	--
LISTED HAZARDOUS CONSTITUENTS (Table A and Appendix I, 40 CFR Part 192)				
Antimony				
Tailings	0/0	--	NA	--
Background	9/46	<0.003	<0.003	0.027[b]
Toe drain	1/1	--	<0.003	--
Arsenic[a]				
Tailings	15/15	0.09	0.19	0.57
Background	12/92	<0.001	<0.01	0.03[b]
Toe drain	1/1	--	0.34	--
Barium				
Tailings	0/15	<0.10	<0.10	<0.10
Background	27/72	<0.01	<0.10	0.90
Toe drain	1/1	--	<0.01	--
Beryllium[a]				
Tailings	5/15	<0.01	<0.01	0.16
Background	5/52	<0.005	<0.01	0.023
Toe drain	1/1	--	<0.01	--
Cadmium[a]				
Tailings	15/15	<0.014	0.037	0.063
Background	14/92	<0.001	<0.001	0.019
Toe drain	1/1	--	0.019	--

Table 2.6 Summary of water quality data for tailings solutions, background ground water, and toe drain effluent (DUR-03), Bodo Canyon disposal site, Durango, Colorado (Continued)

Parameter	Frequency of detection	Minimum	Median	Maximum
Chromium[a]				
Tailings	5/15	<0.01	<0.01	0.26
Background	6/72	<0.01	<0.01	0.12
Toe drain	1/1	--	<0.01	--
Cyanide				
Tailings	0/10	<0.01	<0.01	<0.01
Background	1/30	<0.01	<0.01	0.18
Toe drain	0/0	--	NA	--
Lead				
Tailings	7/15	<0.01	<0.01	0.02
Background	9/88	<0.001	<0.01	0.02[b]
Toe drain	1/1	--	<0.01	--
Nitrate				
Tailings	9/15	<1.0	1.6	22
Background	38/87	<0.1	<1.0	43
Toe drain	1/1	--	<0.1	--
Mercury[a]				
Tailings	5/15	<0.0002	<0.0002	0.0004
Background	4/68	<0.0002	<0.0002	0.0004
Toe drain	1/1	--	<0.0002	--
Molybdenum[a]				
Tailings	5/15	0.81	1.73	3.98
Background	25/92	<0.01	<0.01	0.22
Toe drain	1/1	--	1.69	--
Nickel[a]				
Tailings	3/5	<0.04	0.04	0.07
Background	7/58	<0.01	<0.04	0.07
Toe drain	1/1	--	0.060	--
Net gross alpha				
Tailings	1/15	0.0	0.0	.67
Background	48/82	0.0	2.9	35
Toe drain	0/0	--	NA	--
Radium-226[a]				
Tailings	15/15	5.9	9.9	18
Background	12/90	<0.1	<1.0	2.0
Toe drain	1/1	--	14.0	--

Table 2.6 Summary of water quality data for tailings solutions, background ground water, and toe drain effluent (DUR-03), Bodo Canyon disposal site, Durango, Colorado (Concluded)

Parameter	Frequency of detection	Minimum	Median	Maximum
Radium-228				
Tailings	0/15	<1.0	<1.0	<1.0
Background	20/90	<0.9	<1.0	15
Toe drain	1/1	--	1.0	--
Selenium[a]				
Tailings	15/15	0.045	0.13	0.41
Background	18/92	<0.001	<0.005	0.042[b]
Toe drain	1/1	--	0.093	--
Silver[a]				
Tailings	7/15	<0.01	<0.01	0.07
Background	2/68	<0.01	<0.01	0.03
Toe drain	1/1	--	0.01	--
Thallium				
Tailings	0/15	<0.01	<0.01	<0.01
Background	1/35	<0.01	<0.01	0.01[b]
Toe drain	1/1	--	<0.01	--
Uranium[a]				
Tailings	15/15	1.5	4.5	22
Background	53/89	<0.001	0.001	0.077
Toe drain	1/1	--	4.0	--
Vanadium[a]				
Tailings	5/5	5.7	11	14
Background	27/79	<0.01	<0.01	0.06
Toe drain	1/1	--	14	--

[a]Constituents in tailings having concentrations significantly greater than that background (at the 95 percent confidence level).
[b]Maximum observed above detection.

Notes:
1. All data in mg/L except for the following: Net gross alpha, radium-226 and radium-228 in picocuries per liter (pCi/L); pH in standard units; oxydation-reduction potential in millivolts.
2. Data for background are from wells completed in the bedrock aquifer (monitor wells -0605, -0607, -0609, -0611, -0612, -0613, -0616, -0617, -0621, and -0625). Data are for filtered samples collected during the period from 1987 through 1994.
3. Data for tailings solutions are from wells completed within the disposal cell (monitor wells -0200, -0201, -0202, and -203, -0204). Data are for filtered samples collected during the period from 1987 through 1990.
4. Data for the toe drain effluent from Remedial Action Plan, Attachment 3, Table 3.22 (DOE, 1991).

NA – indicates not analyzed.

range from approximately 900 to 1300 mg/L, the pH ranges from 7.6 to 8.0, and the redox potential ranges from approximately 150 to 260 mV.

The TDS in downgradient bedrock wells DUR-03-0607, -0611, and -0612 to the southeast of the cell range from approximately 1000 to 5500 mg/L, while pH ranges from 5.5 to 7.8, and the redox potentials range from approximately 140 to 440 mV.

Trace elements detected, at least once, in bedrock monitoring wells, include antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, molybdenum, nickel, radium-226, radium-228, selenium, silver, thallium, uranium, and vanadium. Of the constituents with MCLs, cadmium, chromium, molybdenum, radium-226 plus radium-228, and uranium have exceeded their MCLs at least once, though median concentrations are generally below both method detection limits and MCLs for these constituents.

Water quality in POC well -0621 is notable because of its acidity (pH of about 4.9). The acid ground water in well -0621 and adjacent well -0616 is thought to be associated with the natural oxidation of pyrite (iron sulfide) occurring in the bedrock aquifer. The naturally acid water is associated with high levels of dissolved iron (up to 452 mg/L), manganese (up to 6.04 mg/L), sulfate (up to 4000 mg/L) and sulfide (up to 16 mg/L). Indicators of ground water contamination from tailings solutions (uranium, molybdenum, and selenium) are not present at levels above background in these to wells. Future interpretation of water quality in POC well -0621 should take into account the naturally acidic conditions in this well.

2.3.2 Contaminant delineation

Mill tailings area (DUR-01)

The primary source of ground water contamination in the mill tailings area were the large and small tailings piles (Figure 2.13). Surface remediation removed these sources of contamination. Using constituents that are known to be related to uranium processing at the site, it appears that contamination has been slowly moving downgradient in two primary plumes, one associated with each tailings pile. For example, Figure 2.14 is a November 1983 spacial distribution map for sulfate. The November 1994 sulfate data are also presented for comparison. There appears to be a general decrease in sulfate levels related to remediation; contamination decreased in the areas of wells -0612, -0626, -0618 and perhaps -0619. Contamination is increasing in monitor well DUR-01-0617, possibly due to downgradient migration of contaminants from the small tailings pile. Monitor well DUR-01-0612 currently has the highest levels of most constituents (Table 2.3). It is predicted that uranium processing constituents will continue to decline in monitor well DUR-01-0612 while the first plume moves downgradient and into the Animas River. Contaminants will increase in monitor well DUR-01-0617, then decline as the second plume reaches the well and then moves on past.

range from approximately 900 to 1300 mg/L, the pH ranges from 7.6 to 8.0, and the redox potential ranges from approximately 150 to 260 mV.

The TDS in downgradient bedrock wells DUR-03-0607, -0611, and -0612 to the southeast of the cell range from approximately 1000 to 5500 mg/L, while pH ranges from 5.5 to 7.8, and the redox potentials range from approximately 140 to 440 mV.

Trace elements detected, at least once, in bedrock monitoring wells, include antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, molybdenum, nickel, radium-226, radium-228, selenium, silver, thallium, uranium, and vanadium. Of the constituents with MCLs, cadmium, chromium, molybdenum, radium-226 plus radium-228, and uranium have exceeded their MCLs at least once, though median concentrations are generally below both method detection limits and MCLs for these constituents.

Water quality in POC well -0621 is notable because of its acidity (pH of about 4.9). The acid ground water in well -0621 and adjacent well -0616 is thought to be associated with the natural oxidation of pyrite (iron sulfide) occurring in the bedrock aquifer. The naturally acid water is associated with high levels of dissolved iron (up to 452 mg/L), manganese (up to 6.04 mg/L), sulfate (up to 4000 mg/L) and sulfide (up to 16 mg/L). Indicators of ground water contamination from tailings solutions (uranium, molybdenum, and selenium) are not present at levels above background in these to wells. Future interpretation of water quality in POC well -0621 should take into account the naturally acidic conditions in this well.

2.3.2 Contaminant delineation

Mill tailings area (DUR-01)

The primary source of ground water contamination in the mill tailings area were the large and small tailings piles (Figure 2.13). Surface remediation removed these sources of contamination. Using constituents that are known to be related to uranium processing at the site, it appears that contamination has been slowly moving downgradient in two primary plumes, one associated with each tailings pile. For example, Figure 2.14 is a November 1983 spacial distribution map for sulfate. The November 1994 sulfate data are also presented for comparison. There appears to be a general decrease in sulfate levels related to remediation; contamination decreased in the areas of wells -0612, -0626, -0618 and perhaps -0619. Contamination is increasing in monitor well DUR-01-0617, possibly due to downgradient migration of contaminants from the small tailings pile. Monitor well DUR-01-0612 currently has the highest levels of most constituents (Table 2.3). It is predicted that uranium processing constituents will continue to decline in monitor well DUR-01-0612 while the first plume moves downgradient and into the Animas River. Contaminants will increase in monitor well DUR-01-0617, then decline as the second plume reaches the well and then moves on past.

