DOE/AL/62350-21F
REV. 3

United States Department of Energy

REMEDIAL ACTION PLAN AND SITE DESIGN FOR STABILIZATION OF THE INACTIVE URANIUM MILL TAILINGS SITES AT SLICK ROCK, COLORADO

REMEDIAL ACTION SELECTION REPORT
ATTACHMENT 2, GEOLOGY REPORT
ATTACHMENT 3, GROUND WATER HYDROLOGY REPORT
ATTACHMENT 4, WATER RESOURCES PROTECTION STRATEGY

Final

August 1996

Appendix B of the
Cooperative Agreement
No. DE-FC04-81AL16257

UMTRA

Uranium Mill Tailings Remedial Action Project

DOE/AL/62350-21F
REV. 3

REMEDIAL ACTION PLAN AND SITE DESIGN FOR STABILIZATION OF THE INACTIVE URANIUM MILL TAILINGS SITES AT SLICK ROCK, COLORADO

Final

August 1996

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

Prepared by
Jacobs Engineering Group Inc.
Albuquerque, New Mexico

Page Changes

for

Attachment 3, Ground Water Hydrology Report

Slick Rock RAP

August 1996

ATTACHMENT 3
GROUND WATER HYDROLOGY REPORT

TABLE OF CONTENTS

LIST OF FIGURES

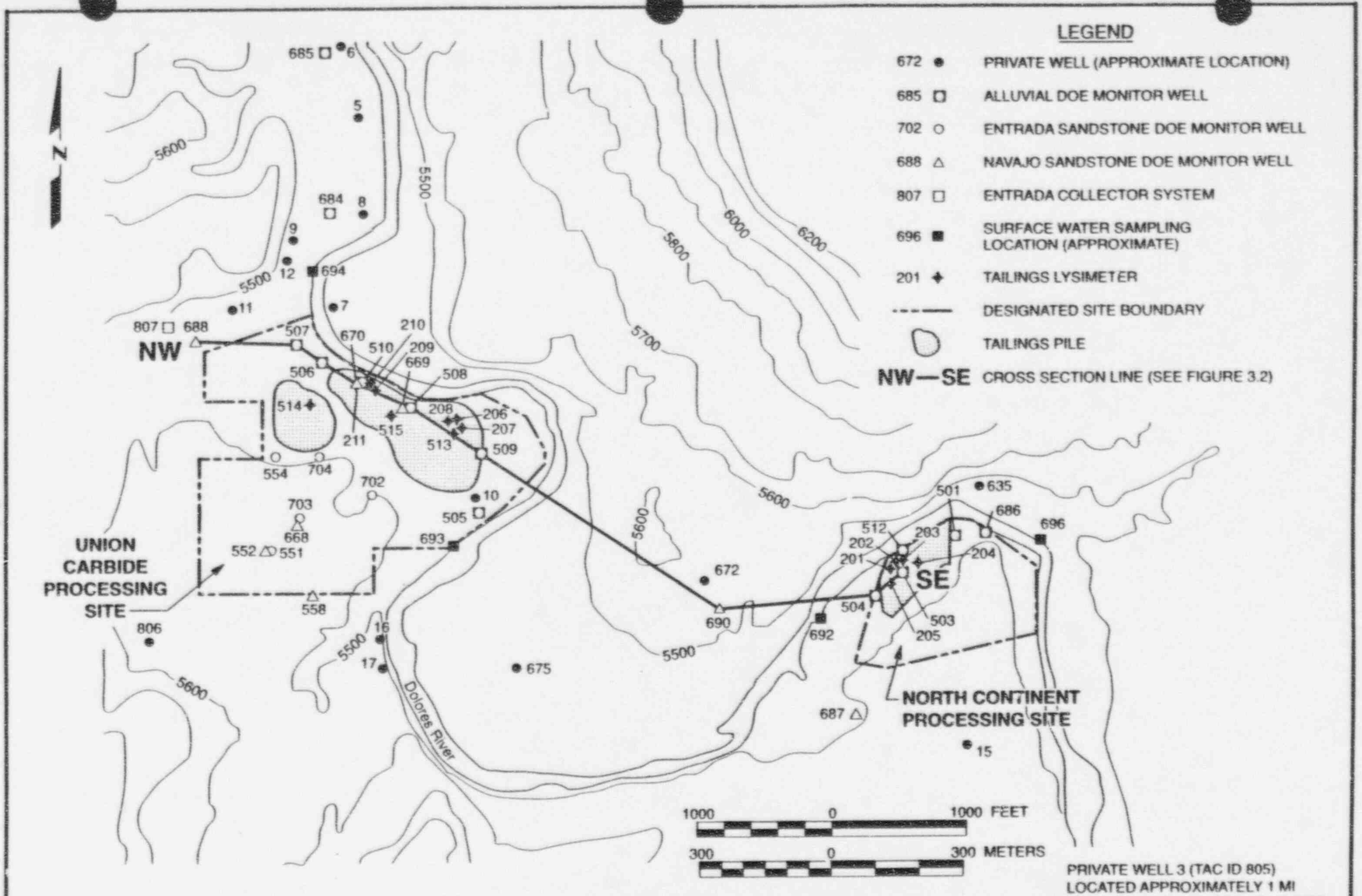

FIGURE 3.1
GROUND WATER AND SURFACE WATER SAMPLING LOCATIONS NEAR SLICK ROCK, COLORADO

MAC: SITE/SRK/RAS/ATTCH#3/BASE-WATQUAL

ATTACHMENT #3

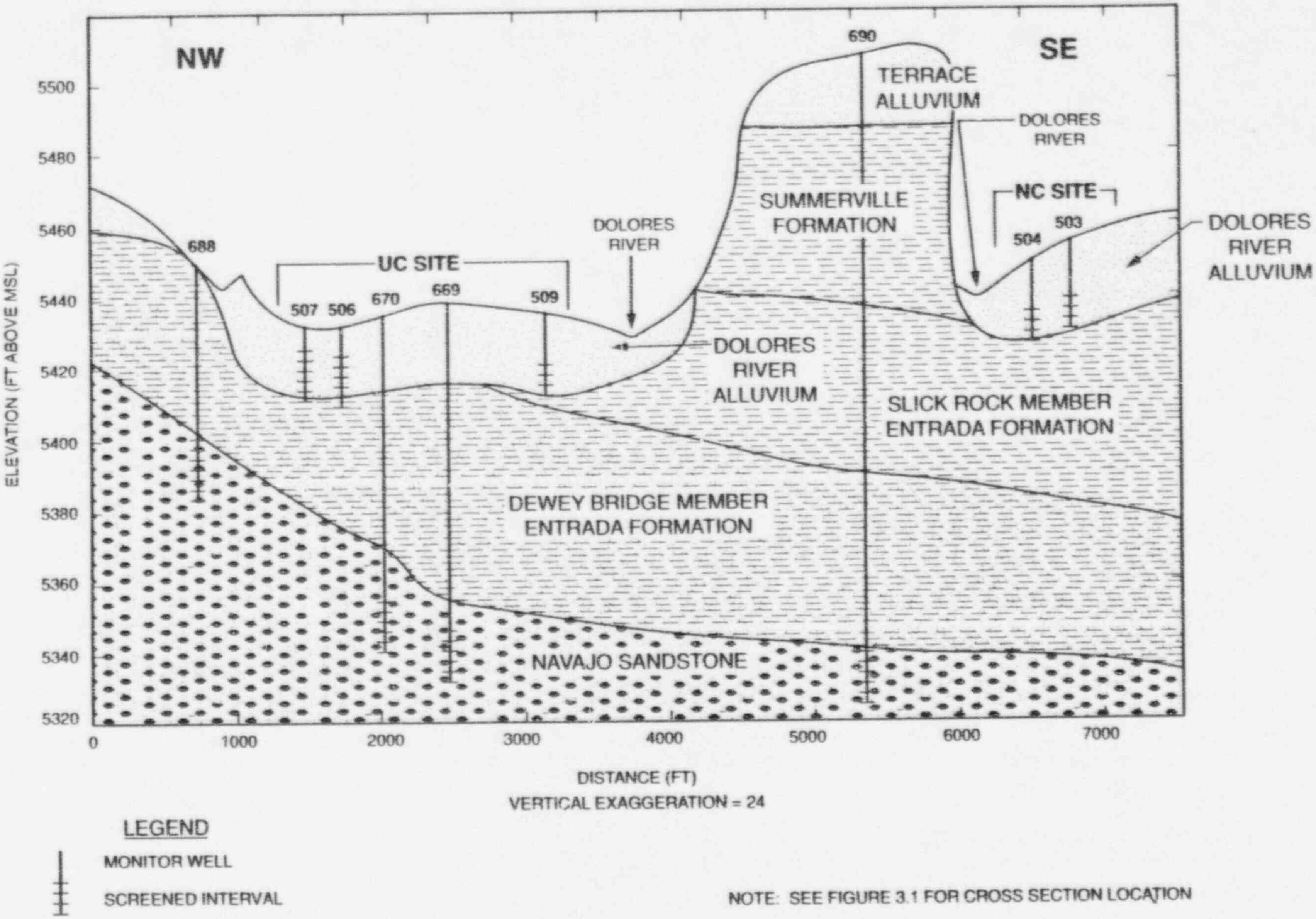

FIGURE 3.2
GEOLOGIC CROSS SECTION (NORTHWEST-SOUTHEAST)
NC AND UC SITES NEAR SLICK ROCK, COLORADO

of nitrate or nitrite. On the other hand, the mobility of iron and manganese will be enhanced by the reducing conditions. However, as the reducing ground waters mix with oxidizing waters downgradient, the iron and possibly the manganese will be oxidized and precipitate out of solution. As iron precipitates out of solution, it could cleanse the water of other contaminants through coprecipitation and adsorption reactions.

