GROUNDWATER STUDY
1994 UPDATE
WHITE MESA FACILITY
BLANDING, UTAH

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EXECUTIVE SUMMARY

(1) The first aquifer beneath the White Mesa Facilitly is in the Entrada/Navajo Sandstone at a depth of approximately 1500 feet below the ground surface. Contamination of this aquifer is precluded by the presence of two aquitards in the subsurface and the hydrostatic pressures within this confined aquifer.

(2) The saturated zone in the Burro Canyon is not an aquifer down gradient of the White Mesa Facility due to the limited extent of the saturated thickness of the unit, low hydraulic conductivity values and low recharge to the area. Investigators for the U.S. DOE also consider water in the Dakota and Burro Canyon not to be an aquifer at the UMTRA Slick Rock and Naturita sites.

(3) Fluid travel times to the Burro Canyon saturated zone from potential cell releases have been estimated based on analysis on the boring and well test data. Travel times can be as short as a few weeks through joints directly in contact with tailings solutions to 50 years for partially saturated flow conditions.

(4) The chemistry of groundwater from the monitoring wells is extremely variable, but all tend to be dominated by the sulfate anion. Upgradient Monitor Wells MW-1, MW-18 and MW-19 confirm this variability.

(5) Use of a single monitoring well for background purposes appears to be inappropriate. Temporal comparisons of a specific indicator ion species (chlorides) within specific wells is recommended for determining operational impacts on the saturated zone in the Burro Canyon Formation.

(6) Analyses of subsurface data collected from the present and past studies and analysis of groundwater chemistry show that uranium recovery operations at White Mesa have not affected the groundwater in the saturated zone of the Burro Canyon Formation.

1.0 INTRODUCTION

The purpose of this report is to present geohydrological data obtained during the 1992 field program at the White Mesa Facility, to provide analytical results from the new monitoring wells obtained during 1993 and to assess the present and future impact of uranium mill tailings disposal operations on geohydrologic conditions in the subject area. The 1992 field program was conducted by Umetco Minerals Corporation in conjunction with Peel Environmental Services. Work activities during 1992 consisted of the following:

- Review of existing data and previous studies.
- Preparation of study and data acquisition plan.
- Site inspection and mapping by a geologist and geotechnical engineer.
- Aquifer pump testing and geophysical logging of existing monitor wells.
- Drilling, geophysical logging and testing hydrogeologic properties of four new borings.
- Construction of the four new borings as monitor wells.

During 1993, the new monitoring wells were sampled on a quarterly basis. Analytical results from the new monitoring wells are presented in Appendix A.

Results from the field investigations and laboratory analyses were presented to the U. S. Nuclear Regulatory Commission, Environmental Protection Agency, Department of Energy and State of Utah on February 9, 1994. Specific diagrams and technical analyses presented at that meeting are included in this updated groundwater study.

Numerous technical studies were used in the preparation of this document. Regional geologic and geohydrologic data were obtained primarily from U. S. Geological Survey and State of Utah publications. Site specific information was obtained from the 1978 Environmental Report prepared by Dames and Moore, from the 1991 License Renewal Application (License SUA-1358) prepared by Umetco, and by the Groundwater Hydrology Report prepared by Hydro-Engineering in 1991. Additional references consulted during preparation of the documents include site specific reports by Chen and Associates (1973) and D Appolonia (1982).

2.0 REGIONAL GEOLOGY

The White Mesa Mill is situated near the western margin of the Blanding Basin in southeastern Utah. Thousands of feet of multi-colored marine and non-marine sedimentary rocks have been uplifted and warped, and subsequent erosion has carved a spectacular landscape for which the region is famous.

2.1 Physiography and Structure

The White Mesa Mill site is located within the Canyon Lands section of the Colorado Plateau physiographic province (Figure 2.1-1). To the north, this region is bounded by the Bookcliffs and Grand Mesa of the Uinta Basin; the western margins are defined by the technically controlled high plateaus of the Monument Uplift. The eastern boundary, less distinct, falls where the elevated surface of the Canyon Lands section merges with the Southern Rocky Mountain province. The southern boundary is arbitrarily defined as the San Juan River.

The Canyon Lands has undergone epirogenic uplift and subsequent erosion which have produced the region's characteristic topography represented by high plateaus, mesas, buttes, and deep canyons incised into relatively flat lying sedimentary rocks of pre-Tertiary age. Elevations range from approximately 3,000 feet in the bottoms of the deep canyons along the southwestern margins of the region to more than 11,000 feet in the Henry, Abajo and La Sal Mountains located to the northwest and northeast of the White Mesa Mill. With the exception of the deep canyons and isolated mountain peaks, an average elevation slightly in excess of 5,000 feet persists over most of the Canyon Lands.

The Mill site is located near the western edge of the Blanding Basin, which is situated east of the north-south trending Monument Uplift, south of the Abajo Mountains and southwest of the northwest-trending Paradox fold and fault belt (Figure 2.1-1). The southern boundary is defined by the Tyende Saddle and Carrizo Mountains just south of the Utah-Arizona border.

Topographically, the Abajo Mountains are the most prominent feature in the area, rising more than 4,000 feet above the broad, flat surface of the Great Sage Plain. The Great Sage Plain is a structural slope, capped by the resistant Burro Canyon Formation and Dakota sandstone. These strata lie almost horizontal in an east-west direction, but dip to the south with a regional dip of about 2,000 feet over a distance of nearly 50 miles. Though not as deeply or intricately dissected as other parts of the Canyon Lands, the plain is cut by narrow, vertical-walled south-trending valleys which range from 100 to more than 500 feet in depth.

The strata underlying White Mesa have a regional dip of 1/2° to 1° to the south; however, local dips of 5° have been measured. Haynes, et al (1972) includes a map showing the structure at the base of the Dakota Formation. No faults have been mapped in the immediate vicinity of White Mesa. During an investigation of the site a number of fracture attitudes were measured along the rims of Corral and Cottonwood Canyons. Analysis of these data indicates that there are two joint sets. The distance between the joints in each set varies from 5 to 20 feet. The primary joints strike from north-south to N20E with a vector mean of N11E (Figure 2.1-2) and the secondary fractures have a strike ranging between N40W to N60W with a vector mean of N47W (Figure 2.1-3). All joint sets are near vertical to vertical. Only one fracture was found in the cores during recent drilling. However, this is to be expected in an area of widely-spaced vertical joints.

These tension relief joints are caused by the removal of the effective confining pressures by erosion of the canyons. Field investigations show the joints along the canyon walls are generally open on the rims and become closed within a short distance of the canyon walls. Joints on the bedrock surface during the construction of Cell 4-A were observed to be widely spaced, cemented or extremely tight. Joints occurring in the lower part of the Dakota Sandstone on Burro Canyon Formation are most likely to be cemented or tight due to the confining overburden pressure and self-heating process in the siltstones and shales.