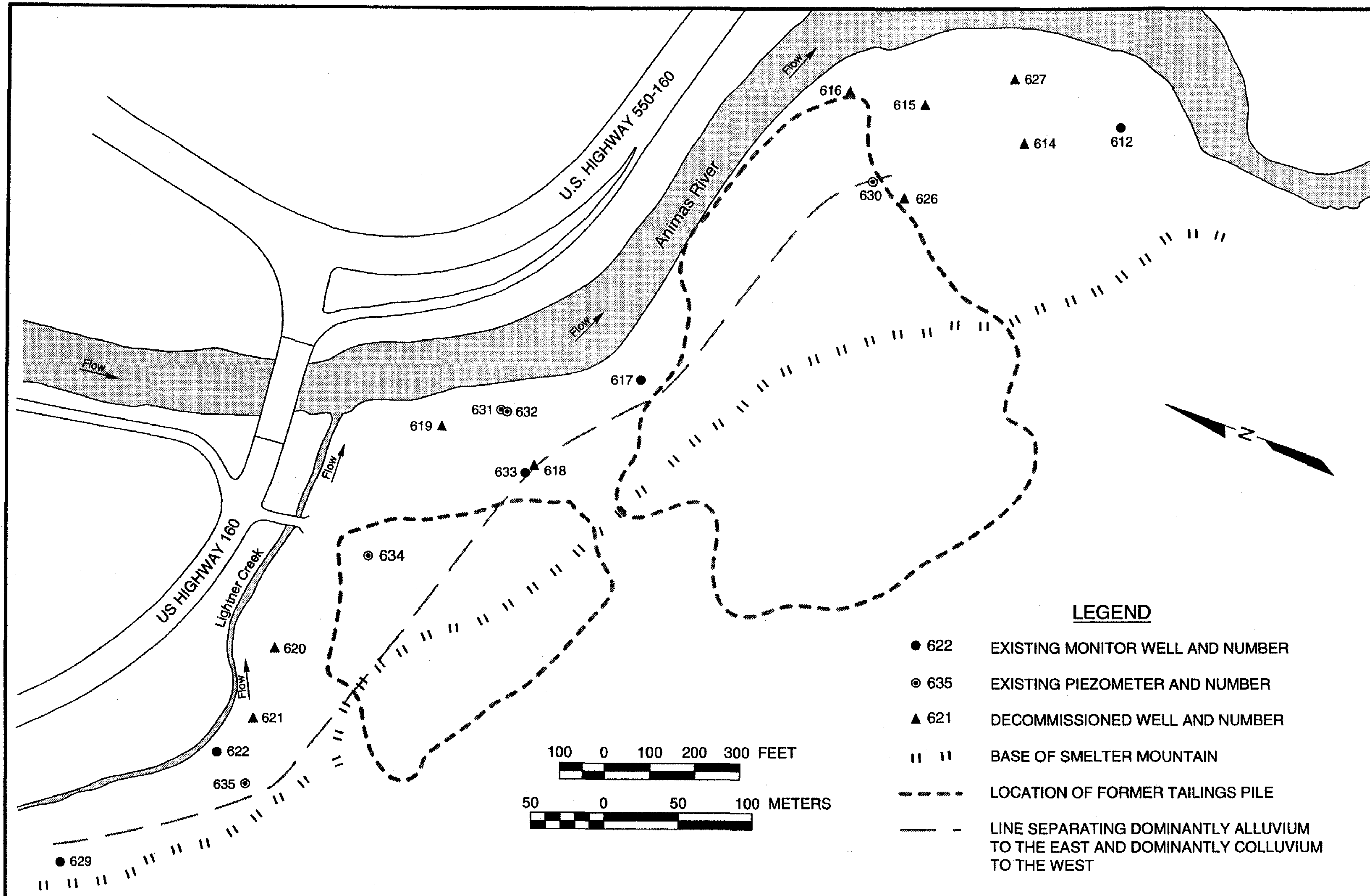


FIGURE 2.13
LOCATIONS OF MONITOR WELLS AND PIEZOMETERS IN THE MILL TAILINGS AREA (DUR-01) DURANGO, COLORADO, SITE

MAC: SITE\DUR\WSAP\ BASE-PIEZO

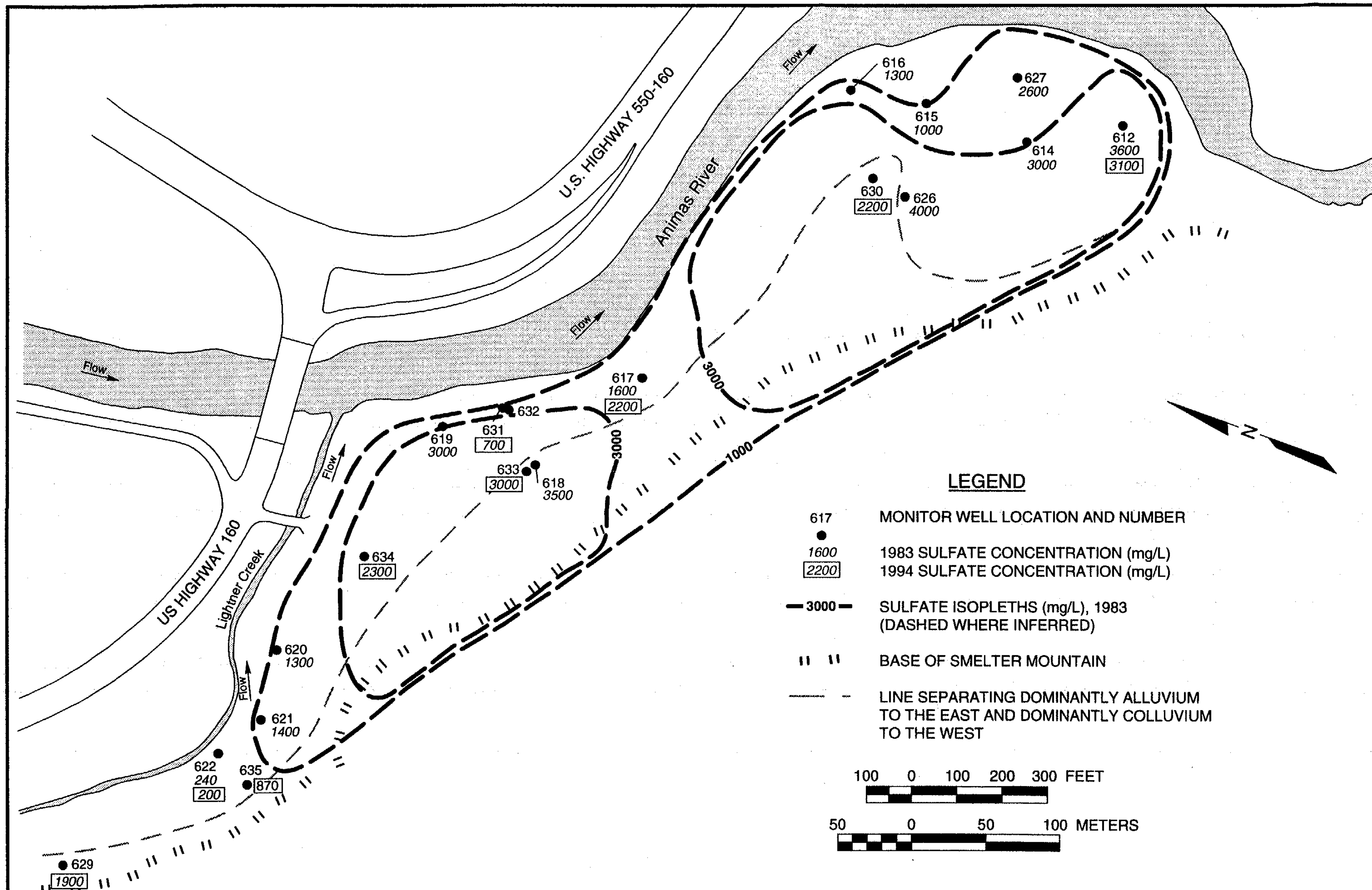


FIGURE 2.14
SULFATE DISTRIBUTION IN GROUND WATER IN NOVEMBER 1983 COMPARED TO NOVEMBER 1994 (DUR-01) MILL TAILINGS AREA, DURANGO, COLORADO, SITE

MAC: SITE\DUR\WSAP\ BASE–SULF

Raffinate ponds area (DUR-02)

Several constituents can be used to determine the extent of ground water contamination at the raffinate ponds area, including chloride, sulfate, sodium, uranium, and manganese. Of these, chloride is the best indicator because it is nonreactive in ground water, was present in the raffinate at relatively high concentrations (greater than 1000 mg/L), and is low in background (less than 100 mg/L).