As the reducing conditions in the alluvial aquifers return to naturally oxidizing conditions, the contaminants immobilized by reduction precipitation reactions may be remobilized, depending on the oxidation potential achieved in the aquifer. For example, any uranium immobilized by reduction will undoubtedly be remobilized. Selenium and nitrogen may or may not be converted to more mobile species, depending on the natural oxidation potential in the aquifer.

Adsorption reactions involve the attachment of simple and complex ions to the exterior surfaces of minerals in the aquifer matrix and/or ion exchange on interior exchange sites. Although the details of the surface attachment reactions are not completely known, it is well known that surfaces of iron and manganese oxides and oxyhydroxides have a high affinity for transition metals and oxyanions such as molybdate. The metals and oxyanions do not all have the same affinity for these oxides and oxyhydroxides. Based on theoretical derivations, the relative affinities cannot be reliably predicted in complex natural systems such as the ground water associated with uranium mill tailings sites. These relative affinities must be measured in a laboratory by either batch or column experiments.

The ion exchange reactions are better understood and largely involve cation exchange. However, even the relative affinities of mineral phases for cationic contaminants such as Ra-226, cadmium, and zinc must be determined experimentally in batch and/or column experiments.

3.1.9 Ground water use, value, and alternative supplies

No municipal water supply wells exist at or in the vicinity of Slick Rock, Colorado. The community of Slick Rock consists of a combination restaurant/ general store. About 10 people, including residents of two trailers in the Slick Rock vicinity, live within 10 mi (16 km) of the UC and NC sites.

A well survey conducted in February 1994 has indicated that 18 private wells exist (currently or historically) within a 2-mi (3-km) radius of the Slick Rock UC and NC processing sites. Fourteen of these wells are registered with the Colorado Division of Water Resources, and the remaining four are nonregistered. Information regarding well permits, sampling dates, well construction, ground water units of completion, well status, and water use is provided in Table 3.41. Approximate locations of these wells are provided in Figure 3.1. Well permit information indicates that the nearby private wells are screened in the alluvium and the Entrada and Navajo Sandstone Formations. The 1994 well survey and follow-up water sampling have indicated that of the 18 private wells, 2 are actively used, 11 existing wells are presumed to be inactive, 3 wells adjacent to the site that could not be located in the field are presumed to be sealed, and the status of 2 registered wells located approximately 2 mi (3 km) east (upgradient of the processing sites) is unknown because of limited roadway access. Three private wells are downgradient of the UC site and are expected to be beyond the reach of the contaminant plume, as evidenced by the water quality in downgradient alluvial DOE monitor wells 684 and 685. The remainder of the wells are upgradient or crossgradient of the UC site. Of the two active wells, one (well 672) is crossgradient and across the Dolores River from the NC and UC sites. Of these three wells located across the Dolores River from the NC site, only one private well is useable. Water quality monitoring conducted in February 1994 indicates that the water quality in well 672 is not affected by the site. A ground water flow boundary appears to follow the course of the Dolores River and is expected to hydrologically separate three wells from the NC tailings, which are on the opposite side of the Dolores River from the private wells. Additional site characterization (water level and quality measurements) will be necessary to support the assumption that the private wells on the north side of the Dolores River are hydrologically separated from residual ground water contamination from the NC tailings. The other active well is upgradient of both sites.

In addition to the 18 private wells, a collector system that taps the Entrada Formation is located along a cliff face approximately 1500 ft (450 m) west (upgradient) of the UC site. This collector system appears in good shape and is believed to be used for livestock.

Staff from the Bureau of Land Management (BLM) and USGS have reported, as of February 1994, that they are unaware of any additional ground water users within 2 mi (3 km) of the Slick Rock processing sites.

Surface water from the Dolores River is another potential source of water in the vicinity of the processing site. Water from the Dolores River may be used temporarily to suppress dust, decontaminate vehicles, and compact tailings. Rights to this surface water will be secured prior to surface remedial action construction.

Water use is expected to decrease significantly following remedial action construction. A detailed evaluation of projected water use has been deferred until the UMTRA Project ground water compliance program for Slick Rock is under way.

3.2 DISPOSAL SITE

3.2.1 Previous investigations

Three previous site-specific hydrologic investigations were conducted in the vicinity of the Burro Canyon disposal site. In 1985, preliminary testing was conducted southeast of the current Burro Canyon disposal site location. These initial site characterization activities consisted of excavating eight test pits and three boreholes to determine whether the location was suitable as a relocated disposal site. The area was found to be suitable for tailings disposal (DOE, 1986).

A second detailed site investigation was conducted during 1990 and 1991 at the current Burro Canyon site. During 1990, the DOE installed 14 monitor wells, 4 boreholes, and 13 test pits to characterize lithology, ground water elevations and hydraulic gradients, aquifer properties, and ground water quality at the disposal site.

Additional testing was conducted in 1991 in response to two issues raised by the Colorado Department of Public Health and Environment (CDPHE): 1) the extent of the mudstone aquitard between the upper and middle sandstone units of the Burro Canyon Formation southeast (downgradient) of the proposed disposal site, and 2) the degree of downgradient saturation in the upper sandstone unit. An exploration core hole was drilled approximately 900 ft (300 m) from the edge of the disposal cell and to a total depth of 179 ft (54.6 m) below land surface. The core hole confirmed that the Burro Canyon mudstone and sandstone units were continuous. A monitor well was placed approximately 10 ft (3 m) north of the exploration core hole and was completed to the base of the upper Burro Canyon sandstone unit for a total depth of 113 ft (34.4 m). A second monitor well, placed approximately 650 ft (198 m) southeast of the edge of the proposed disposal cell, was drilled through the upper sandstone unit (from 72 to 101 ft [22 to 30.8 m]), the mudstone aquitard (from 101 to 169 ft [30.8 to 51.5 m]), and 10 ft (3 m) into the middle sandstone unit for a total depth of 179 ft (54.6 m). This well was then backfilled with bentonite and a screen was installed at the base of the upper sandstone unit from 80 to 100 ft (24 to 30 m), with filter pack material from 65 to 102 ft (20 to 31.1 m). Geophysical logs (natural gamma, gamma-gamma, neutron, and resistivity) were run in the exploratory core hole and five DOE monitor wells.

The locations of the monitor wells and piezometers are shown on Figure 3.14. Monitor well information is presented in Table 3.42 of Appendix A. In the following discussion, all depths recorded are measured from ground surface. Lithologic logs and monitor well construction information are provided in Appendix B to Attachment 3.

The chemical and mineralogical properties of Burro Canyon sediment samples were characterized in 1990 by Pittsburgh Mineral & Environmental Technology, Inc. (PMET, 1990). Sediment samples were collected from the Dakota Sandstone (sandstones and shales) and from Burro Canyon (mudstones and sandstones). The laboratory work included chemical analyses, polarized light microscopy with modal analyses, and X-ray diffraction analyses.

Relatively undisturbed samples were recovered for visual inspection and laboratory tests to determine unsaturated hydraulic conductivity, porosity, and other selected parameters. Five sediment samples were collected from mudstones and claystones of the Burro Canyon Formation. Laboratory analyses were conducted to determine moisture contents, bulk densities, porosities,