2.2 Stratigraphy

Rocks of Upper Jurassic and Cretaceous age are exposed in the canyon walls in the vicinity of the White Mesa Mill site (Figure 2.2-1). These rock units include, in ascending order, the Salt Wash sandstone, the Recapture shale, the Westwater Canyon sandstone and the Brushy Basin shale members of the Upper Jurassic Age Morrison Formation. Overlaying these units are the Cretaceous Age Burro Canyon Formation, Dakota sandstone, and erosional remnants of Mancos shale. Erosional remnants of Mancos shale are only found north of the Mill site. Eolian sand of Quaternary age and varying thickness overlies the Dakota sandstone and Mancos shale on the mesa, and alluvium, also of Quaternary age, occurs in the bottoms of steam valleys. A thin deposit of talus derived from rock falls of Dakota sandstone and Burro Canyon Formation mantles the lower valley flanks.

A description of each stratigraphic unit at the project area, based on borehole information, field reconnaissance and information provided by other investigators follow:

Salt Wash Member - Medium to thick bedded, hard, gray to bluish-gray, fine- to coarse-grained sandstone, fractured to slightly fractured in the outcrop, interbedded with thinly laminated, hard, light bluish-gray siltstone. This unit is approximately 105 feet thick.

Recapture Member - Thinly laminated, friable to well indurated, yellowish brown to reddish-gray argillaceous siltstone, unfractured. Interbedded with a 20-foot thick grayish brown sandstone layer which pinches out to the south of the Mill site (D'Appolonia, 1982). The thickness of this unit is 120± feet.

Westwater Canyon Member - Thick bedded, well indurated, light grayish green silty sandstone (fine- to coarse-grained), fractured to slightly fractured, fine- to coarse-grained, interbedded with thinly laminated greenish-gray silty claystone and clayey siltstone. The thickness of this unit is 60± feet.

Brushy Basin Member - Thinly laminated to medium bedded, soft to hard, variegated claystone and siltstone, interbedded with thick lenses of gray sandstone. Total thickness is approximately 300 feet.

Burro Canyon Formation - Thin cross-bedded, well indurated, light to dark greenish-gray, gray and light brown sandstone occasionally conglomeratic, interbedded with thick, soft, light greenish-gray, waxy shale and siltstone. Thickness is 75± feet.

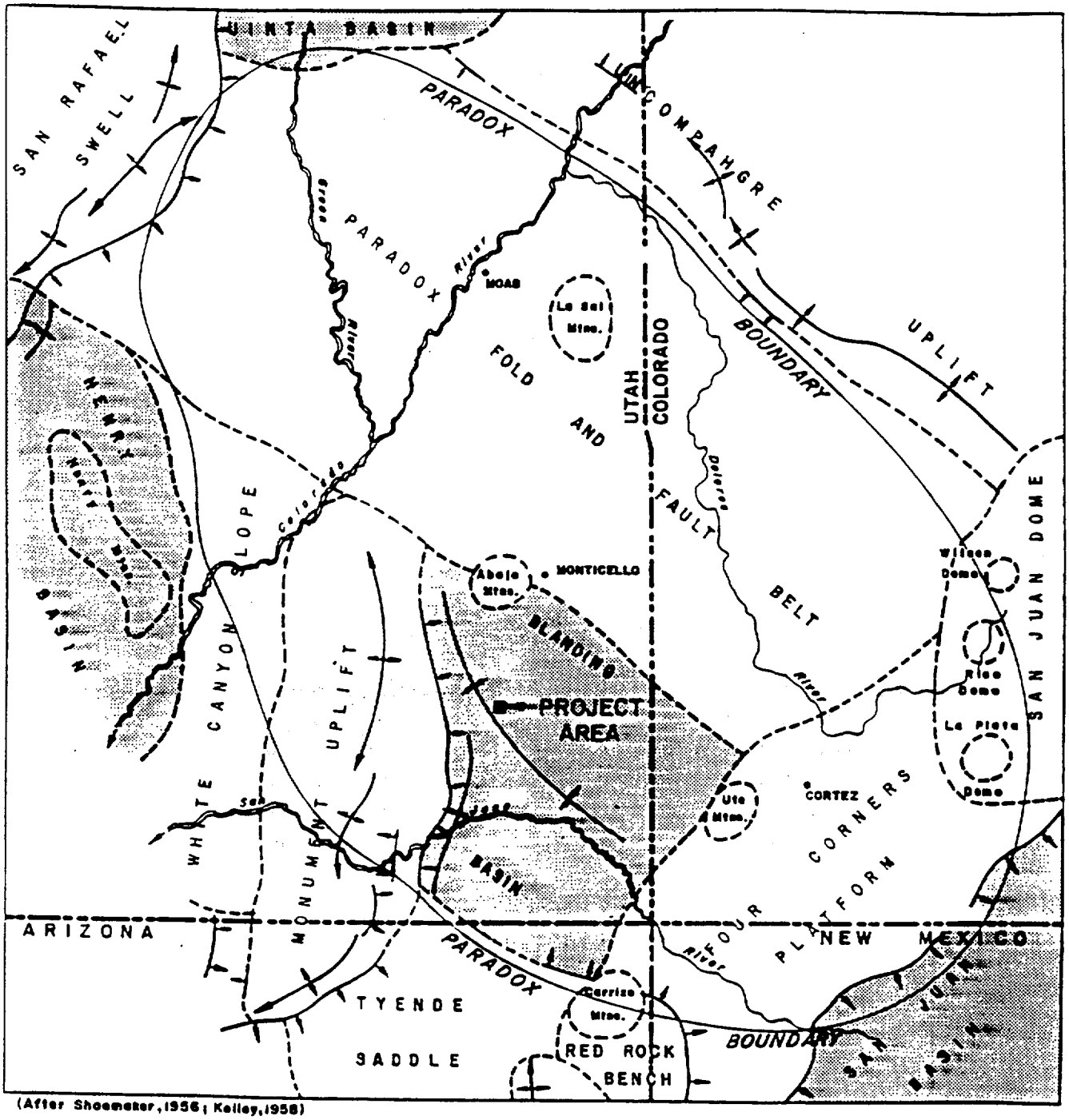
Dakota Sandstone - Thin bedded, well indurated, light yellowish-brown, poorly sorted, very fine- to medium-grained, kaolinitic, sandstone. The thickness of this formation is 60± feet.

Mancos Shale - Light gray, thin bedded, soft, shale. Only random occurring, thin (<5-foot thick remnants) occur in the area north of the mill site.

Eolian Sand - Reddish brown, very fine sand and silt, unconsolidated to partially cemented with caliche, approximately 20 feet thick. In some areas, particularly south of the Mill site, a 3- to 6-inch layer of caliche was encountered at a depth of 5 feet.

Talus and Colluvium - Sandstone rock fall debris, talus and slope wash, sizes range from cobbles to massive blocks derived from Dakota sandstone and Burro Canyon Formation. Talus is commonly incorporated with clay and silt slopewash, forming a matrix of angular sandstone cobbles mixed with finer materials and containing numerous voids. Thickness of this unit varies considerably, probably from zero to a maximum of 20 feet (D'Appolonia, 1982).