Figure 2.15 shows the concentrations of chloride using chloride in excess of 100 mg/L as an indicator of contamination. In general, recent data demonstrate that areas upgradient of the raffinate ponds area (monitor wells DUR-02-0607, -0599, and -0600) are, at present, not obviously contaminated. However, historical data for monitor well DUR-02-0607 (a relatively shallow well completed in both alluvium and bedrock) demonstrates that this area was contaminated in the past but has since been flushed.

There are not sufficient data to determine the extent of contamination cross-gradient and downgradient of the site. Older data from a decommissioned well (DUR-02-0601; Figure 2.16) demonstrate that contamination extended from the southern ponds area (near monitor well DUR-02-0607) east towards the Animas River. Recently, slightly elevated concentrations of chloride (160 mg/L) in well DUR-02-0595 suggest that contamination also extends north of the ponds area towards the Animas River. Data to determine the extent of contamination east and downgradient of the ponds area are limited; contamination extends at least to the eastern property boundary, as evidenced by wells DUR-02-0602, -0628, and -0593. There are no wells in the area between the site boundary and the Animas River.

The vertical extent of contamination is also not known. Older data (1982 to 1985) indicated that contamination extended to at least a depth of between 124 and 138 ft (37.8 to 42.1 m) below the land surface of the fault (in monitor well DUR-02-0624), and to a depth at least 65 to 80 ft (20 to 24 m) in the bedrock (in monitor well DUR-02-0610) (Figure 2.16).

Disposal cell (DUR-03)

Table 2.6 provides information on the levels of major elements and hazardous constituents identified in tailings solutions sampled from monitoring wells completed within the Bodo Canyon disposal cell and from the disposal cell toe drain holding pond. In general, results from the tailings wells and toe drain pond agree, suggesting that levels of constituents are relatively homogeneous within the cell.

A statistical comparison of concentration levels measured in tailings wells to levels measured in background bedrock wells (Table 2.6) was conducted to determine which hazardous constituents from among those listed in Appendix I and Table 1 of 40 CFR part 192 are present in the residual radioactive material

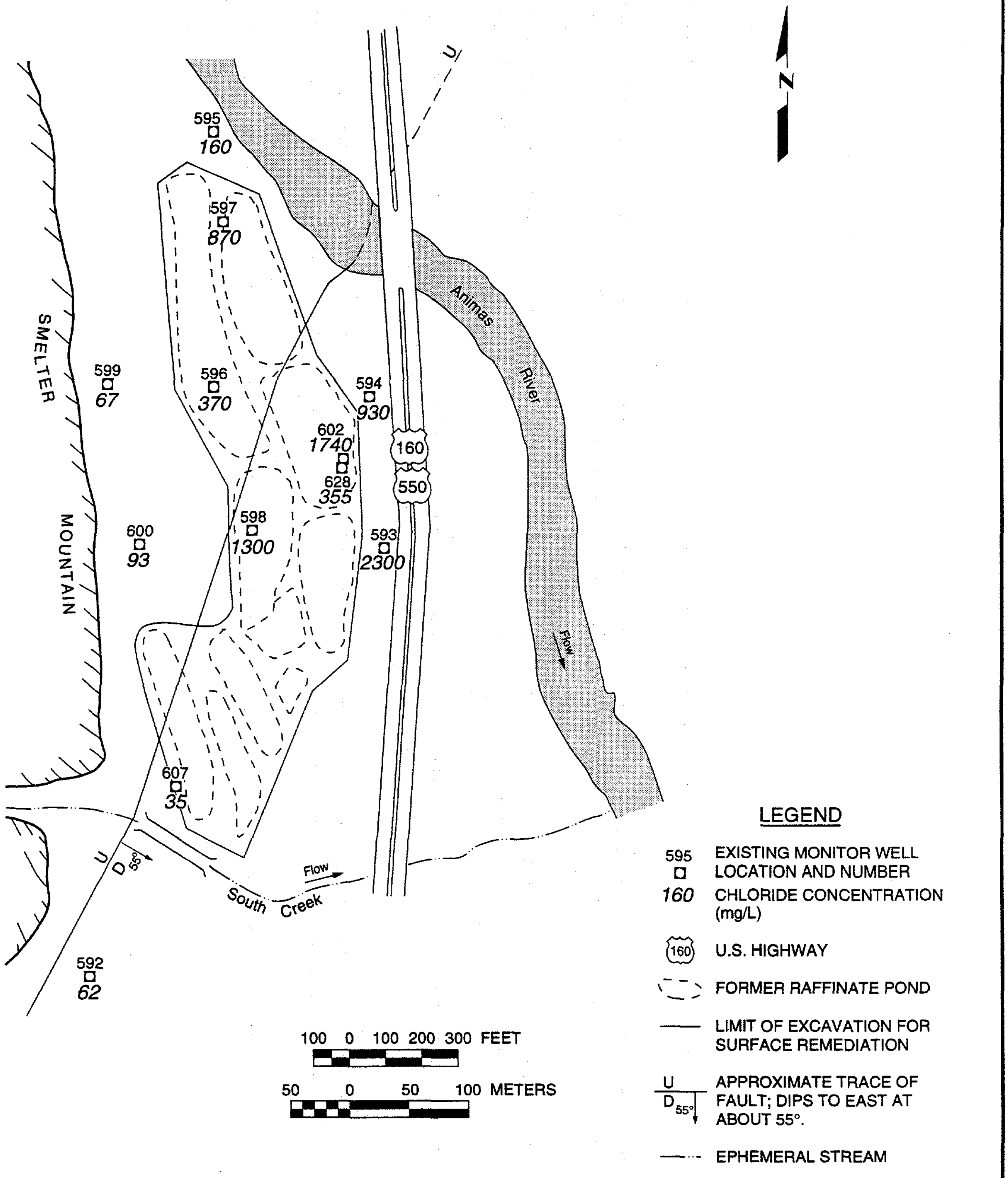


FIGURE 2.15
DISTRIBUTION OF CHLORIDE IN GROUND WATER, RAFFINATE PONDS AREA NOVEMBER 1993 AND JANUARY 1994 DATA (DUR-02) DURANGO, COLORADO, SITE

MAC: SITE/DUR/WSAP/LOCMONRAFF-CHLORIDE

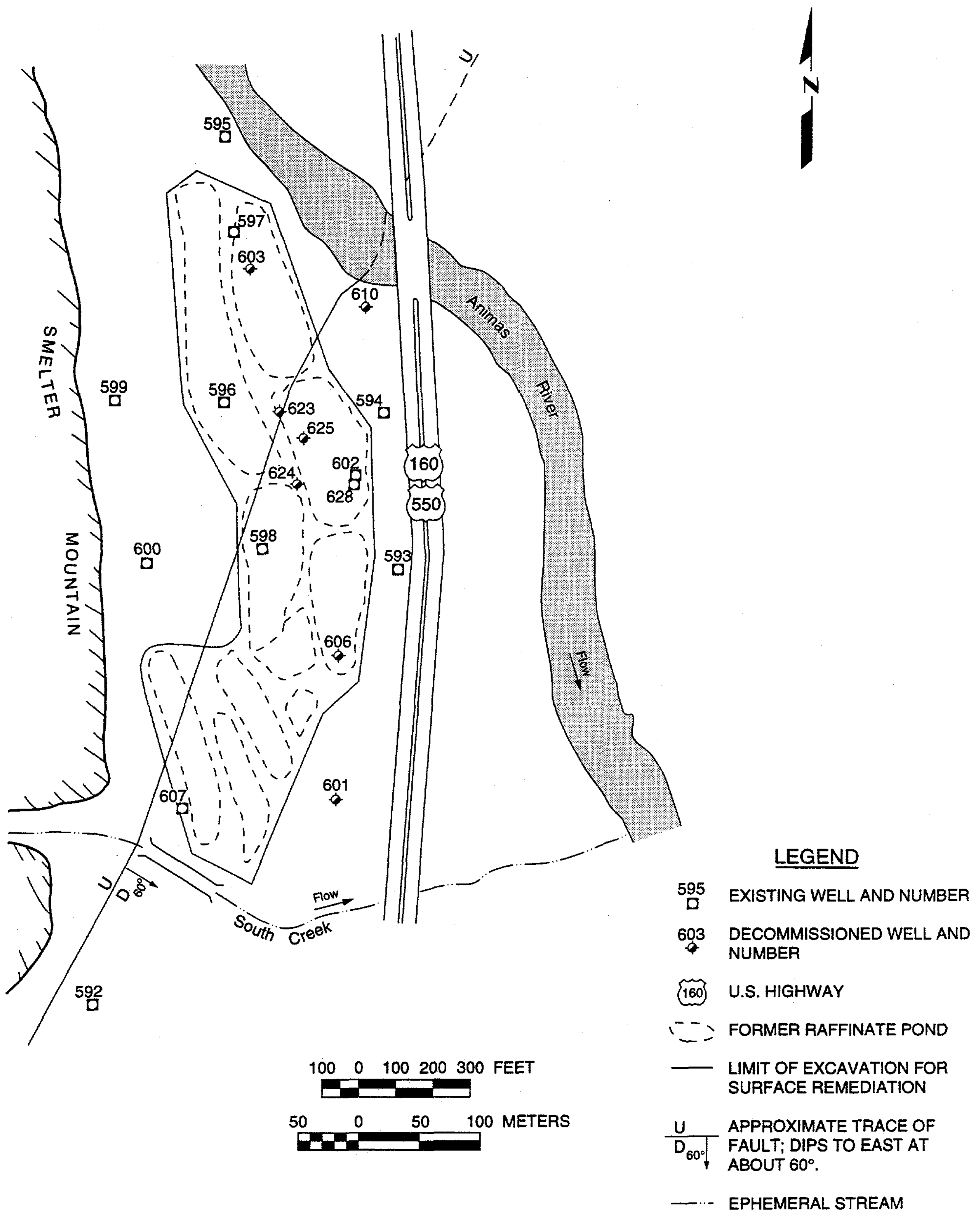


FIGURE 2.16
LOCATIONS OF MONITOR WELLS IN THE RAFFINATE PONDS AREA (DUR-02)
DURANGO, COLORADO, SITE

MAC: SITE/DUR/WSAP/LOCMONRAFF-WELLS

(RRM) at levels above ambient background. Details of the statistical tests are discussed in the LTSP (DOE, 1995a). Levels of arsenic, cadmium, molybdenum, radium-226, selenium, uranium, and vanadium are significantly elevated in tailings pore fluids both from a statistical perspective and a practical perspective; the median concentration from tailings pore fluids exceed the median background level by at least an order of magnitude.