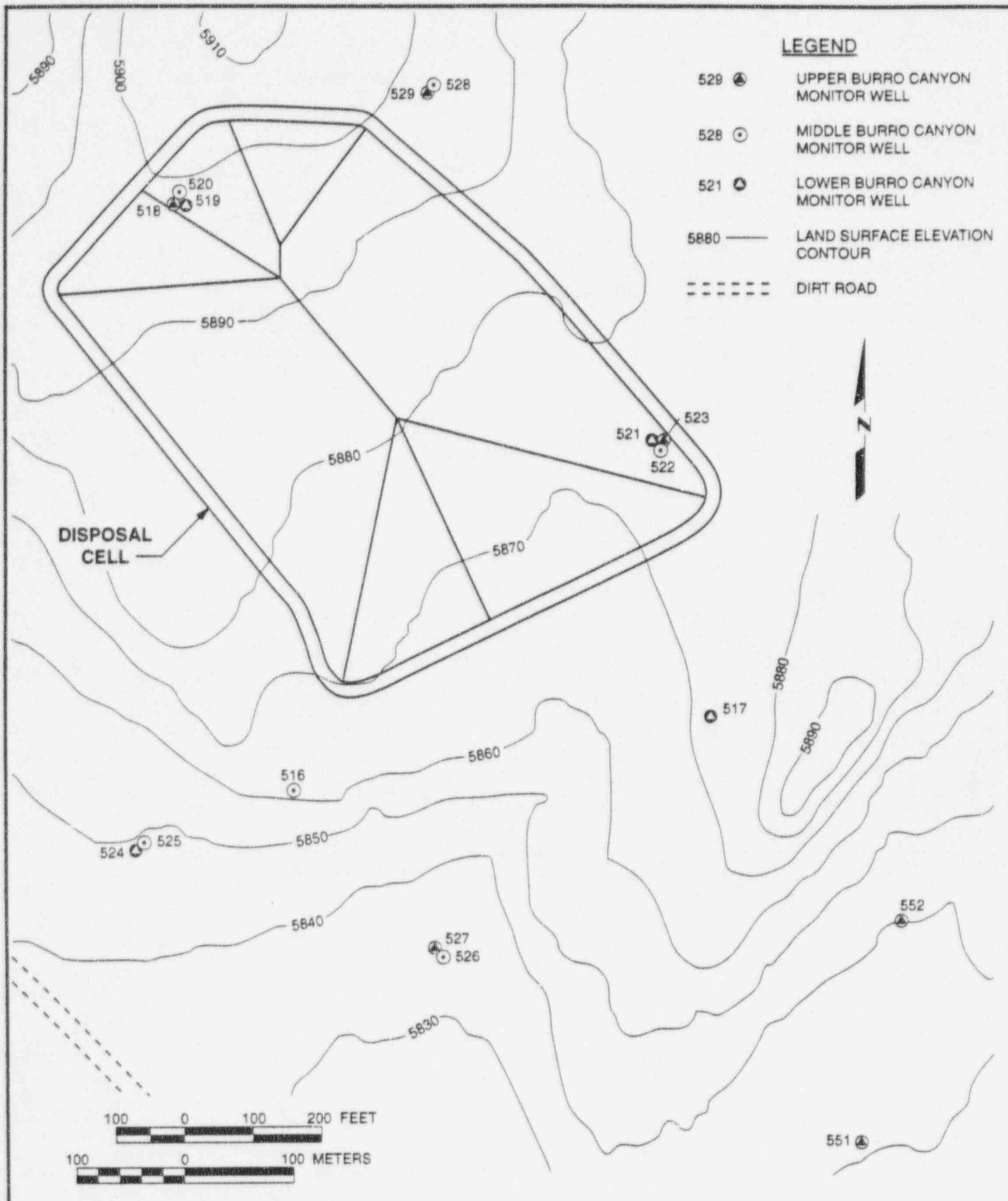

FIGURE 3.14
MONITOR WELL LOCATIONS
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

saturated hydraulic conductivities, soil moisture retention curves, and particle densities (Daniel B. Stephens & Associates, Inc., 1991).

Ground water elevations were measured to map the potentiometric surface to determine the direction of ground water flow and hydraulic gradients. Bailer recovery tests, aquifer performance tests, and slug injection tests were performed to measure hydraulic parameters of the upper, middle, and lower Burro Canyon sandstone units. Water quality samples were collected from selected wells in the Burro Canyon sandstone units to establish background water quality at the disposal site.

3.2.2 Geology and hydrostratigraphy

To characterize the hydrogeology of the site in the Burro Canyon Formation, the DOE installed six monitor wells in the upper sandstone unit, six wells in the middle sandstone unit, and four wells in the lower sandstone unit. Construction information for these monitor wells is summarized in Table 3.42 of Appendix A. Detailed lithologic logs and construction information are presented in Appendix B.

The Burro Canyon disposal site is on a weathered pediment of Dakota Sandstone that overlies the interbedded mudstones, siltstones, and sandstones of the Burro Canyon Formation. The lowest unit of Dakota Sandstone consists primarily of low-permeability carbonaceous shale and mudstone. Two thin sandstone layers ranging in thickness from 1 to 6 ft (0.3 to 2 m) are interbedded with the shales and mudstones in the lower Dakota Sandstone. The Dakota Sandstone is unsaturated in the site vicinity and is therefore not discussed in detail in this report. Ground water beneath the site occurs in the sandstone units of the Burro Canyon Formation.

The Burro Canyon Formation is relatively uniform in thickness in the vicinity of the site (Shawe et al., 1968). The grade of the Burro Canyon Formation is approximately 3 percent, as discussed in Section 3.1 of Attachment 2. Three water-bearing sandstone units lie beneath the disposal cell. The tops of these sandstone units generally are within the Burro Canyon Formation at approximate depths of 100, 200, and 300 ft (30, 60, and 90 m), and are described as the upper, middle, and lower units, respectively. They are fine- to medium-grained sandstone layers ranging from 25 to 75 ft (7.6 to 23 m) in thickness and are separated by thick interbedded claystone, mudstone, and siltstone sequences (hereafter referred to as mudstone), as shown in Figure 3.15. The three sandstone units are hydrogeologically separated from each other, as evidenced by 1) differences in the geologic and hydraulic properties of the sandstone versus the mudstone units, 2) differences in potentiometric surfaces for each unit, and 3) differences in the ground water geochemistry of each unit. The low-permeability mudstone/claystone units above the upper sandstone unit and between the upper, middle, and lower sandstone units are effective aquitards, inhibiting the potential migration of fluids and contaminants from the area of the disposal cell. The presence and movement of ground water is discussed in greater detail in Section 3.2.3.

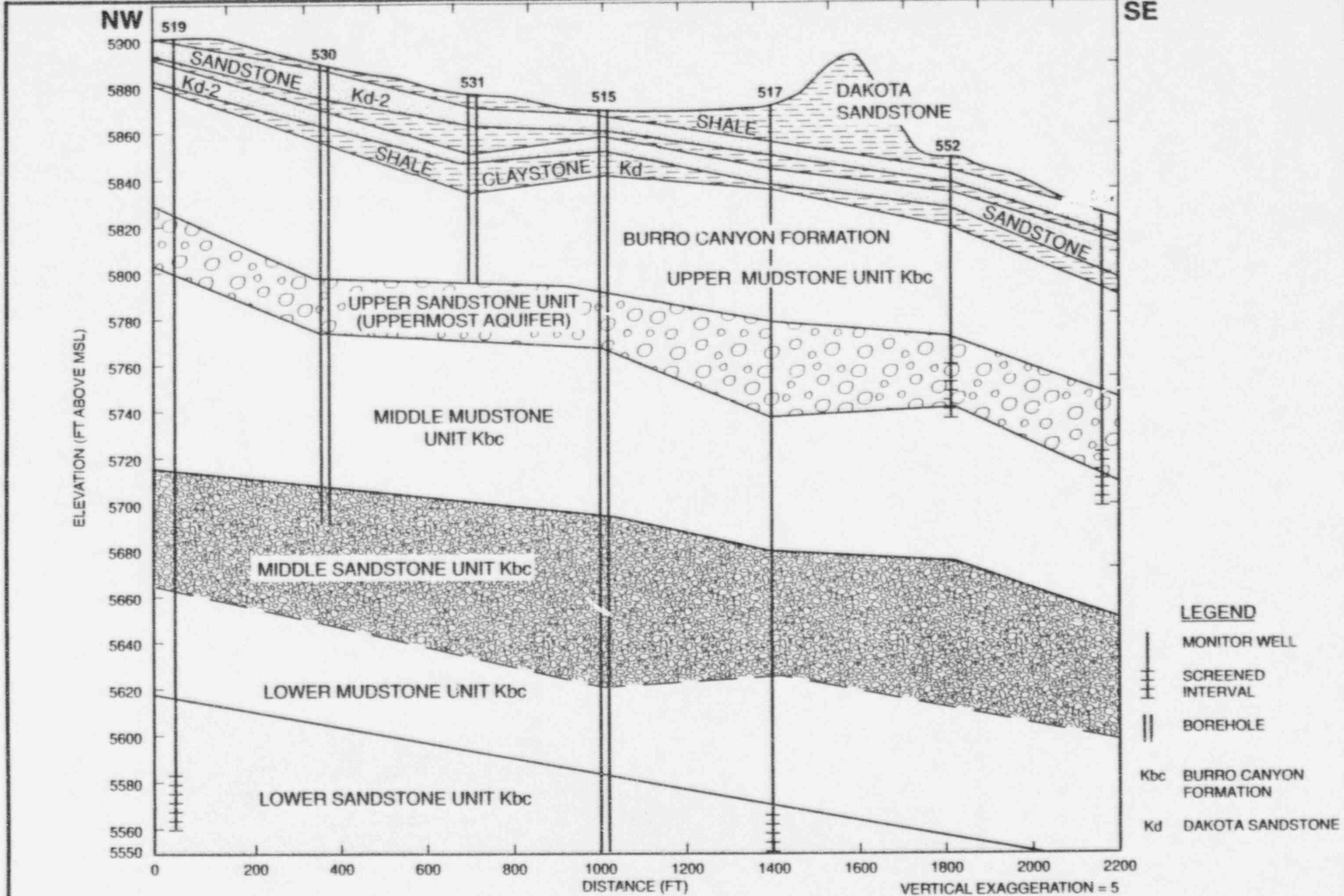

FIGURE 3.15
GEOLOGIC CROSS SECTION (NORTHWEST-SOUTHEAST)
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

MAC: SITE/SBK/RAS/ATTCH#3/X-SEC(NW-SE)

ATTACHMENT #3

A geologic northwest-southeast cross section is provided for the disposal site in Figure 3.15. As indicated on this figure, the thicknesses of the units remain relatively uniform. Ground water elevations measured in each monitor well at the Burro Canyon disposal site from February 1990 to November 1992 are provided in Table 3.43 of Appendix A.