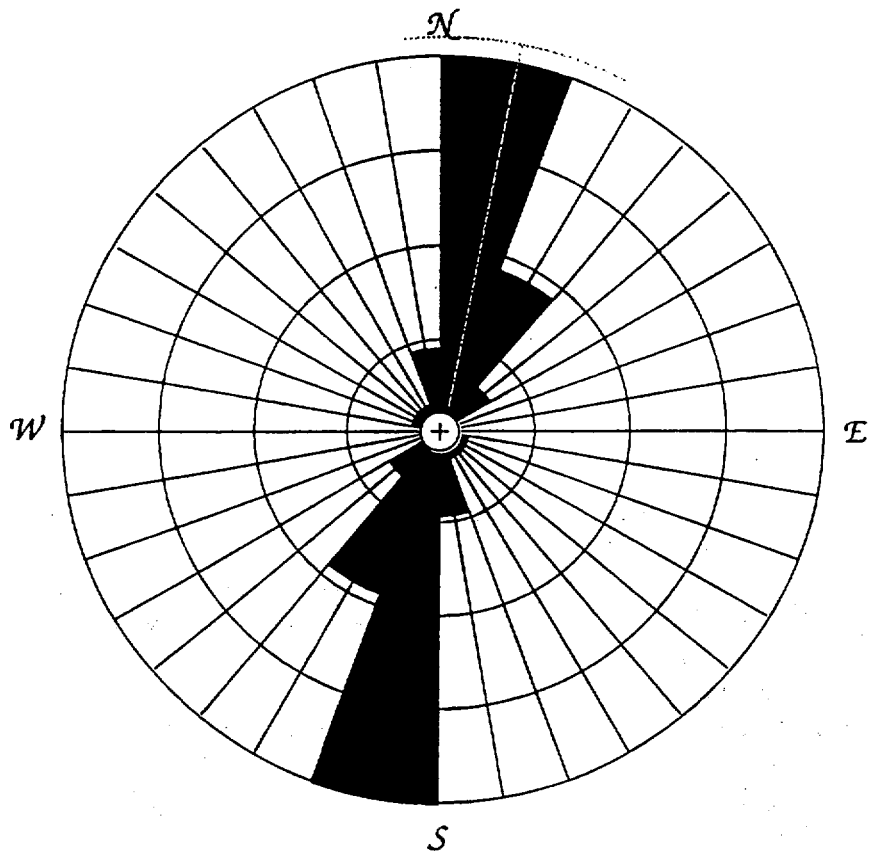
Alluvium - Soft, reddish-brown to yellowish-brown sandy silt with lenses of loose sandy gravel, slightly calcareous.



(After Shoemaker, 1956; Kelley, 1958)

Tectonic Map of Southeastern Utah and Southwestern Colorado

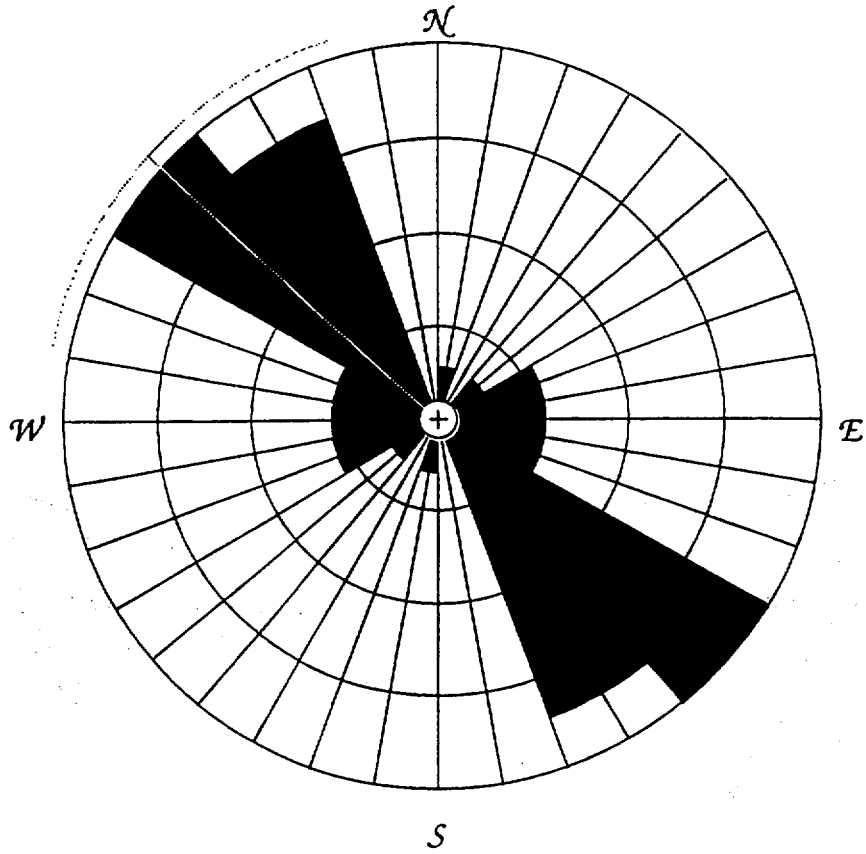
Figure 2.1 - 1



Number of readings = 27
Class Interval = 20 degrees
Maximum Percentage = 48.1
Mean Percentage = 14.29
Standard Deviation = 15.70
Vector Mean = N11E