A second group of hazardous constituents, including beryllium, chromium, mercury, nickel, and silver, were determined to be statistically elevated in tailings pore solutions compared to background, in spite of the fact that their concentrations in more than half of the tailings samples were below the detection limit. Furthermore, the detected concentrations from tailings solutions were not remarkably higher than the detection limit or than observable background levels. The statistical significance of these constituents is attributed to a greater frequency of detection in tailings samples compared to background samples. These constituents are retained as hazardous constituents at the Bodo Canyon site. They are not expected to be reliable indicators of potential contamination of ground water because they occur infrequently in the tailings solutions and are below detection in the toe drain effluent; and they occur near background levels and will likely be attenuated by reactions with the clay liner and alluvial material present, reducing concentrations to background levels before reaching the bedrock aquifer.

Several constituents listed in Table 1 or Appendix I of 40 CFR part 192 were either not detected in the tailings or toe drain effluent (antimony, barium, cyanide, net gross alpha, thallium) or occurred at levels equal to or less than levels found in background ground water based on statistical testing (lead, nitrate, and radium-228). Those constituents not detected, or which occurred in tailings solutions at levels equal to or below that of background, are not designated as hazardous constituents at the Bodo Canyon disposal site (DOE, 1995a).

2.3.3 Surface water and sediment sampling and results

Processing site (DUR-01 and -02)

The Durango uranium ore processing site is bounded by Lightner Creek to the north, the Animas River to the east, and South Creek to the south. Hydrologic gradients (Figures 2.5 and 2.9) indicate that the Animas River receives ground water discharge from the tailings and raffinate ponds areas of the site. Subsequently, surface waters and sediments were sampled during November 1993 to assess impacts of ground water discharge on those media. This sampling period was chosen to coincide with the seasonal low flow in the river and creeks since the potential impact of contaminant discharge would be greatest during this period. The results of this sampling and analysis are presented in Tables 2.7 and 2.8.

Table 2.7 Surface water quality data, Durango, Colorado, site

Constituent	Lightner Creek		Animas River					
	DUR-01-0650 (Upstream)	DUR-01-0651 (Downstream)	DUR-01-0652 (Upstream)	DUR-02-0654 (Downstream)	DUR-02-0656 (Downstream)	DUR-02-0657 (Downstream)	DUR-01-0690[a] (Downstream)	DUR-01-0691[a] (Downstream)
Ammonium	NA	NA	NA	NA	NA	NA	<0.1-0.2	<0.1-0.1
Antimony	NA	NA	NA	NA	NA	NA	<0.003-<0.01	<0.003-<0.01
Arsenic	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.001-<0.03 (<0.005)	<0.001-<0.03 (<0.005)
Barium	NA	NA	NA	NA	NA	NA	0.05-0.07	0.04-0.07
Beryllium	NA	NA	NA	NA	NA	NA	<0.005-<0.01	<0.005-<0.01
Cadmium	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.002)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001-<0.003 (<0.001)	<0.001-<0.002 (<0.001)
Calcium	86.4 (80.4)	87.2 (82.3)	93.3 (89.5)	94.6 (88.6)	96.4 (90.3)	94.7 (90.7)	29.0-93.8 (89.9)	29.0-99.7 (91.1)
Chloride	NA	NA	NA	NA	NA	NA	<0.1-22.2	3.0-35.0
Chromium	NA	NA	NA	NA	NA	NA	<0.01-0.03	<0.01-0.03
Cobalt	NA	NA	NA	NA	NA	NA	<0.03-<0.05	<0.03-<0.05
Copper	NA	NA	NA	NA	NA	NA	<0.01-<0.02	<0.01-0.02
Cyanide	NA	NA	NA	NA	NA	NA	<0.01-<0.01	<0.01-<0.01
Fluoride	NA	NA	NA	NA	NA	NA	0.01-0.4	0.2-0.5
Iron	<0.03 (0.06)	<0.03 (0.08)	<0.03 (0.30)	<0.03 (0.12)	<0.03 (0.12)	<0.03 (0.11)	<0.01-0.04 (0.10)	<0.01-0.07 (0.12)
Lead	<0.003 (<0.003)	<0.003 (<0.003)	<0.003 (0.020)	<0.003 (<0.003)	<0.003 (<0.003)	<0.003 (<0.003)	<0.003-0.01 (<0.003)	<0.003-0.01 (<0.003)
Magnesium	29.5 (30.3)	29.9 (30.5)	12.8 (13.4)	13.5 (13.8)	13.7 (14.0)	13.4 (14.0)	3.79-30.0 (21.0)	4.34-17.7 (14.4)
Manganese	<0.01 (<0.01)	<0.01 (<0.01)	0.11 (0.13)	<0.11 (<0.12)	<0.11 (<0.12)	<0.11 (<0.12)	<0.01-0.20 (0.08)	<0.01-0.24 (0.13)
Mercury	<0.0002 (0.0002)	<0.0002 (<0.0002)	<0.0002 (0.005)	<0.0002 (<0.0002)	<0.0002 (<0.0002)	<0.0002 (0.0004)	<0.0002-0.0008 (<0.0002)	<0.0002-0.0005 (<0.0002)
Molybdenum	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01 (0.01)	<0.01 (<0.01)	<0.01 (<0.01)	<0.01-0.02 (<0.01)	<0.01-0.02 (0.01)

Table 2.7 Surface water quality data, Durango, Colorado, site (Concluded)

Constituent	Lightner Creek		Animas River					
	DUR-01-0650 (Upstream)	DUR-01-0651 (Downstream)	DUR-01-0652 (Upstream)	DUR-02-0654 (Downstream)	DUR-02-0656 (Downstream)	DUR-02-0657 (Downstream)	DUR-01-0690[a] (Downstream)	DUR-01-0691[a] (Downstream)
Nickel	NA	NA	NA	NA	NA	NA	<0.03-<0.04	<0.03-<0.04
Nitrate	10.7 (10.8)	10.9 (11.0)	10.7 (11.3)	12.3 (11.8)	14.6 (11.5)	11.2 (10.9)	0.20-11.0 (11.4)	0.20-11.1 (11.1)
Potassium	NA	NA	NA	NA	NA	NA	0.90-4.29	0.90-4.93
Radium-226	NA	NA	NA	NA	NA	NA	0.0-0.8	0.0-0.8
Selenium	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)	<0.001-0.008 (<0.005)	<0.001-0.007 (<0.005)
Silver	NA	NA	NA	NA	NA	NA	<0.01-<0.01	<0.01-<0.01
Sodium	NA	NA	NA	NA	NA	NA	4.3-25.7	4.4-28.2
Sulfate	157 (158)	154 (161)	139 (144)	168 (130)	147 (149)	148 (149)	38-177 (149)	48-174 (153)
Sulfide	NA	NA	NA	NA	NA	NA	<0.1-0.7	<0.1-<0.1
Thallium	NA	NA	NA	NA	NA	NA	<0.01-<0.03	<0.01-<0.03
Thorium-230	NA	NA	NA	NA	NA	NA	0.0-0.2	0.0-0.8
Tin	NA	NA	NA	NA	NA	NA	<0.005-0.006	<0.005-0.005
Uranium	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)	0.001 (<0.001)	0.0006-0.0055 (<0.001)	0.0006-0.0029 (<0.001)
Vanadium	NA	NA	NA	NA	NA	NA	<0.01-0.01	<0.01-0.01
Zinc	0.009 (0.031)	0.010 (0.026)	0.051 (0.116)	0.012 (0.088)	0.019 (0.088)	0.008 (0.093)	<0.005-0.107 (0.061)	0.012-0.131 (0.083)

[a]Sampling at locations DUR-01-0690 and -0691 was performed during several rounds between 1987 and 1993. The range of concentrations (minimum and maximum) is reported based on all available data. If a high detection limit reported for a non-detect sample exceeded the maximum detectable concentration for a constituent, the maximum detect is reported.

Note: Concentrations are reported in milligrams per liter. Unfiltered samples are reported in parentheses under filtered data when available. For locations DUR-01-0650, -0651, and -0652 and DUR-02-0654, -0656, and -0657, reported values are from the November 1993 sampling round (the only data available).

DUR-01 – mill tailings area.
DUR-02 – raffinate ponds area.