3.2.3 Presence and movement of ground water

Burro Canyon upper sandstone unit

The upper sandstone unit of the Burro Canyon Formation (including some interbedded mudstone layers) ranges from 20 to 40 ft (6 to 12 m) thick beneath the disposal cell footprint, and underlies approximately 50 ft (15 m) of mudstone. The Burro Canyon upper sandstone unit is the uppermost aquifer; ground water occurs under unconfined conditions and the yield is very low. Ground water movement is to the southeast, as shown in Figure 3.16. The top of the upper sandstone unit occurs from 50 to 100 ft (20 to 30 m) below land surface. The depth to the water table ranges from 75 to 110 ft (23 to 34 m) below land surface in the upper sandstone unit. Figure 3.17 shows that ground water elevations have remained constant. Recharge to the upper sandstone unit is expected to be from infiltrating the surface outcrop (upgradient of the site). Additional hydraulic information for this unit is provided in Section 3.2.4.

Burro Canyon middle sandstone unit

The middle sandstone unit ranges from 55 to 75 ft (17 to 23 m) thick beneath the site and underlies approximately 60 to 70 ft (18 to 21 m) of mudstone. The top of the middle sandstone unit occurs at a depth between 140 and 190 ft (42 to 58 m) below land surface in the vicinity of the disposal cell footprint. Ground water occurs under confined conditions and has an upward hydraulic gradient; the potentiometric surface is approximately 40 ft (12 m) above the top of the middle sandstone unit. A potentiometric surface contour map of the middle sandstone unit is provided in Figure 3.18. Ground water flows to the southeast. Ground water elevations have remained constant, as shown in Figure 3.19.

Recharge to the middle sandstone unit occurs upgradient from the disposal cell, approximately 0.25 to 0.75 mi (0.40 to 1.2 km) northeast of the site. Sandstone beds outcrop along the east limb of the Disappointment syncline and intercept tributaries to the Nicholas Wash drainage system. Ground water then flows to the south-southeast and eventually dissipates (discharges) into the surrounding geologic strata of the Burro Canyon Formation south of the Burro Canyon disposal site.

Burro Canyon lower sandstone unit

The lower water-bearing sandstone unit beneath the disposal cell is 39 ft (12 m) thick, and the top of the unit is approximately 250 to 300 ft (76 to 91 m) below land surface. A potentiometric surface contour map of the lower sandstone unit

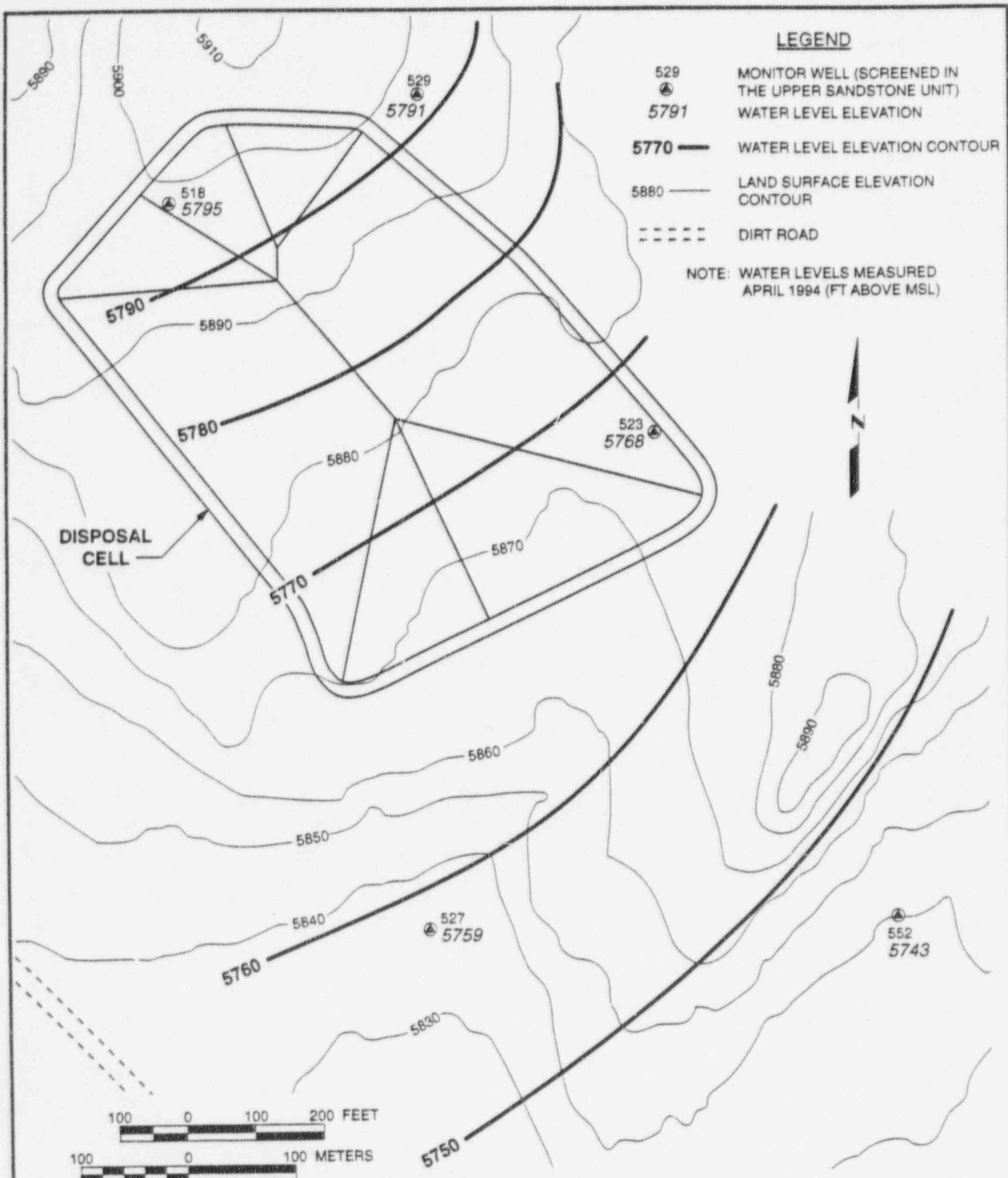

FIGURE 3.16
POTENTIOMETRIC SURFACE OF THE BURRO CANYON UPPER SANDSTONE UNIT
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