White Mesa Primary Joints
Dakota and Burro Canyon Formations

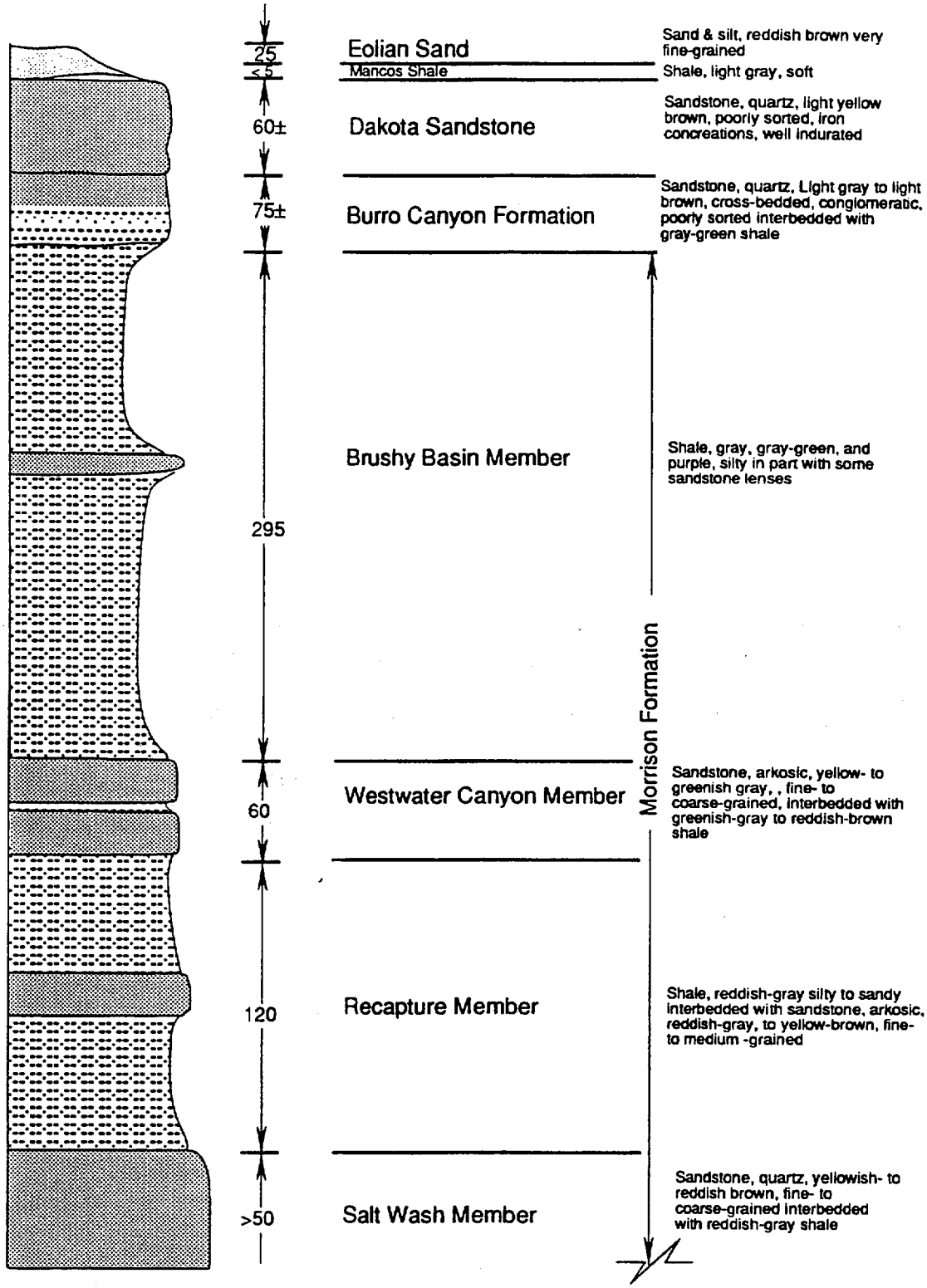
Figure 2.1 - 2



Number of readings = 25
Class Interval = 20 degrees
Maximum Percentage = 28.0
Mean Percentage = 12.50
Standard Deviation = 8.87
Vector Mean = N47W

White Mesa Secondary Joints
Dakota and Burro Canyon Formations

Figure 2.1 - 3



Local Stratigraphic Section

Figure 2.2 - 1

3.0 HYDROGEOLOGY

3.1 Regional Hydrogeology

The regional occurrence and distribution of groundwater in the project area are controlled by the type and extent of rock formations and the structural features of the Canyon Lands section of the Colorado Plateau Physiographic Province.

An intricate system of deep canyons along and across hogbacks and cuestas has resulted from faulting, upwarps and dislocation of rocks around the intrusive rock masses such as Abajo Mountains, approximately 25 miles to the north of the project site. Thus, the region is divided into numerous hydrological areas controlled by structural features such as the San Rafael Swell, the Monument Upwarp, and the Abajo, Henry and La Sal Mountains, as well as the faulted anticlines in Salt, Spanish and Lisbon Valleys.

Water-bearing sedimentary rock formations of Cambrian and Devonian through Cretaceous age are exposed in the region or have been identified in the Blanding Basin.

3.1.1 Bedrock Aquifers

Regionally, the formations that are recognized as bedrock aquifers are the Cretaceous-age Dakota sandstone and Sandstones within the upper part of the Morrison Formation of late Jurassic age; the Bluff, the Entrada and the Navajo Sandstones of Jurassic age; the Wingate sandstone and the Shinarump member of the Chinle Formation of Triassic age, and the DeChelle member of the Cutler Formation of Permian age. These units are shown in Figure 3.1.1-1, a generalized section of stratigraphic units showing the fresh water-bearing units in southeastern Utah.

Other formations within this sequence also contain water but its quality varies from slightly saline to very saline. Beneath the Permian, Cutler Formation are saline water-bearing units within the Rico and the Hermosa Formations of Pennsylvanian age from which oil is produced in the Blanding Basin. Hydrogeologic data on the formations in the area are limited

The Bluff sandstone, found only in southern San Juan County, has reportedly yielded 13 and 25 gpm in two wells drilled near Bluff (Feltis, 1966). The Entrada sandstone is reported to yield an average of 143 gpm at five wells drilled in San Juan County, but yields as high as 1200 gpm have been reported in other areas of southeast Utah (Feltis, 1966).

The Navajo sandstone is one of the most permeable bedrock aquifers in the region with reported yields as high as 1335 gpm (Feltis, 1966), although many wells drilled into the Navajo in southeast Utah only have yields varying between 35 to 72 gpm. One of the Umetco/Energy Fuels industrial wells drilled into the Navajo sandstone is reported to have yielded 120 gpm after 1.5 hours of pumping shortly after it was drilled.

Throughout the area, small quantities of water are produced from shallow wells constructed in the alluvium that occurs in stream valleys and as a veneer on the flattop mesas. These wells are subject to great seasonal variation in yield and the water withdrawn is generally of poor quality.

3.1.2 Regional Recharge

The source of recharge to bedrock aquifers of the region is precipitation. Precipitation in southeastern Utah is characterized by wide variations in seasonal and annual rainfall and by long periods of deficient rainfall. Short duration summer storms furnish rain in small areas of a few square miles and this is frequently the total rainfall for an entire month within a given area. The average annual precipitation in the region ranges from less than 8 inches at Bluff to more than 16 inches on the eastern flank of the Abajo Mountains, as recorded at Monticello. The mountain peaks in the

Henry, La Sal and Abajo Mountains may receive more than 30 inches of precipitation, but these areas are very small in comparison to the vast area of much lower precipitation in the region.

Recharge to bedrock aquifers in the region occurs by direct infiltration of precipitation into the aquifers along the flanks of the Abajo, Henry and La Sal Mountains and along the flanks of the folds, such as Comb Ridge Monocline and the San Rafael Swell, where the permeable formations are exposed at the surface. Recharge by direct infiltration also occurs on the wide expanses of flat lying beds that cap the mesas between these major structural features.