Table 2.8 Sediment quality data, Durango, Colorado, site

	Lightner Creek		Animas River						
Constituent	**DUR-01-650 (Upstream)**	**DUR-01-651 (Downstream)**	**DR-01-0652 (Upstream)**	**DUR-02-0654 (Downstream)**	**DUR-02-0656 (Downstream)**	**DUR-02-0657 (Downstream)**	**DUR-01-0690 (Downstream)**	**DUR-01-0691 (Downstream)**	**DUR-02-655[a] (Downstream)**
Arsenic	9.5	8.8	12.0	31.2	12.1	11.9	9.7	14.1	8.1
Cadmium	1.4	0.7	9.0	3.2	3.6	4.0	1.2	1.8	1.1
Iron	22,100	19,800	16,300	32,800	25,300	16,500	17,000	17,300	13,500
Lead	23.8	14.7	152	106	159	75.6	26.3	39.6	25.8
Manganese	215	229	1,520	736	1200	825	231	569	486
Mercury	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Molybdenum	3	2	7	<1.0	4	<1.0	3	2	8
Nitrate	<0.10	<0.10	<0.10	2.3	<1.0	<1.0	<0.10	<1.0	1.5
Selenium	1.6	1.6	1.2	0.6	1.0	0.7	1.6	1.9	<0.5
Sulfate	61.3	69.6	204	196	14.2	53.7	69.5	57.6	6,920
Uranium	1.5	1.4	3.2	1.8	2.3	1.7	1.5	1.6	2.4
Zinc	134	82.5	443	210	702	254	99.9	241	54.7

[a]Sample was collected from the Animas River shore above the water line. Sample was associated with evaporites.

Note: Concentrations are reported in milligrams per kilogram. Values reported are from a single sampling round in November 1993.

DUR-01 – mill tailings area.
DUR-02 – raffinate ponds area.

Both filtered and unfiltered samples of surface water were also collected monthly by the Bureau of Reclamation (BOR) at two locations along the Animas River. One location was upstream of the site, and the second was downstream, at the raffinate ponds area. This sampling included water analyses during both low and high river flow during the period from January 1993, through July 1993. A summary of analytical results are presented in Table 2.9.

In Lightner Creek, background surface water and sediments were sampled once at location DUR-01-0650, approximately 500 ft upstream (150 m) of the site (Figure 2.12). Downstream samples were also collected once at location DUR-01-0651, located near the confluence of Lightner Creek and the Animas River.

Comparison of water quality at these two locations for this sampling event does not indicate a difference in water quality upstream or downstream of the site (Table 2.6). Lightner Creek sediments also appear comparable upstream and downstream of the site for this one sampling event (Table 2.8). Consequently, there are no anomalous constituents in Lightner Creek sediments attributable to uranium processing activities based on one sampling round.

In the Animas River, background surface water and sediment were sampled at location DUR-01-0652, located about 300 ft (40 m) upstream of the site and immediately upstream of the confluence of the Lightner Creek and the Animas River (location DUR-01-0690). Location DUR-01-0691 is located downstream of the mill tailings area. DUR-02-0657 is located downstream of the mill tailings area and sewage treatment plant outfall but upstream of the raffinate ponds area. DUR-02-0656 and -0654 are located downstream of both the mill tailings and raffinate ponds areas. Water in the Animas River at Durango is a calcium bicarbonate or calcium bicarbonate sulfate type, generally ranging from hard to very hard (DOE, 1985). Comparing downstream and upstream water quality data indicates similar surface water quality (Table 2.7).

Additional data collected and analyzed by the BOR are consistent with data collected by the DOE. Concentrations of constituents of potential concern are the same or similar upstream and downstream of the site for both filtered and unfiltered surface water samples from the Animas River (Table 2.9) comparing BOR and DOE data. Thus ground water discharged from the site into the Animas River appears to have a negligible impact on surface water quality in the Animas River. This conclusion is supported further by modeling of the potential impact of the ground water discharge on the Animas River (discussed in the baseline risk assessment [DOE, 1995a]).

Based on samples collected in November 1993, Animas River sediments are also similar upstream and downstream of the site (Table 2.8). There is one anomalous value for sulfate in sample DUR-02-0655. The source of the sulfate could be either evaporated river water or ground water. This sample was collected above the river shoreline, in sediments associated with surface evaporites (TAC, 1994a). The evaporite is not associated with elevated

Table 2.9 BOR water quality data from the Animas River, filtered and unfiltered water samples, Durango, Colorado, site

	Animas River upstream of site				Animas River at raffinate ponds area			
Parameter	Frequency of detection[a]	Minimum[b]	Maximum[c]	Mean[d]	Frequency of detection[a]	Minimum	Maximum	Mean
Filtered								
Calcium	7/7	22	95	61	7/7	23	136	72
Chloride	7/7	1	21	11	7/7	1	22	12
Fluoride	5/7	<0.2	0.5	0.3	5/7	<0.2	0.5	0.3
Potassium	7/7	0.2	4	2	7/7	0.2	4	2
Magnesium	7/7	3	14	10	7/7	3	71	23
Sodium	7/7	2	23	13	7/7	2	50	20
Nitrate	3/7	0.2	1.0	0.5	3/7	<0.5	3	1.2
Sulfate	7/7	22	185	113	7/7	22	186	111
Silver	0/7	<0.0001	<0.0002	ND	0/7	<0.0001	<0.0002	ND
Arsenic	4/7	<0.001	0.033	0.004	3/7	<0.001	0.012	0.003
Cadmium	3/7	0.0002	0.0006	0.0002	4/7	0.0002	0.0004	0.0002
Chromium	0/7	<0.005	<0.005	ND	0/7	<0.005	<0.005	ND
Copper	1/7	<0.001	0.019	0.002	1/7	<0.001	0.019	0.002
Iron	0/7	<0.05	<0.05	ND	1/7	<0.05	0.34	0.06
Manganese	4/7	<0.05	0.09	0.06	4/7	<0.05	0.16	0.07
Nickel	0/7	<0.005	<0.005	ND	0/7	<0.005	<0.005	ND
Lead	1/7	<0.001	0.002	0.001	1/7	<0.001	0.002	0.001
Selenium	0/6	<0.002	<0.002	ND	0/7	<0.002	<0.002	ND
Zinc	3/7	<0.010	0.060	0.014	1/7	<0.010	0.016	0.004

Table 2.9 BOR water quality data from the Animas River, filtered and unfiltered water samples, Durango, Colorado, site (Concluded)

	Animas River upstream of site				Animas River at raffinate ponds area			
Parameter	Frequency of detection[a]	Minimum[b]	Maximum[c]	Mean[d]	Frequency of detection[a]	Minimum	Maximum	Mean
Unfiltered								
Silver	5/7	<0.0001	0.0005	0.0002	6/7	<0.0001	0.0005	0.0002
Arsenic	7/7	0.011	0.087	0.031	7/7	0.009	0.089	0.032
Cadmium	5/7	<0.0003	0.0009	0.0006	6/7	<0.0003	0.0016	0.0006
Chromium	5/7	<0.005	0.021	0.011	6/7	<0.005	0.019	0.013
Copper	5/7	<0.005	0.031	0.013	5/7	<0.005	0.036	0.014
Iron	7/7	0.20	1.01	0.41	7/7	0.15	1.90	0.67
Manganese	7/7	0.08	0.33	0.19	7/7	0.08	0.37	0.23
Nickel	7/7	0.006	0.036	0.015	6/7	<0.005	0.034	0.015
Lead	6/7	0.003	0.080	0.018	6/7	<0.005	0.026	0.011
Selenium	4/7	<0.002	0.034	0.007	5/7	<0.002	0.028	0.007
Zinc	7/7	0.06	0.24	0.11	7/7	0.06	0.28	0.13
Uranium	0/4	<0.005	<0.005	ND	0/4	<0.005	<0.005	ND

[a]Frequency of detection = number of analyses above the detection limit/the total number of analyses.
[b]Minimum detected concentration or detection limit, whichever is lower.
[c]Maximum detected concentration.
[d]Arithmetic average; for analyses below detection, one-half the detection limit was used as a proxy concentration in the calculations.

Note: All concentrations reported in milligrams per liter; samples collected monthly from January 1993 through July 1993.

BOR – Bureau of Reclamation.
ND – not detected.

concentrations of process-related metals including uranium, molybdenum, and manganese.

Overall, most analyzed concentrations of elements in sediments from the Animas River are similar (within a factor of 2) to the average abundance of elements in rocks and soil of the earth (Krauskopf, 1979; Shacklette and Boerngen, 1984). However, the presence of cadmium, lead and zinc are greater than average (by a factor of 10). All three are elevated in the upstream sediment samples and are commonly associated with naturally occurring lead-zinc deposits. Therefore, they could be derived from the erosion of natural lead and zinc deposits within the Animas River drainage basin and/or from erosion of ores, mine spoil, and other products of mining in the region.

In summary, the Durango site has had no impact on surface water and sediment in Lightener Creek and the Animas River. (Tables 2.7, 2.8 and 2.9). No downstream data are available for South Creek.

Bodo Canyon disposal site (DUR-03)

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

2.4 SITE CONCEPTUAL MODEL

Mill tailings area (DUR-01)

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

Ground water is expected to move beneath the area and discharge into Lightner Creek and the Animas River. Contaminants from the former operations will move with the ground water toward these discharge points. However, ground water discharge from the site to the Animas River appears to have a negligible impact on surface water and sediment quality in the Animas River. Ground water is not expected to move to the west toward Smelter Mountain, under Lightner Creek, or toward the Animas River to the north, east, or south.