MAC: SITE/SRK/RAS/ATTCH#3/BASE2-POTENUPPER

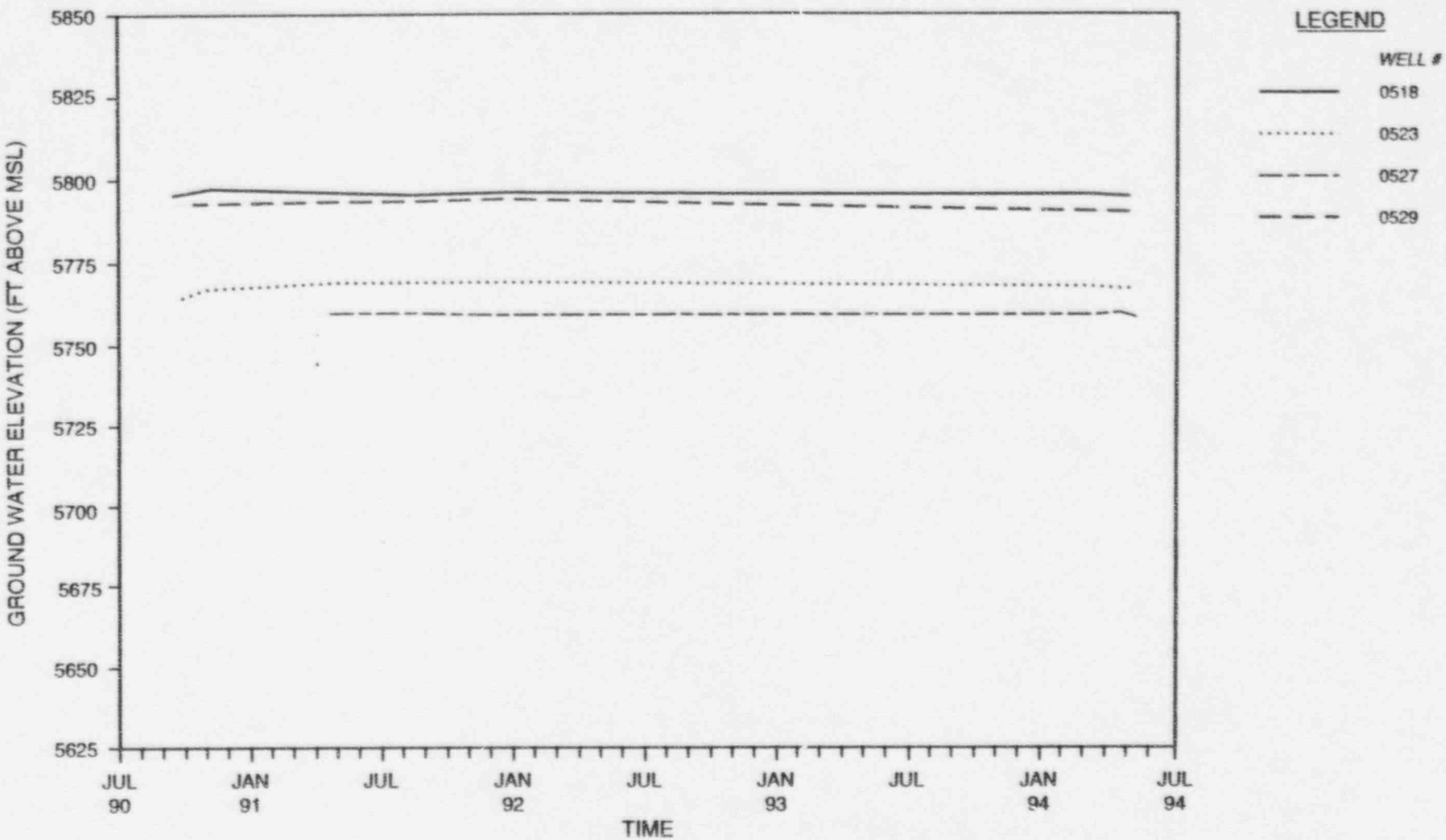

FIGURE 3.17
GROUND WATER HYDROGRAPH OF THE BURRO CANYON UPPER SANDSTONE UNIT
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

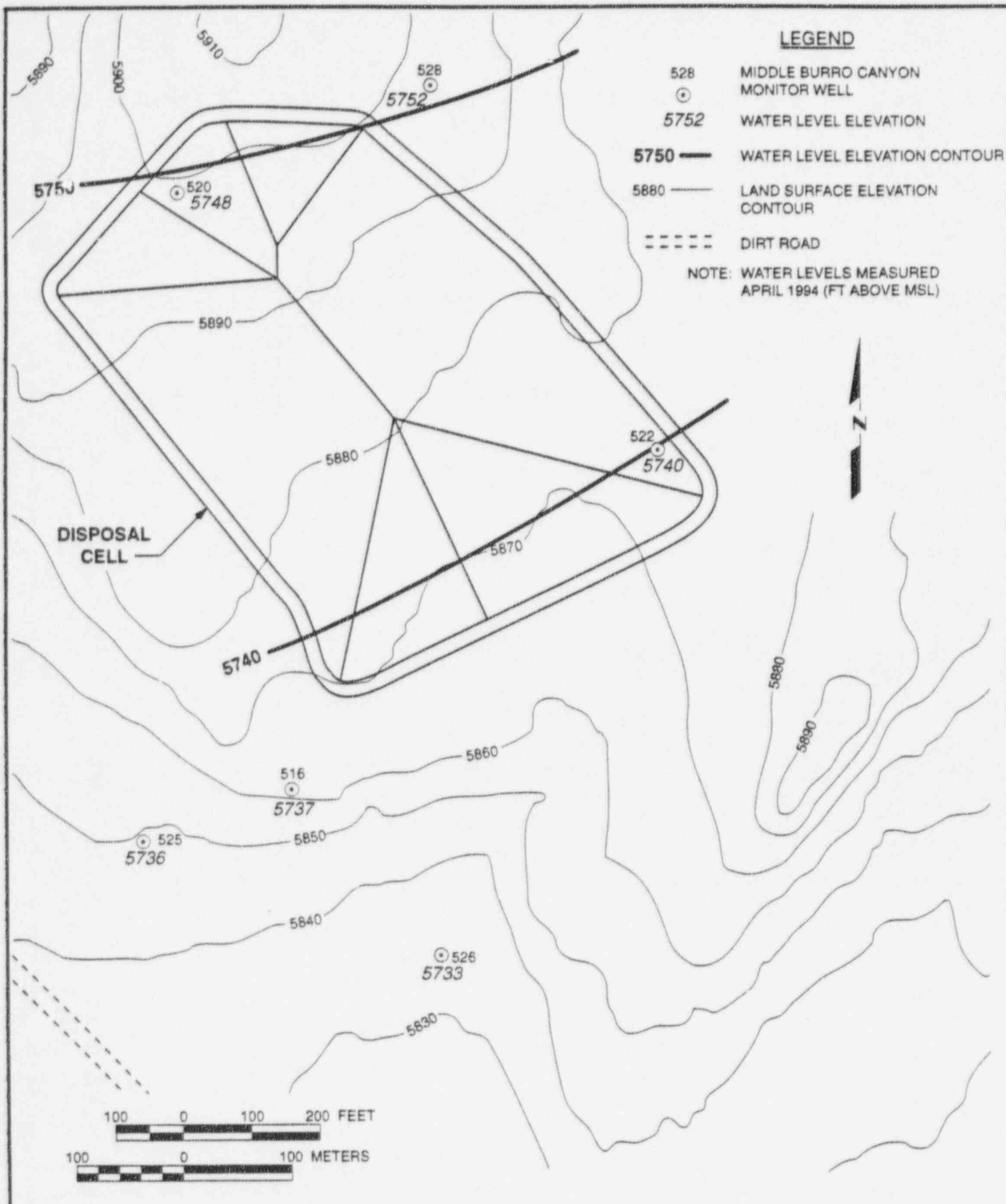

FIGURE 3.18
POTENTIOMETRIC SURFACE OF THE BURRO CANYON MIDDLE SANDSTONE UNIT
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

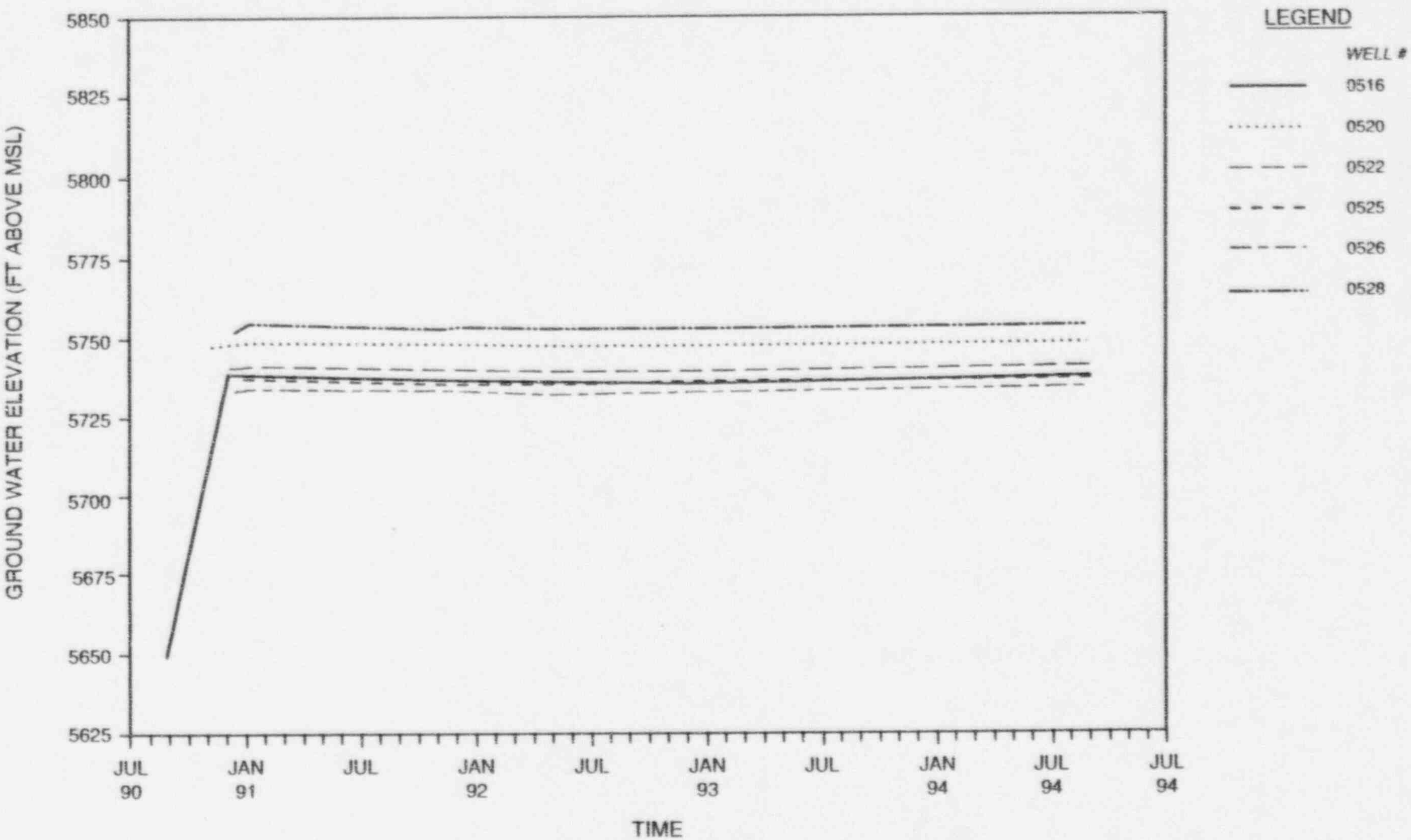

FIGURE 3.19
GROUND WATER HYDROGRAPH OF THE BURRO CANYON MIDDLE SANDSTONE UNIT
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

is provided in Figure 3.20. Ground water in this unit is confined by the thick sequence of overlying low-permeability mudstones and siltstones of the Burro Canyon Formation. Ground water has an upward gradient with the potentiometric surface 169 to 240 ft (51.5 to 73 m) above the top of the lower sandstone unit and averaging 52 ft (16 m) above the middle sandstone unit. The lower sandstone unit has an extremely low velocity and well yield. Ground water elevations have remained constant, as shown in Figure 3.21. Vertical recharge to and discharge from the lower sandstone unit is restricted because the low-permeability interbedded claystone and siltstone strata impede infiltration.