3.2 Groundwater Use

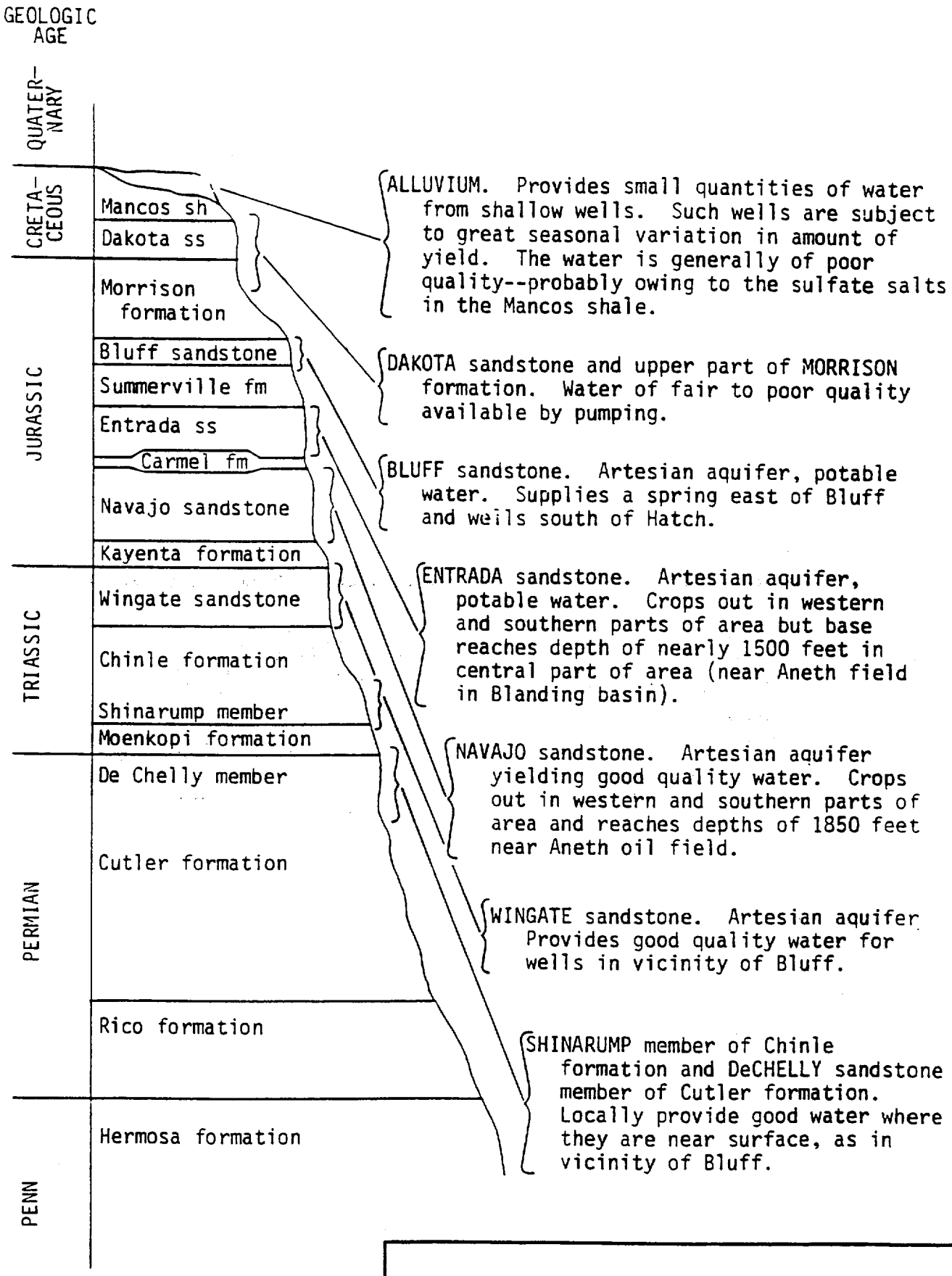
Forty groundwater appropriation applications, within a five-mile radius of the Mill site, are on file with the Utah State Engineer's office. The location of the applications is shown on Figure 3.2-1 and is listed on Table 3.2-1. The majority of the applications are by private individuals and are for wells drawing small quantities of water, less than 8 gallons per minute (gpm), from the Burro Canyon Formation. For the most part, these wells are located upgradient (north) of the White Mesa Mill site. Stockwatering and irrigation are listed as primary use of the majority of the wells. (Studies by consultants performed at the U.S. Department of Energy's disposal site at Naturita also note that the Dakota sandstones, Burro Canyon Formation and upper sandstones of the Brushy Basin member are not considered an aquifer due to the low permeability, discontinuous nature and limited thickness of these units.) Union Carbide and Plateau Resources have appropriation applications on file for deep wells (Entrada Formation) capable of much larger volumes of water production for industrial use.

Two water wells exist approximately 4.5 miles southeast of the site on the Ute Indian Reservation. These wells supply domestic water for the village on the mesa along Highway 191. Both wells are completed in the Entrada sandstone which is 1500± feet below the ground surface.

Table 3.2-1
Wells Located Within A 5-Mile Radius of
The White Mesa Mill Site
White Mesa Project
San Juan County, Utah

Map No.	Water Right	SEC	TWP	RNG	CFS	USE	Depth
1	Nielson, Norman and Richard C.	11	37S	22E	0.015	IDS	150-200
2	Guymon, Willard M.	10	37S	22E	0.015	S	82
3	Nielson, J. Rex	10	37S	22E	0.015	IDS	160
4	Nielson, J. Rex	10	37S	22E	0.013	S	165
5	Lyman, Fred S.	10	37S	22E	0.022	IDS	120
6	Plateau Resources	15	37S	22E	0.015	O	740
7	Plateau Resources	15	37S	22E	0.015	O	135
8	Nielson, Norman and Richard C.	14	37S	22E	0.015	IS	150-200
9	Lyman, George F.	15	37S	22E	0.015	S	135
10	Holt, N. E., McLaws, W	15	37S	22E	0.007	S	195
11	Perkins, Dorothy	21	37S	22E	0.015	S	150
12	Union Carbide Corporation	21	37S	22E	0.6	O	1600
13	Union Carbide Corporation	22	37S	22E	1.11	O	1820
14	Utah Launch Complex	27	37S	22E	0.015	D	650
15	Union Carbide Corporation	28	37S	22E	1.11	O	1885
16	Union Carbide Corporation	28	37S	22E	1.11	O	1850
17	Union Carbide Corporation	28	37S	22E	0.015	DSO	1800
18	Union Carbide Corporation	28	37S	22E	0.6	O	1600
19	Jones, Alma U.	33	37S	22E	0.015	S	200
20	Union Carbide Corporation	33	37S	22E	0.6	O	1600
21	BLM	8	37S	22E	0.01	S	170
22	Halliday, Fred L.	11	37S	22E	0.015	IS	180
23	Perkins, Paul	2	37S	22E	0.015	ID	180
24	Redd, James D.	2	37S	22E	0.1	ID	200
25	Brown, Aroe G.	1	37S	22E	0.015	IS	210
26	Brown, George	1	37S	22E	0.015	IDS	140
27	Brown, Ilo M.	1	37S	22E	0.004	IDS	141
28	Rentz, Alyce M.	1	37S	22E	0.015	ID	180
29	Rogers, Clarence	2	37S	22E	0.015	S	142
30	Perkins, Dorothy	2	37S	22E	0.015	S	100-200
31	Brandt J.R. & C.J.	1	37S	22E	0.015	IDS	160
32	Montella, Frank A.	3	37S	22E	0.015	IDO	190
33	Snyder, Bertha	1	37S	22E	0.1	IDS	160
34	Martineau, Stanley D.	1	37S	22E	0.015	ID	160
35	Kirk, Ronald D. & Catherine A.	1	37S	22E	0.015	IDS	160
36	Palmer, Ned J. and Marilyn	1	37S	22E	0.015	IDS	0
37	Grover, Jess M.	1	37S	22E	0.015	S	160
38	Monson, Larry	1	37S	22E	0.015	IDS	140
39	Neilson, Norman and Richard	1	37S	22E	0.015	IS	132
40	Watkins, Henry Clyde	1	37S	22E	0.015	IS	150