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

Raffinate ponds area (DUR-02)

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 flushes continuously beneath the site.

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

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

Bodo Canyon disposal site (DUR-03)

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 disposal cell site has decreased the amount of water infiltrating the alluvium beneath the cell and, with time, the alluvium beneath the cell will become dewatered. The unsaturated zone attenuates 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 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 regulatory requirements for sampling at the site are specified in 40 CFR Part 192 (1994) and are described in the WSAP guidance document (DOE, 1995b).

3.2 POINT OF COMPLIANCE

The POC at the disposal site is the downgradient edge of the disposal cell in the uppermost aquifer, which is the Cliff House/Menefee aquifer (DOE, 1991). POC wells are DUR-03-0607 and -0612 southeast of the disposal cell, and -0621 to the northeast (Figure 2.4) (DOE, 1995a). Background water quality in the uppermost aquifer will be monitored in well DUR-03-0605.

3.3 COMPLIANCE MONITORING

To achieve compliance with the EPA ground water protection standards (60 FR 2854 [1995]) at the Bodo Canyon disposal site, the DOE proposes meeting background concentrations or 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 collections 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 selected 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 is addressed further in that report (DOE, 1995a).

The ground water monitoring program will be implemented and carried out over a specified period of time, adequately demonstrating that disposal cell performance complies with the design requirements.

3.4 SITE CHARACTERIZATION

Ground water monitoring will continue at the mill tailings and raffinate pond areas and water levels will be measured. The objectives are to:

1. Monitor trends that may indicate movement, flushing, and attenuation of contaminants in ground water at the processing site. Identify and document these trends to provide information for evaluating remedial alternatives.

2. Monitor levels of contaminants of human health concern, as identified in the site baseline risk assessment.

3. Expand the data base for levels of constituents in background. Additional background data for certain constituents are needed to determine if observed levels in contaminated ground waters exceed background. In addition, more data are needed for all background constituents in order to better characterize their statistical range.

Surface water samples will be collected at three locations along the Animas River. The data collection objective is to demonstrate that contaminated ground water discharge into the Animas River is having a negligible impact on surface water quality.

Site characterization at the Bodo Canyon disposal site is complete.

4.0 DATA QUALITY REQUIREMENTS

Data quality requirements define the manner in which samples are collected, handled, and analyzed. The objectives include:

- Define analytical support levels
- Follow standard procedures for water sampling, preservation, transport, and various other field procedures
- Perform activities in accordance with quality assurance and quality control protocols
- Provide analytical data validation.

The WSAP Guidance Document (DOE, 1995b) and applicable Standard Operating Procedures (JEG, n.d.) state the data quality objectives to be followed during data collection and evaluation activities.

5.0 SAMPLING PLAN

This section presents the sampling locations, analytes (including field analyses), and sampling frequencies for the upcoming 2 years. After two years, data collection objectives will be evaluated and the sampling plan for the following three years may be modified to reflect remaining data needs. The end point for routine monitoring at the processing site will occur when the ground water compliance strategy is accepted. The end point for sampling at the disposal cell depends in part on the effectiveness of the remedial action determined through the ongoing monitoring program (DOE, 1995a).

Also presented in this section are the data evaluation methods and response to anomalous data. This plan covers sampling at the former Durango uranium processing site, including both the mill site (DUR-01) and raffinate ponds area (DUR-02), as well as the Bodo Canyon disposal cell (DUR-03). Sampling at the Bodo Canyon disposal cell is in accordance with the LTSP (DOE, 1995a).

5.1 SAMPLING LOCATIONS

5.1.1 Ground water

A list of all existing monitor wells is provided in Table 2.2. The wells are identified according to site location (DUR-01, -02, or -03) and well ownership (DOE, BOR, or private). Table 5.1 summarizes the ground water monitoring wells to be routinely sampled at these three sites.

Mill tailings area (DUR-01)

There are four DOE monitoring wells and six piezometers at the mill tailings area (DUR-01) of the processing site. Off the site and near the mill tailings area there is one domestic well (DUR-01-0658) used for determining background water quality for the mill tailings area.

Ground water contamination at the mill tailings area is found in both the alluvial gravels and colluvium. Contamination does not extend much below these units because they are underlain by the relatively impermeable Mancos Shale. The highest levels of contaminants occur in monitor well -0612, located furthest downgradient of the site. With the exception of the background wells (-0629 and private well -0658) all other wells and piezometers (-0622, -0635, -0633, -0634, -0631, -0617, and -0630) display evidence of contamination. In general, levels of contamination are lowest in areas immediately adjacent to Lightner Creek and the Animas River. Comparisons of recent data (1994) to older data (1983) suggest that levels of contamination are decreasing in upgradient areas of the plumes (Figure 2.14). However, more data are required to monitor this trend, especially because the source of contamination, the tailings piles, has been removed.

Table 5.1 Order for sampling and summary of ground water monitoring wells and surface water sampling locations for routine sampling, Durango, Colorado, site

Location ID	Aquifer	Sampling justification
Bodo Canyon disposal site monitoring wells		
DUR-03-0605	Bedrock	Monitor concentrations in background
DUR-03-0623	Alluvium	Monitor concentrations in background
DUR-03-0608	Alluvium	Monitor concentrations in alluvium
DUR-03-0621	Bedrock	Monitor concentrations at POC
DUR-03-0607	Bedrock	Monitor concentrations at POC
DUR-03-0612	Bedrock	Monitor concentrations at POC
Durango processing site monitoring wells		
DUR-01-0658 (private well)	Alluvium	Private well, monitor background
DUR-01-0629	Colluvium	Monitor concentrations in background
DUR-02-0592 (BOR well)	Bedrock/fault	Monitor concentrations in background
DUR-02-0607	Bedrock	Monitor contaminant concentrations
DUR-01-0622	Alluvium	Monitor contaminant concentrations
DUR-01-0635	Alluvium	Monitor contaminant concentrations
DUR-01-0634	Alluvium	Monitor contaminant concentrations
DUR-01-0633	Alluvium	Monitor contaminant concentrations
DUR-01-0631	Alluvium	Monitor contaminant concentrations
DUR-01-0617	Alluvium	Monitor contaminant concentrations
DUR-01-0630	Alluvium	Monitor contaminant concentrations
DUR-01-0612	Alluvium/colluvium	Monitor contaminant concentrations
DUR-02-0602	Bedrock	Monitor contaminant concentrations
DUR-02-0628	Alluvium/bedrock	Monitor contaminant concentrations
Durango processing site surface water sampling locations		
DUR-01-0652	Animas River	Monitor background
DUR-01-0691	Animas River	Monitor downstream of mill tailings area
DUR-02-0654	Animas River	Monitor downstream of raffinate ponds area

Note: Location ID includes well number.

DUR-01 - mill tailings area.
DUR-02 - raffinate ponds area
DUR-03 - Bodo Canyon disposal cell.

An attempt will be made to routinely sample private well DUR-01-0658 in order to collect more information on background water quality in the alluvial aquifer (there is only one round of sampling data available for a limited suite of constituents at this location). Also, on-site background well DUR-01-0629 will be sampled to collect more information on background ground water quality in the colluvium (there are only two sampling rounds of data available at this location). Additionally, both background locations will be sampled for constituents that have no available background data (Table 5.2).

The remaining three DOE monitoring wells and five DOE piezometers completed in the alluvial aquifer at the mill site area will be sampled for ground water in order to document trends in water quality associated with natural flushing of contaminants from the aquifer. The design and installation of the piezometers meets DOE standards required of monitoring wells. Table 5.1 lists wells to be routinely sampled at the mill tailings area (DUR-01). Well locations are shown in Figure 2.12.

<u>Raffinate ponds area (DUR-02)</u>

There are presently three DOE monitoring wells at the raffinate ponds area (DUR-02) of the processing site. Additionally, the BOR has installed nine monitoring wells at the raffinate ponds area (DUR-02). These nine wells are routinely sampled by the BOR and will not be routinely sampled by the DOE, with the exception of background well DUR-02-0592. The DOE will request BOR data, including quality control data, for BOR monitor wells on an annual basis.