3.2.4 Hydraulic characteristics

Table 3.44 of Appendix A presents the average aquifer parameters and average linear ground water velocities in each water-bearing unit of the Burro Canyon Formation. Calculations of average hydraulic gradients and average ground water velocities are presented in Calculation No. SRK-05-93-14-06-00 in Appendix C. Analyses for aquifer performance and slug tests are presented in Calculation No. SRK-06-91-14-03-00 in Appendix C.

Unsaturated Dakota Sandstone and Burro Canyon Formations

The hydraulic conductivity of the unsaturated Dakota Sandstone bedrock and unsaturated Burro Canyon Formation mudstones was determined by field packer tests. Sixteen packer tests were conducted in three core holes at selected depths to measure the hydraulic conductivity of the bedrock. The tests were analyzed using the approach outlined in the U.S. Bureau of Reclamation's *Earth Manual* (USBR, 1974), and the results are summarized in Table 3.44 of Appendix A. The average horizontal hydraulic conductivity of the lower Dakota Sandstone Formation was 4×10^{-1} ft/day (1×10^{-4} cm/s), and the average horizontal hydraulic conductivity of the mudstones in the Burro Canyon Formation was estimated to be 6×10^{-3} ft/day (2×10^{-6} cm/s). Packer tests indicate that the saturated horizontal hydraulic conductivity of the sandstone in the Dakota Sandstone is moderate, and is several orders of magnitude greater than that of the Burro Canyon Formation. In addition, the hydraulic conductivity decreases with depth in the Burro Canyon mudstone, reflecting decreased fracture permeability with depth.

Burro Canyon upper sandstone unit

To determine the hydraulic properties of the upper sandstone unit, low-yield aquifer performance pumping tests were conducted on monitor wells 523 and 529; bailer recovery tests were conducted on monitor wells 518 and 527. Monitor well 523 was pumped at an average rate of 0.13 gallons per minute (gpm) (the lowest possible pumping rate to approximate 150 gpd) (8.2×10^{-3} L/s) for 39 hours. Substantial drawdown (61 percent of the available drawdown) occurred during the aquifer performance pumping test. The pumping rate was increased to 0.5 gpm (3.2×10^{-2} L/s) to determine if the well could support a higher pumping rate; however, the well went dry. In a

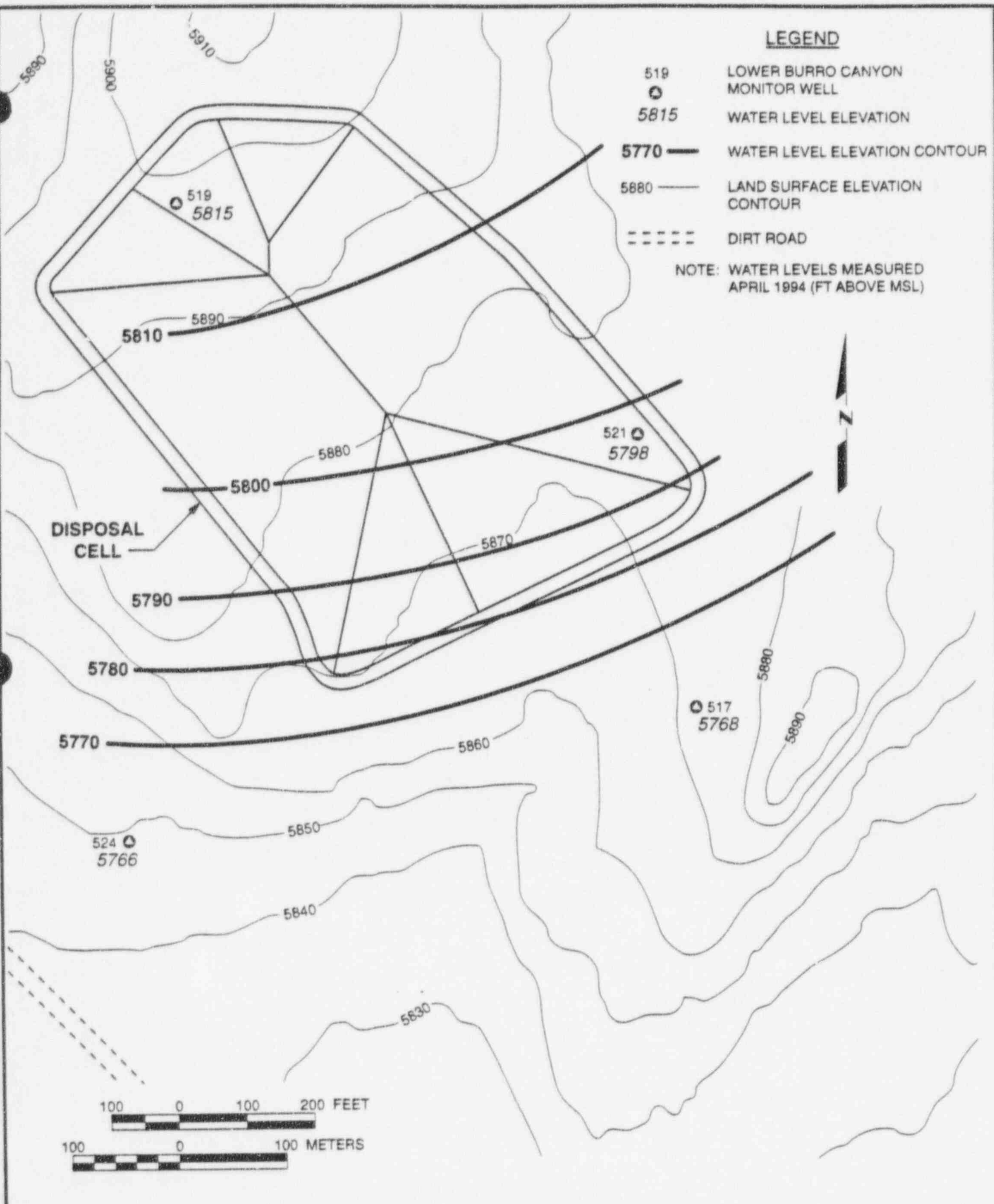

FIGURE 3.20
POTENTIOMETRIC SURFACE OF THE BURRO CANYON LOWER SANDSTONE UNIT BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