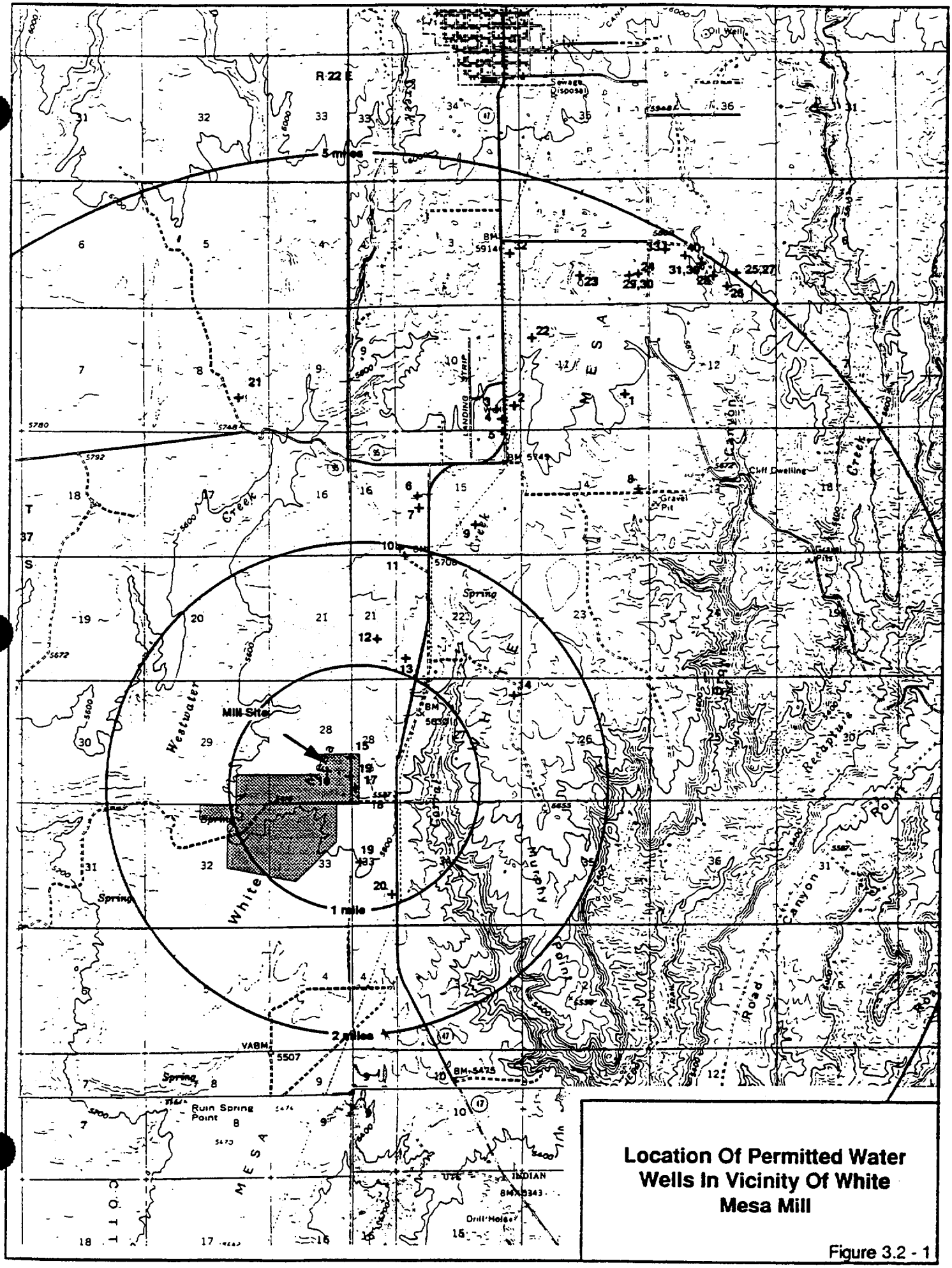
D - Domestic
I - Irrigation
S - Stockwatering
O - Industrial



Generalized Stratigraphic Section Showing Fresh Waterbearing Units In Southeastern Utah

After Goode (1958)

Figure 3.1.1 - 1



Location Of Permitted Water Wells In Vicinity Of White Mesa Mill

Figure 3.2 - 1

4.0 SUBSURFACE CONDITIONS

4.1 General

The subsurface conditions at the White Mesa facility have been previously investigated by Dames & Moore (1978), D'Appolonia (1980), and Chen & Associates (1978). Monitoring wells have been previously installed by D'Appolonia and Sampson & Associates.

This investigation included the drilling of four new borings (WMMW-16 through WMMW-19). The physical and hydrogeological properties of the bedrock were evaluated by performing field borehole aquifer and laboratory tests on core samples. Additionally, groundwater samples were obtained and analyzed for various chemical consituants.

4.2 White Mesa Stratigraphy

The lithology of the Dakota and Burro Canyon Formations at White Mesa was verified by drilling four new borings to depths from 95 to 150 feet below the existing ground surface.

The generalized stratigraphy through White Mesa (Figure 4.2-1) is shown on Figure 4.2-2. The description of the drilling process and boring logs is shown in Appendix A. All of the borings were drilled through the Dakota/Burro Canyon Formations and were terminated in the Brushy Basin member of the Morrison Formation. The boring log descriptions are based on visual descriptions of air rotary cuttings and core samples. The contacts between the different rock types or beds are based on examination of samples, gamma-ray logging and drilling characteristics. It was apparent from drilling and logging that the physical characteristics of the bedrock materials vary considerably, both vertically and laterally. This reflects the nature of the fluvial and coastal plain depositional environments in which they were deposited.

4.2.1 Dakota Formation

Directly below 3 to 6 feet of very silty clays to clayey silts and silts, the borings penetrated the Dakota Formation to depths of 43 to 66 feet (elevations 5572 to 5518 feet) below the surface. The Dakota at this site is typically composed of moderately hard to hard sandstones with random discontinuous shale (claystone) and siltstone layers. The sandstones have beds varying from a few inches to 10 feet in thickness and are occasionally cross bedded. The sandstones are moderately cemented (upper part of formation) to well cemented with kaolinitic clays.

The porosity of the Dakota is predominately intergranular. Laboratory tests performed (see Table 4.2-1) show the total porosity of the sandstones varies from 13.4 to 26.0 percent with an average value of 19.9 percent. The effective porosity of the formation is estimated to be 15.0 percent.

The formation is very dry to dry with volumetric water contents varying from 0.6 to 7.1 percent with an average value of 3 percent. Saturation values for the sandstones vary from 3.7 to 27.2 percent.

The claystones and siltstones are typically 2 to 3 feet thick. Boring WMMW-19 encountered a siltstone layer having a thickness of 8 feet at a depth of 33 to 41 feet. No groundwater or perched water conditions were found in drilling of the four borings in the Dakota Formation.