All three existing DOE monitor wells located in the raffinate ponds area (DUR-02-0602, -0607, and -0628) display evidence of contamination. Unlike the mill area, alluvial gravels at the raffinate ponds area are generally unsaturated and contaminated ground water is found in the underlying bedrock units. These bedrock units consist of interbedded sandstones, shales, and coals and are displaced by a normal fault in the bedrock. Contaminated ground water also extends into this fault to a depth of at least 120 ft (37 m). The three wells monitor as follows:

- Well -0628 samples contaminants near the alluvium-bedrock contact.
- Well -0602 samples ground water in the bedrock over a large depth interval (16 to 68 ft [4.9 to 20.7 m]) and long-term trends suggest that reactions with the bedrock are causing decreased levels of contamination in this well (DOE, 1995b).
- Well -0607 is in the upper portion of the bedrock and is located near the upgradient edge of the raffinate pond area. Levels of most contaminants have steadily decreased to near background levels since surface

Table 5.2 Proposed monitored contaminants, Durango, Colorado, site

	Mill area						Ponds area					
	Filtered			Unfiltered			Filtered			Unfiltered		
	Background maximum	Plume maximum	Plume detects	Background maximum	Plume maximum	Plume detects	Background maximum	Plume maximum	Plume detects	Background maximum	Plume maximum	Plume detects
Cadmium[a]	<0.001	0.070	6/7	<0.001	0.047	3/3	<0.001	0.081	7/7	NA	0.007	1/2
Calcium	278	499	7/7	554	550	3/3	120	491	17/17	NA	475	4/4
Chloride[a]	24	795	7/7	26	952	3/3	69	2400	15/15	NA	2380	5/5
Iron [1]	0.28	0.15	3/7	3.12	5.2	3/3	0.02	2.5	6/6	NA	2.96	5/5
Lead[a,b]	<0.003	0.02	1/7	<0.003	0.042	1/3	<0.005	0.070	2/17	NA	<0.01	0/4
Magnesium	215	309	7/7	205	301	3/3	160	724	13/13	NA	644	4/4
Manganese[a]	0.16	6.7	7/7	0.26	6.2	3/3	0.070	7.3	4/4	NA	2.5	4/4
Molybdenum[a]	0.01	0.21	7/7	<0.01	0.13	3/3	<0.01	0.10	3/17	NA	<0.01	0/4
Potassium	4.6	34	7/7	4.8	33	3/3	6.6	82	17/17	NA	68	4/4
Selenium[a]	<0.005	0.16	7/7	<0.005	0.08	3/3	<0.05	0.08	4/7	NA	0.07	2/4
Sodium[a]	473	1200	7/7	478	1190	3/3	250	4600	4/4	NA	3370	4/4
Uranium[a]	0.002	3.8	6/6	0.002	4.0	3/3	<0.005	0.35	2/12	NA	0.57	6/6
Vanadium[a]	<0.01	0.53	7/7	<0.01	0.52	3/3	<0.005	0.06	5/17	NA	<0.01	0/4
Sulfate[a]	1860	3290	6/6	1830	2250	3/3	680	10000	9/9	NA	7740	4/4
Antimony[a,b]	NA	0.022	1/4	NA	0.025	1/1	NA	0.166	1/4	NA	0.196	1/1
Arsenic	<0.005	<0.05	0/7	<0.005	<0.01	0/3	<0.005	0.04	1/17	NA	0.04	1/4
Lead-210	NA	NA	NA	3.6	6.0	12/15	NA	NA	NA	NA	2.1	8/15
Polonium-210	NA	NA	NA	0.8	0.35	15/20	NA	NA	NA	NA	0.2	10/15
Radium-226	NA	0.5	7/14	1.0	12.6	15/20	NA	0.4	8/9	0.6	1.3	36/44
Radium-228	NA	2.4	13/15	0.5	4.8	14/19	NA	2.2	7/9	0.7	3.4	43/51
Thorium-230	NA	NA	NA	1.8	3.9	16/16	NA	NA	NA	0.4	4.5	38/51
Tin[a]	NA	0.015	1/3	NA	0.015	1/3	NA	0.089	2/3	NA	0.133	1/1
Thallium[c]	NA	<0.03	0/4	NA	<0.01	0/3	NA	0.06	2/5	NA	<0.01	0/3

[a]Contaminant of potential human health concern (DOE, 1995b).
[b]Unfiltered samples notably higher levels than filtered. Values listed for the constituent is for unfiltered samples.
[c]Primary drinking water standard for thallium (0.002 mg/L) below maximum detection limit.

Note: All data in milligrams per liter (mg/L) except lead-210, polonium-210, radium-226, radium-228, and thorium-230 which are in picocuries per liter (pCi/L).

NA – not analyzed.

remediation. However, levels of selenium have steadily increased with time, possibly due to desorbtion from the bedrock aquifer matrix.

Continued sampling of the three DOE monitoring wells at the raffinate ponds area is recommended to further document trends in contaminant concentrations. Background ground water quality will be monitored in BOR well DUR-02-0592 in order to determine concentrations in background for several constituents for which few or no data are available (Table 5.2). Table 5.1 lists wells to be routinely sampled at the raffinate ponds area (DUR-02) of the processing site. Well locations are shown in Figure 2.12.

Bodo Canyon disposal site (DUR-03)

At the Bodo Canyon disposal site, ground water quality will be monitored in four wells in the uppermost aquifer (background well -0605 and POC wells -0607, -0612 and -0621). These wells are completed in the bedrock aquifer, which is designated as the uppermost aquifer at the disposal site. In addition, ground water quality will be monitored in two wells completed in alluvium (background well -0623 and downgradient well -0608) as proposed in the RAP (DOE, 1991) and LTSP (DOE, 1995a). Table 5.1 lists wells to be sampled at the disposal site (DUR-03). Well locations are shown in Figure 2.4.

Private wells

There are about 18 private wells within 2 mi (3.2 km) of the processing site and none of these wells should be affected by site-related contamination (DOE, 1995b). Therefore, with the exception of private well -0658 (a background well), private wells will not be routinely sampled.

5.1.2 Surface water sampling locations

Measured hydrologic gradients at the processing site indicate that contaminated ground water at the site discharges into the Animas River. However, sampling and analysis of surface water in Lightner Creek and the Animas River has found no evidence of impact to these rivers from site-related contamination (DOE, 1995b). Furthermore, modeling of the ground water discharged from the processing site into the Animas River rivers demonstrates that this discharge has a negligible impact on Animas River water quality (DOE, 1995b). To further demonstrate the lack of significant site impacts to the Animas River, water quality will be monitored for an indicator parameter (uranium) at three locations. These are at a location upstream of the site (DUR-01-0652) for monitoring background water quality, a location in the area of ground water discharge from the mill tailings area (DUR-01-0691), and a location downstream of the raffinate ponds area (DUR-02-0654). Figure 2.12 shows these surface sampling locations.

Analyses of sediments indicate no evidence of site-related contamination of the sediments in the Animas River (DOE, 1995b). Therefore, there will be no routine sampling of sediments.

5.1.3 Sampling order

In general, ground water wells will be sampled in the order of increasing contamination (or in the order of increasing potential for contamination at the Bodo Canyon site) to minimize possible effects of equipment contamination. Ground water will be sampled at the Bodo Canyon disposal site first, beginning with the background wells (-0605 and -0623) and followed by the downgradient wells (-0607, -0612, -0608, and -0621). If practical, domestic well -0658 will be sampled during this period and prior to sampling at the processing site. At the processing site, background wells -0629 and -0592 will be sampled first, followed by downgradient wells in the order provided in Table 5.1.

5.2 ANALYTE SELECTION

5.2.1 Processing site (DUR-01 and -02)

Table 5.3 summarizes proposed monitored constituents at the processing site. Analytes to be measured in ground water at the processing site include field parameters as indicators of general water quality and selected constituents identified as site-related contaminants in ground water (DOE, 1995b). Measured field parameters are static water levels, total depth of well, alkalinity, dissolved oxygen, oxidation-reduction potential, pH , specific conductivity, temperature, and turbidity. Selected site-related contaminants in ground water to be analyzed in the laboratory are cadmium, calcium, chloride, iron, lead, magnesium, manganese, molybdenum, potassium, selenium, sodium, sulfate, uranium, and vanadium. These were selected because they are demonstrated to be site-related contaminants and to have maximum levels which clearly exceed background which could pose a risk to human health and the environment (DOE, 1995a). The maximum observed levels of these contaminants are presented in Table 5.2. Additionally, more information is needed to determine if arsenic, antimony, tin, and thallium are (or are not) site-related contaminants in ground water (Table 5.2). Therefore, those four elements will be analyzed.

The analyte selection at the Durango processing site has been chosen to efficiently monitor the level of contamination at the site and to provide information for future site observational work plans. The analyte selection does not include constituents which have been determined not to exceed background concentrations (DOE, 1995b). Also, some constituents that were identified as possible ground water contaminants in the Durango baseline risk assessment (DOE, 1995a) are not selected. The decision was made not to analyze those constituents which would not pose a significant risk to human health or the environment (DOE, 1995a) and that the levels observed-to-date have displayed no evidence of increasing trend levels over time. A summary of analytical data

Table 5.3 Summary of field parameters and laboratory analytes to be measured in ground water, Durango, Colorado, processing and disposal sites

	Processing site	Disposal site	
Analyte	Ground water	Surface water	Ground water
Field measurements			
Static water level	X		X
Total depth of well	X		X
Alkalinity	X		X
Dissolved oxygen	X		X
Oxidation-reduction potential	X		X
pH	X	X	X
Specific Conductivity	X	X	X
Turbidity	X	X	X
Temperature	X	X	X
Laboratory measurements (filtered samples)			
Arsenic	X		
Antimony	X		
Cadmium	X		
Calcium	X		X
Chloride	X		X
Iron	X		X
Lead	X		
Magnesium	X		X
Manganese	X		X
Molybdenum	X		X
Potassium	X		X
Selenium	X		X
Sodium	X		X
Sulfate	X		X
Tin	X		
Thallium	X		
Total dissolved solids	X		X
Uranium		X	X
Vanadium	X		

Table 5.3 Summary of field parameters and laboratory analytes to be measured in ground water, Durango, Colorado, processing and disposal sites (Concluded)

	Processing site	Disposal site	
Analyte	Ground water	Surface water	Ground water
Laboratory measurements (unfiltered samples)			
Iron	X		
lead	X		
Lead-210	X		
Polonium-210	X		
Radium-226	X		
Radium-228	X		
Thorium-230	X		
Uranium	X		

for these constituents is provided in Table 5.4. In most cases (ammonium, barium, cobalt, copper, fluoride, nickel, nitrate, silica, strontium, and sulfide) background data are not available or are insufficient numbers of measurement above detection limits to allow for quantitative comparison to background. For the purposes of risk assessment (DOE, 1995a), these were considered as potential contaminants by default. The risk assessment demonstrated that the observed levels of the above-mentioned constituents did not pose a significant risk to human health or the environment.