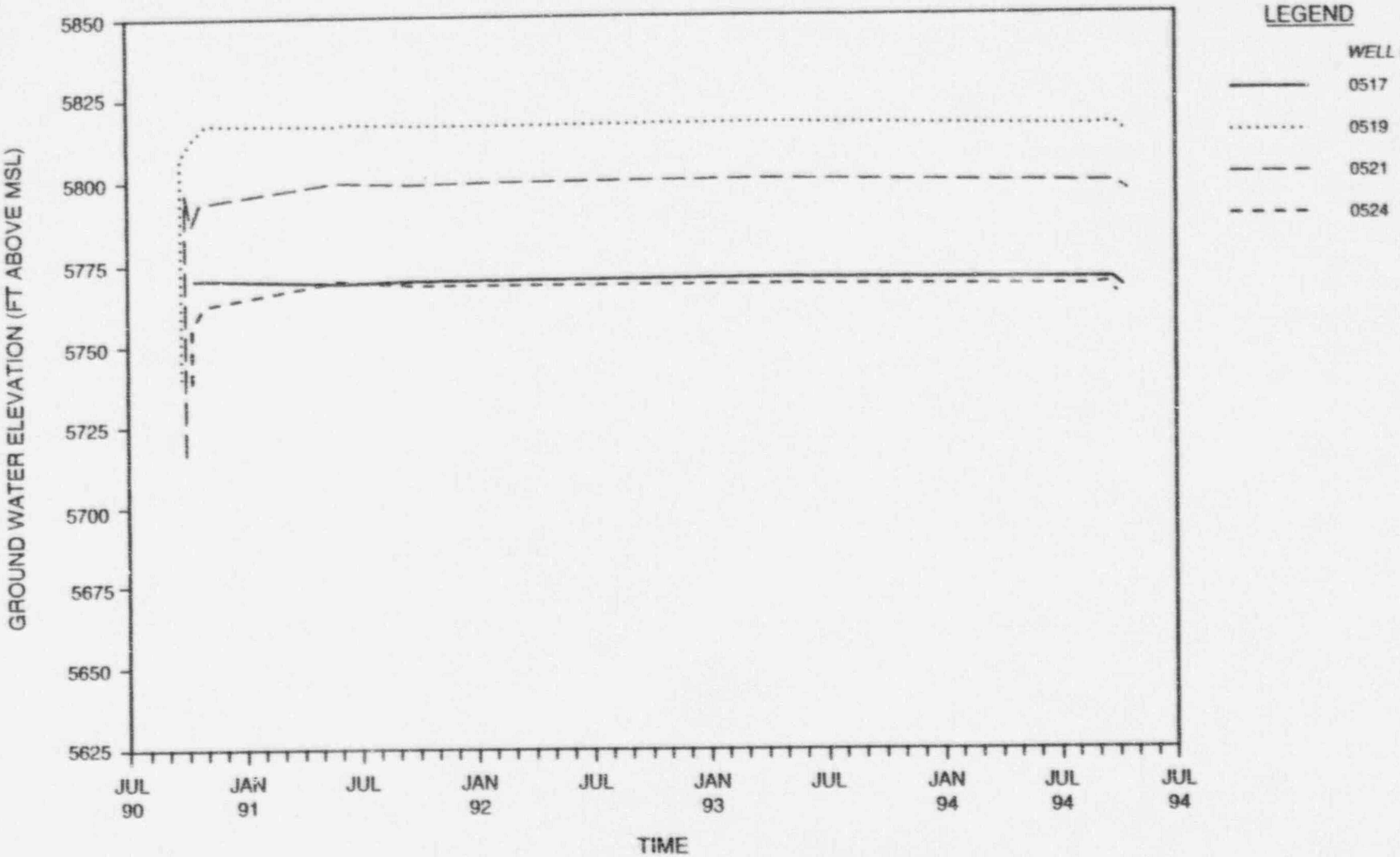

FIGURE 3.21
GROUND WATER HYDROGRAPH OF THE BURRO CANYON LOWER SANDSTONE UNIT
BURRO CANYON DISPOSAL SITE NEAR SLICK ROCK, COLORADO

second pumping test, monitor well 529 was pumped at a rate of 0.13 gpm (8.2×10^{-3} L/s), and went dry within 2 hours. During both pumping tests, no response was observed in nearby monitor wells completed in the upper and middle sandstone units. Bailer recovery tests conducted on the upper sandstone unit indicated that the transmissivity ranges from 0.02 ft^2/day to 1.04 ft^2/day (2.2×10^{-8} square meters [m^2]/s to 1.1×10^{-6} m^2/s), and averages 0.16 ft^2/day (1.7×10^{-7} m^2/s). However, borehole storage effects are believed to be significant and the aquifer may not have been stressed. The average hydraulic conductivity of the upper sandstone unit is 4×10^{-2} ft/day (1×10^{-5} cm/s). The results of these tests are presented in Calculation No. SRK-06-19-14-03-00 in Appendix C, using the analytical Well Hydraulics Interpretation Program (WHIP).

Darcy's Law was used to calculate the average linear ground water velocity in the upper sandstone unit of the Burro Canyon Formation (Calculation No. SRK-05-93-14-06-00, Appendix C). The average linear ground water velocity in the upper sandstone unit was estimated to be 6 ft/year (6×10^{-6} cm/s) (Table 3.44 of Appendix A), based on an average hydraulic conductivity of 4×10^{-2} ft/day (1×10^{-5} cm/s), a hydraulic gradient of 0.04, and an effective porosity of 0.10 (Freeze and Cherry, 1979).

The upper sandstone unit has a low transmissivity and an average saturated thickness of 12 ft (4 m). Drawdown for a hypothetical well completed in the upper sandstone was calculated using an analytical solution of the Theis nonequilibrium well equation. Using a transmissivitiy of 0.8 ft^2 per day, a storage coefficient of 0.1, and a well yield of 150 gpd (6.6×10^{-3} L/s), a drawdown of 21.4 ft (6.5 m) was calculated for the hypothetical well (Calculation No. SRK-11-94-14-09-00). The calculated drawdown exceeds the maximum observed saturated thickness of 18.9 ft (5.8 m) in the upper sandstone unit and suggests that this unit cannot sustain a minimum well yield of 150 gpd (6.6×10^{-3} L/s). The results of the aquifer performance tests and the analytical calculation demonstrate that the uppermost aquifer at the disposal site cannot provide a sustained yield of 150 gpd (6.6×10^{-3} L/s) because 1) only one out of four wells (the one with the greatest saturated thickness) could sustain a similar pumping rate for over 24 hours; 2) when pumped at the same rate, a well with a saturated thickness of 15 ft (4.6 m) went dry in less than 2 hours; 3) the average saturated thickness of the upper sandstone unit is only 12 ft (3.7 m); 4) the upper sandstone unit of the Burro Canyon Formation is present only as a cap at the top of the Joe Davis Canyon; and 5) there is no evidence of springs or seeps where the upper sandstone unit crop out. Because of the demonstrated low yield from the aquifer (less than 150 gpd), ground water is classified as limited use, in accordance with 40 CFR §192.11(e) of the final EPA ground water standards. As a result of the limited quantity of water available, the upper sandstone unit (uppermost aquifer) is not, and never can be, a viable source of water.

<u>Burro Canyon middle sandstone unit</u>

To determine the aquifer parameters of the middle unit and the degree of hydraulic connection with the upper and lower units, a 72-hour pumping test was conducted on monitor well 522; drawdown and recovery were observed in all six other monitor wells completed in the middle unit. Monitor well 522 was pumped at an average rate of 0.5 gpm (3×10^{-2} L/s) for the entire duration of the test; a preliminary step test indicated the well could not support a pumping rate of 1 gpm (6×10^{-2} L/s) because of excessive drawdown.

The pumping and recovery tests on the middle unit indicated that the transmissivity of the aquifer ranges from 5 to 7 ft^2/day (5 to 7×10^{-6} m^2/s), and averages 6 ft^2/day (6×10^{-6} m^2/s) (Table 3.44 of Appendix A). During the 72-hour test, responses were noted in five observation wells screened in the middle sandstone unit. However, no responses were observed in the upper or lower water-bearing units.

The average hydraulic conductivity of the middle sandstone unit is 9×10^{-2} ft/day (3×10^{-5} cm/s), assuming an average saturated thickness of 65 ft (20 m). The average linear ground water velocity in the middle sandstone unit is 2 ft/year (2×10^{-6} cm/s) (Table 3.44 of Appendix A), assuming an average hydraulic conductivity of 9×10^{-2} ft/day (3×10^{-5} cm/s), a hydraulic gradient of 0.02, and an effective porosity of 0.20 (Freeze and Cherry, 1979).

The confined conditions in this unit cause a substantial upward hydraulic potential. The potentiometric surface of the middle unit averages 42 ft (13 m) above the top of the sandstone unit. This potentiometric surface, however, is not higher in elevation than the overlying potentiometric surface measured in monitor wells screened in the upper sandstone unit. Calculations are documented in Appendix C (Calculations No. SRK-06-91-14-03-00 and No. SRK-05-93-14-06-00).

Burro Canyon lower sandstone unit

Slug injection tests conducted on monitor wells 519, 521, and 524 completed in the lower sandstone unit indicate that the unit transmissivity averages 0.1 ft^2/day (1×10^{-7} m^2/s) (Table 3.44 of Appendix A). However, borehole effects are likely to be significant. As a result, transmissivity values may be biased by borehole stage effects. The average hydraulic conductivity of the lowermost unit is 5×10^{-3} ft/day (2×10^{-6} cm/s). The average linear ground water velocity in the lower sandstone unit is 1 ft/year (1×10^{-6} cm/s), assuming a hydraulic conductivity of 5×10^{-3} ft/day (2×10^{-6} cm/s), a gradient of 0.06, and an effective porosity of 0.10 (Table 3.44 of Appendix A). Calculations are documented in Appendix C (Calculations No. SRK-05-93-14-06-00 and No. SRK-06-91-14-03-00).

3.2.5 Background ground water quality

Background ground water quality in each hydrostratigraphic unit within the Burro Canyon Formation was determined from analyses of ground water from monitor wells completed in each unit. Ground water quality data were characterized individually for each hydrostratigraphic unit because the units are hydrogeologically separated (Calculation No. SRK-05-93-12-10-00 in Appendix C).

In general, ground water pH is near-neutral, and TDS concentrations tend to decrease with depth. The average TDS concentration is 761 mg/L in the upper sandstone unit, 555 mg/L in the middle sandstone unit, and 345 mg/L in the lower sandstone unit.

Burro Canyon upper sandstone unit

Six background ground water monitor wells are screened and filter packed into the upper sandstone unit of the Burro Canyon Formation. These monitor wells are identified as 518, 523, 527, 529, 551, and 552 in Figure 3.16. Ground water quality data by parameter are provided in Table 3.45 of Appendix A. Ground water quality statistics are provided in Table 3.46 and summarized in Table 3.47 of Appendix A.