4.2.2 Burro Canyon Formation

Previous investigators have made no distinction between the Dakota and Burro Canyon Formations. However, examination of borehole cuttings, cores and geophysical logging methods has allowed separation of the two formations for analysis purposes. Directly below the Dakota Formation, the borings encountered sandstones and random discontinuous shale layers of the Burro Canyon Formation were found to extend to depths of 91 to 141 feet (elevation 5509 to 5421 feet).

Although similar to the Dakota, the Burro Canyon Formation varies from a very fine- to coarse-grained sandstone. The sand grains are generally poorly sorted. The coarse- grained layers also tend to be conglomeratic. The grains are cemented with both silica and kaolin but the silica cemented sandstones are prominent. The formation becomes argillaceous near the contact with the Brushy Basin member of the Morrison Formation.

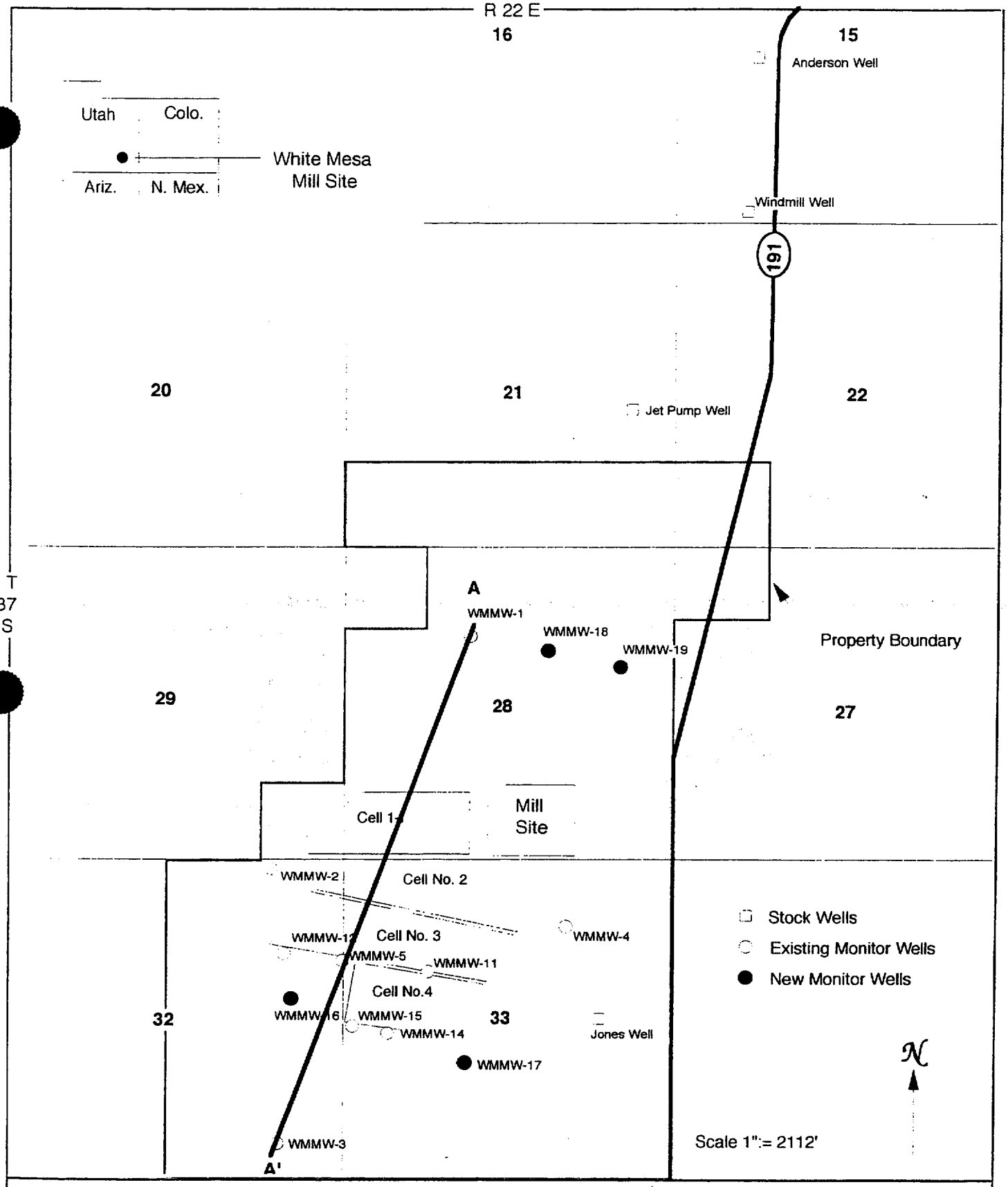
Based on the core samples tested, the sandstones of the Burro Canyon Formation vary in total porosity from 1.7 to 27.6 percent; the average being 16.0 percent. Volumetric water content in these sandstones ranges from 0.1 to 7.1 percent, averaging 2.2 percent, with the fine grained materials having the higher moisture content. Porosities in the claystone layers vary from 16.4 to 29.1 percent with saturation values ranging from 33.8 to 77.2 percent. A perched groundwater table was found at the base of the Burro Canyon Formation.

4.2.3 Brushy Basin Member

Each of the borings penetrated the Burro Canyon Formation and was terminated within the Brushy Basin member of the Morrison Formation. The borings encountered moderately plastic dark green to dark reddish-brown mudstones of medium consistency.

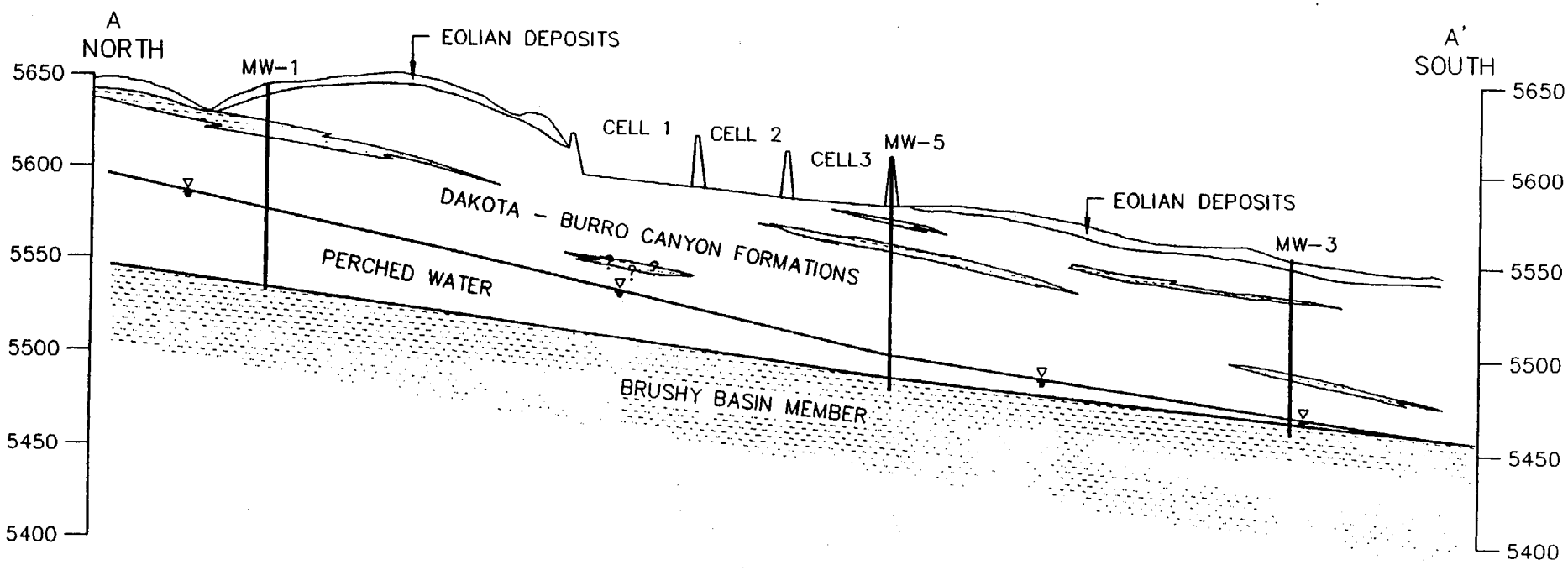
Table 4.2-1
Rock Properties
White Mesa Project
San Juan County, Utah