Based on limited data, radiological constituents, lead-210, polonium-210, radium-226, radium-228, and thorium 230, do not appear to exceed background levels (DOE, 1995a). However, this conclusion is based on a limited number of sampling rounds. The observed radioactive constituents in ground water are considered potential carcinogens with additive effects. For these constituents, there is no lower threshold for adverse health effects and these constituents cannot be screened out on the basis of low toxicity. The collection of additional data, especially for background, will help to demonstrate the lack of significant site-related impacts to ground water from these radioactive constituents.

Surface water at the processing site will be sampled and analyzed for selected field parameters and for uranium. Modeling of the effects of contaminated ground water discharge on Animas River quality demonstrate that those effects will not be distinguishable from background. However, modeling also indicates that the best indicator of contaminated ground water discharge to the river is uranium. Therefore, surface waters will be monitored for uranium to further demonstrate the lack of significant impact to the Animas River.

In general, filtered ground water and surface water samples will be collected and analyzed. Unfiltered samples will also be collected and analyzed for iron and lead which are generally at higher concentrations in unfiltered samples. Also, in general, radiological constituents in ground water will be analyzed in unfiltered samples.

5.2.2 Disposal site (DUR-03)

Analytes to be monitored at the Bodo Canyon disposal site include major elements, field parameters indicative of general ground water quality, and indicator parameters for detecting ground water contamination derived from the disposal cell (Table 5.2). A detailed discussion of these selected parameters is provided in the Bodo Canyon disposal site LTSP (DOE, 1995a). The parameters listed for the disposal site in Table 5.2 are for routine screening monitoring. If there is an exceedance of proposed concentration limits in ground water collected from POC wells and when sampling, evaluating, and resampling do not eliminate the disposal cell as the cause for the water-quality exceedance, an evaluative monitoring program will be initiated by the DOE as is described in the LTSP. This will involve the analysis of constituents, in addition to those listed in Table 5.2. These constituents are, at a minimum, arsenic, cadmium, chromium,

Table 5.4 Contaminants not to be monitored in ground water, Durango, Colorado, processing site[a]

	Mill area						Ponds area					
	Filtered			Unfiltered			Filtered			Unfiltered		
	Background maximum	Plume maximum	Plume detects	Background maximum	Plume maximum	Plume detects	Background maximum	Plume maximum	Plume detects	Background maximum	Plume maximum	Plume detects
Cobalt	NA	<0.05	0/3	NA	<0.05	0/1	<0.005	0.005	1/11	NA	<0.05	0/1
Copper	NA	<0.02	0/5	NA	<0.02	0/1	<0.005	0.011	2/13	NA	<0.02	0/1
Nickel	NA	<0.04	0/5	NA	<0.04	0/1	<0.02	0.025	4/13	NA	<0.04	0/1
Ammonium	NA	<0.20	1/2	NA	NA	NA	NA	3.3	2/2	NA	NA	NA
Barium	NA	<0.10	3/5	NA	<0.10	0/1	0.06	0.05	1/13	NA	<0.10	NA
Fluoride	NA	1.6	5/5	NA	1.2	1/1	NA	0.40	5/5	NA	0.20	NA
Nitrate	NA	2.8	5/5	NA	8.4	2/2	0.53	13.7	3/5	NA	<1.0	0/3
Strontium	NA	3.7	3/3	NA	NA	NA	NA	11	3/3	NA	NA	NA
Sulfide	NA	<0.1	0/3	NA	NA	NA	NA	0.3	1/3	NA	NA	NA
Silica	9.7	23	2/2	14	29	2/2	9	25	2/2	NA	23	4/4
Zinc	<0.5	3.3	7/7	0.11	3.2	3/3	0.028	0.25	8/10	NA	0.11	3/4

[a]Based on maximum levels observed not posing a significant risk to human health (DOE, 1995b) and the lack of increasing trends over time.

Note: All data in milligrams per liter (mg/L).

NA – not analyzed.

mercury, molybdenum, radium-226 and -228, selenium, silver, uranium, beryllium, nickel, and vanadium (DOE, 1995a).

5.3 SAMPLING FREQUENCY

Groundwater will be sampled annually for the next two years. After two years, data collection objectives will be evaluated and the sampling plan for the following three years may be modified to reflect remaining data needs. The end point for routine monitoring at the processing site will occur when the ground water compliance strategy is accepted. The end point for sampling at the disposal cell depends in part on the effectiveness of the remedial action determined through the ongoing monitoring program (DOE, 1995a)(DOE, 1995a).

Annual sampling is recommended because the RAP (DOE, 1991) proposes annual sampling at the disposal site beginning in 1996, five years from completion of the cell; and previously collected data from the processing site indicate trends in contaminants are, in general, stable or slowly decreasing with time. The rate of change is such that yearly sampling will provide adequate characterization of changes in ground water concentrations for the purposes of evaluating remedial actions in the future.

Annual sampling will be conducted between June and October of each year. This is to ensure access to the disposal cell, which is affected by winter snowfall, and to private well DUR-01-0658, which is shut in for the winter (from November through April).

5.4 DATA EVALUATION METHODS

Data results will be compared to previous data and to background to determine changes or trends in site-related contaminants. Increases or decreases in constituent concentrations will be evaluated to determine if evidence exists for the following:

1. Increased or decreased levels of contamination in ground water or surface water at the processing site which would affect the conclusions of the baseline risk assessment (DOE, 1995a).

2. MCLs were exceeded for the first time at a sampled location at the processing site.

3. Proposed concentration limits for screening parameters were exceeded at the POC at the Bodo Canyon disposal site. DOE proposed concentration limits for those parameters (DOE, 1995a) are provided in Table 5.5.

4. Movement of contaminated ground water into areas not previously identified as being contaminated. This will include an evaluation of water quality in the alluvium at the disposal site (in well DUR-03-0608) and evaluation of any

Table 5.5 Proposed concentration limits for hazardous constituents at the Bodo Canyon disposal site POC

Hazardous constituent in tailings solutions	MCL	Tailings pore fluid median	Cliff House/Menefee background ground water: Observed maximum [a]	Cliff House/Menefee background ground water: Median [a]	Proposed concentration limit [a]
Arsenic	0.05	0.19	0.03	<0.01	0.05[b]
Cadmium	0.01	0.037	0.019	<0.001	0.019[c]
Chromium	0.05	<0.01	0.12	<0.01	0.12[c]
Mercury	0.002	<0.0002	0.0004	<0.0002	0.002[b]
Molybdenum	0.1	1.73	0.22	<0.01	0.22[c]
Radium-226 and -228	5.0	10.1	15	<2.0	15.0[c]
Selenium	0.01	0.13	0.042	<0.005	0.042[c]
Silver	0.05	<0.01	0.03	<0.01	0.05[b]
Uranium	0.044	4.5	0.077	0.001	0.077[c]
Beryllium	None	<0.01	0.023	<0.01	0.023[d]
Nickel	None	0.04	0.07	<0.04	0.07[d]
Vanadium	None	11	0.06	<0.01	0.06[d]

[a]In Cliff House/Menefee uppermost aquifer at POC.
[b]Observed maximum in background less than MCL.
[c]Observed maximum background greater than MCL.
[d]Observed maximum in background.

Note: All units are in milligrams per liter (mg/L) except radium-226 and -228, which are in picocuries per liter (pCi/L).

SOURCE: Durango LTSP (DOE, 1995a)

trends in POC wells which might indicate movement of cell-related contaminated ground water toward the POC.

5. Changes in the ground water flow regime. This will include evaluation of water levels at both the disposal cell and the processing site.

Additionally, water levels in alluvial wells at the processing site should be evaluated for trends indicating dewatering of the alluvium beneath the disposal cell, as discussed in the RAP (DOE, 1991).

5.5 RESPONSE TO ANOMALOUS DATA

Data will compare the range of expected values for each ground water and surface water sampling location (if known). This list includes both physical parameters, such as ground water levels, and chemical parameters, such as pH and uranium. Future data that lie outside of these ranges will be assessed to determine if the value is reasonably expected given the standard deviation of previous sampling rounds or the existence of trends. If the value is not reasonably expected, then field and laboratory records will be checked for the possibility of a sampling or transcription error. If that is not the case, remaining samples, if any, will be re-analyzed to determine if the value is an analytical error. If the anomalous data cannot be shown to be due to sampling or analytical errors, then the well will be resampled for the anomalous parameter during the next sampling event.

5.6 REPORTING

Data, results, and a report of the ground water monitoring of the Bodo Canyon disposal site will be provided to the U.S. Nuclear Regulatory Commission and the Colorado Department of Public Health and Environment on an annual basis, when the POC and background wells are sampled, as described in the LTSP (DOE, 1995a).

6.0 LIST OF CONTRIBUTORS

The following individuals contributed to the preparation of this report.

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C. Yancey	Document coordinator, authorship
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B. Smith	Peer review
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L. Sanchez	Text processing

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