Ground waters in this unit are sodium sulfate and sodium bicarbonate types. TDS concentrations range from 556 mg/L to 973 mg/L. Ground water in the upper sandstone unit is neutral to slightly alkaline with pH ranging from 7.5 to 9.1.

As shown in Table 3.48 of Appendix A, the activity of Ra-226 and -228 has equaled or slightly exceeded its MCL on one occasion in samples collected from monitor wells 518 and 529. In addition, the concentration of selenium consistently exceeds the MCLs in ground water samples collected from monitor well 518.

Burro Canyon middle sandstone unit

Six background ground water monitor wells are screened and filter packed into the middle sandstone unit of the Burro Canyon Formation. These monitor wells are identified as 516, 520, 522, 525, 526, and 528 in Figure 3.18. Ground water quality data by parameter are provided in Table 3.49 of Appendix A. Ground water quality statistics are provided in Table 3.50 of Appendix A.

Monitor wells screened in the middle sandstone unit produce ground waters that are characterized as sodium bicarbonate and sodium sulfate types; the pH ranges from 7.2 to 7.6. TDS concentrations range from 422 to 696 mg/L. The activity of Ra-226 and -228 slightly exceeded its MCL in one well (516) in a one-time occurrence (Table 3.51 of Appendix A).

Burro Canyon lower sandstone unit

Four background ground water monitor wells are screened and filter packed into the lower sandstone unit of the Burro Canyon Formation. These monitor wells are identified as 517, 519, 521, and 524 in Figure 3.20. Ground water quality data by parameter are provided in Table 3.52 of Appendix A. Ground water quality statistics are provided in Table 3.53 of Appendix A.

Ground water samples collected from monitor wells screened in the lower sandstone unit are of the sodium bicarbonate type. TDS concentrations range from 256 mg/L to 485 mg/L. The ground water of the lower sandstone unit is slightly alkaline, with pH ranging from 8.6 to 9.6. All water quality samples collected from monitor wells screened in the lower unit have been below the MCLs for all regulated constituents.

Geochemical conditions

Favorable geochemical conditions appear to be present at the Burro Canyon disposal site for attenuation of most hazardous constituents present in the tailings pore fluid. This assessment is based on chemical analyses of the drill cuttings and cores (including chemical analyses, polarized light microscopy with modal analyses, screen analyses, and X-ray diffraction), ground water quality analyses, examination of the stratigraphic section of the geologic materials underlying the disposal site, and preliminary laboratory experiments.

Geochemical conditions that control the transport of the hazardous constituents from the tailings into ground water and by ground water within the aquifers at the disposal site are essentially the same as the conditions controlling transport at the processing site. These conditions include 1) the ground water chemical composition, pH, and Eh of the tailings pore fluid, soil pore fluid, and ground water; and 2) the reactive mineralogy of the subsoils and aquifer materials. The chemical compositions, pH, and Eh of the various fluids determine the types of precipitation/coprecipitation reactions that can occur to control the migration rate of contaminants of concern. The chemical compositions, pH, and Eh of the fluids combined with the reactive mineralogy of the subsoils and aquifer materials determine the sorts of adsorption reactions that can involve contaminants of concern.

Precipitation and coprecipitation reactions can result from acid-neutralization reactions, a general condition of oversaturation in the tailings seepage, and oxidation-reduction reactions. The acid-neutralization reactions occur as a result of the tailings leachate seepage into subsurface units that contain carbonates and other acid-neutralizing phases. Neutralization of acid leachate causes the precipitation of alkali earth and transition metals originally in the leachate. Because the tailings fluids at the UC and NC sites are near-neutral in pH (6.2 to 7.8), acid-neutralization reactions will not be a major retardation mechanism for the contaminants of concern at the processing site. However, even if acid conditions were present, the high calcite content (36 tons $CaCO_3$/1000 tons soil) of the Burro Canyon shale beneath the cell (PMET, 1990) would neutralize the acid.

The tailings pore fluids are generally oversaturated in gypsum, calcite, quartz, and, locally, in other solid phases. Although such oversaturation eventually leads to precipitation, the precipitation reactions are commonly slow to occur. In general, quartz precipitation rates are much slower than gypsum rates at the same level of oversaturation; therefore, gypsum tends to precipitate from oversaturated solutions before quartz. As these phases precipitate in the pore spaces in the tailings within the cell or in the rock units beneath the cell, some trace contaminants of concern may coprecipitate depending on the saturation level of the contaminant species. For example, radium could precipitate with gypsum or barite and cadmium and zinc could coprecipitate with calcite.

The oxidation-reduction induced precipitation reactions are probably the most important class of precipitation reactions at the disposal and processing sites for the same reasons. The Eh and several related parameters were measured with a platinum probe in most wells screened in the middle and lower sandstone units at the Burro Canyon disposal site. Wells in the upper sandstone unit did not yield sufficient quantities of water to allow measurement of Eh or related parameters. In general, wells screened in the lower sandstone unit had relatively high Eh values (400 mV) indicative of oxidizing conditions. Wells in the middle sandstone unit showed a range in Eh from 200 to 400 mV. Beneath the footprint of the cell, the values ranged from 200 to 330 mV with a average value of 250 mV. This value is not sufficiently reducing to convert sulfate to sulfide or U^{+6} to U^{+4}. However, it would result in ammonium being the dominant nitrogen species and native selenium being the dominant form of selenium. Ammonium and native selenium are less mobile than their corresponding oxidized forms. The Burro Canyon mudstone unit directly beneath the cell contains finely disseminated pyrite that may locally provide sufficiently reducing conditions to convert U^{+6} to U^{+4}, at least on the pyrite grain surfaces.

Adsorption reactions involve the attachment of simple and complex ions to the exterior surfaces of minerals and/or ion exchange on interior exchange sites in ion-exchanging minerals. Although the details of the surface attachment reactions are not completely known, it is well known that surfaces of iron and manganese oxides and oxyhydroxides have high affinities for transition metals and oxyanions at neutral to somewhat acidic conditions. However, the metals and oxyanions do not all have the same affinity for these oxides and oxyhydroxides. On the basis of theoretical derivations, the relative affinities cannot be reliably predicted in complex natural systems such as the ground water systems associated with uranium mill tailings sites. These relative affinities must be measured in a laboratory by either batch or column experiments.

Ion exchange reactions involving cations are better understood. The (cation) ion exchange capacities of the upper Burro Canyon Formation mudstone are relatively high (15 to 16 milliequivalents [meq]/100 grams) with the ion exchange capacity of the upper sandstone unit being somewhat lower at 6.6 meq/100 grams. These data suggest a significant exchange capacity exists in the units directly beneath the disposal cell. Results from three point sorption batch experiments performed with synthetic leachate spiked with cadmium, molybdenum, selenium, and uranium and Burro Canyon Formation fine-grained material were used to calculate partitioning coefficients (K_d), contaminant-specific retardation velocities, and travel times through the subsurface. Partitioning coefficient values for more mobile constituents such as chloride, sulfate, and nitrate have also been derived. These data provide information about migration of cations and anionic species, including oxyanions of redox-sensitive elements (i.e., sulfate, selenate, and molybdate) in the environment beneath the disposal cell.

Furthermore, results from composite column tests constructed to reflect the stratigraphy beneath the site have also been evaluated. Although equilibrium conditions were never attained in the columns, this information provides valuable insight into predicting the transport and behavior of individual contaminants in the subsurface.

In summary, the Burro Canyon Formation in the vicinity of the disposal site has been adequately characterized with respect to the attenuation potential of constituents germane to uranium mill tailings leachate. Distribution coefficients (K_d) for select contaminants, including cadmium (K_d = 800 mL/g), molybdenum (K_d = 0.7 mL/g), selenium (K_d = 2 mL/g), and uranium (K_d = approximately 0.5 mL/g), indicate that attenuation will occur as tailings leachate migrates beneath the disposal cell. Therefore, because of the relatively high K_d values and the presence of 60 ft (18 m) of low-permeability Burro Canyon Formation mudstone between the base of the cell and the first water-bearing unit, it is unlikely that leachate will adversely affect ground water beneath the disposal cell.

3.2.6 Ground water use, value, and alternative supplies

No known registered wells or private wells are actively used within the upper sandstone unit of the Burro Canyon Formation within a 2-mi (3-km) radius of the Burro Canyon disposal site.

Ground water development in the vicinity of the disposal site should not increase over the next 50 years. The first hydrostratigraphic zone of saturation has a low yield (less than 150 gpd), and is therefore classified as limited use in accordance with 40 CFR §192.11(e) of the final EPA ground water protection standards. By definition, limited use ground water is not a current or potential source of drinking water. No development is planned adjacent to the Burro Canyon disposal site. Population projections for San Miguel County (Novosad, 1994) estimate a 60 percent increase (3682 to 6333 people) in population from 1995 to 2020. There is no indication about where this increase would occur, but it is reasonable to expect that the largest increase would take place in and around existing population centers (e.g., Telluride). The Burro Canyon disposal site is in a remote location, and the public lands at and around the disposal site are administered by the BLM primarily for livestock grazing. Therefore, it is doubtful that any substantial population increase and corresponding increase in ground water use would occur at or in the vicinity of the disposal site.

Spine and Cover Changes

for

Slick Rock RAP

August 1996