Well No. and Sample Interval		Moisture Content (Percent)	Moisture Content Volumetric	Dry Unit Weight (lbs/cuft)	Porosity (Percent)	Particle Sp. Gr.	Saturation (Percent)	Absorption (Percent)	Liquid Limit	Plastic Limit	Plasticity Index	Rock Type	Formation
WMMW-16	26.4' - 27.1'	1.51	3.3	135.2	17.9	2.64	18.2	5.10				Sandstone	Dakota
WMMW-16	37.8' - 38.4'	0.40	0.8	127.4	22.4	2.63	3.7	6.30				Sandstone	Dakota
WMMW-16	45.0' - 45.5'	5.60	12.6	140.9	16.4	2.7	77.2		29.6	15.4	14.2	Sandy Mudstone	Burro Canyon
WMMW-16	47.5' - 48.0'	2.56	5.9	142.8	12	2.60	48.9	4.37				Sandstone	Burro Canyon
WMMW-16	53.5' - 54.1'	0.68	1.4	129.0	19.9	2.58	7.1	6.38				Sandstone	Burro Canyon
WMMW-16	60.5' - 61.0'	0.11	0.2	117.9	27.6	2.61	0.8	9.89				Sandstone	Burro Canyon
WMMW-16	65.5' - 66.0'	2.62	5.5	131.5	19.6	2.62	28.2	7.13				Sandstone	Burro Canyon
WMMW-16	73.0' - 73.5'	0.13	0.3	130.3	20.6	2.63	1.3	5.50				Sandstone	Burro Canyon
WMMW-16	82.0' - 82.4'	0.05	0.1	134.3	18.5	2.64	0.6	4.78				Sandstone	Burro Canyon
WMMW-16	90.0' - 90.7'	0.12	0.3	161.5	2	2.64	15.8	0.85				Sandstone	Burro Canyon
WMMW-16	91.1' - 91.4'	5.20	9.8	118.1	29.1	2.67	33.8		33.7	16.2	17.5	Claystone	Burro Canyon
WMMW-17	27.0' - 27.5'	0.29	0.6	138.8	13.4	2.57	4.8	5.11				Sandstone	Dakota
WMMW-17	49.0' - 49.5'	3.62	7.1	121.9	26	2.64	27.2	9.60				Sandstone	Dakota
WMMW-17	104.0' - 104.5'	0.17	0.4	161.4	1.7	2.67	26.6	0.81				Sandstone	Burro Canyon



White Mesa Mill Site

Figure 4.2-1



NORTH - SOUTH CROSS SECTION

WHITE MESA FACILITY

Figure 4.2-2

5.0 SITE GROUNDWATER

5.1 Occurrence

Stratigraphic units beneath the site are shown in Figures 2.2-1 and 3.1.1-1. Of particular interest are the sandstones of the Entrada and Navajo Formation, shales the Summerville Formation and Brushy Basin Member of the Morrision Formation, and the sandstones of the Dakota/Burro Canyon Formations. These units comprise the geohydrologic units of concern beneath the White Mesa Facility.

The Entrada/Navajo Formations are massive, cross-bedded sandstone units that form the regional aquifer in the area of the site. Moderate amounts of fair quality water are produced from this geohydrologic unit. Water quality data from the culinary well at the White Mesa Mill shows a TDS of about 250 mg/l and a near neutral pH. This aquifer, at a depth of about 1500 feet below the site, is under artesian (confined) conditions. Water level in the culinary well rises from the formation to within 500 feet of the land surface. The Summerville Formation forms the confining unit (aquitard) for this artesian aquifer. A second aquitard, shales of the Brushy Basin member, also separates the White Mesa Mill site from the Entrada/Navajo aquifer. The presence of these two aquitards and the 1000-foot hydrostatic head pressure within the aquifer precludes any postulated contaminants from the White Mesa Facility from reaching this potential drinking water supply.

Directly beneath the site, the geohydrologic units of interest are the Dakota/Burro Canyon Sandstones and the Brushy Basin Member of the Morrison Formation. The Brushy Basin is characterized by variegated, bentonitic mudstones and siltstones that comprise the aquitard beneath the Dakota/Burro Canyon Sandstones. A saturated zone overlies the Brushy Basin Member (Figures 5.1-1 and 5.1-2). This saturated zone. within sandstones of the Burro Canyon Formation, has a gradient of about .01 ft/ft to the south and averages 11 feet in thickness downgradient of the disposal cell boundary (Figure 5.1-3 and 5.1-4). This area has long-term yields of less than .1 gpm and is of very poor quality with average total dissolved solids of about 3600 mgl. The water is not used for domestic, agricultural or livestock purposes down gradient of the site. These factors indicate that the water in the saturated zone down gradient of the White Mesa disposal cells is not considered an aquifer because it cannot yield a significant, usable amount of water to wells or springs.

At White Mesa a vadose (unsaturated) zone occurs to depths of approximately 73 to 109 feet. Fluids in this zone are held in the bedrock pores under negative pressure conditions. The saturated (groundwater) zone occurs as discontinuous perched water within the Burro Canyon Formation at its contact with the Brushy Basin member of the Morrison Formation. The Brushy Basin member acts as an aquitard to vertical flow. Figures 5.1-1 and 5.1-2 show the depth of thickness of both the vadose and saturated zones below the site. Table 5.1-1 is a list of monitor wells constructed at White Mesa to monitor the saturated zone. Table 5.1-2 shows the data obtained from the existing and new observation wells.

5.1.1 Tailings Disposal System Design and Reclamation

Tailings material from the White Mesa Mill are placed in lined disposal cells that were excavated below grade into the upper part of the Dakota Sandstone. During excavation, the surficial eolian materials were removed and stockpiled for use as reclamation materials. Schematic drawings of cell construction are shown in Figures 5.1.1-1 and 5.1.1-2. Cells 2 and 3 were constructed with a synthetic liner placed over compaced bedding material that functions as a drain layer, This drain layer as well as a sand drain on the side of the downstream tailings embankment are connected by a leak detection lateral along the base of the disposal cell. A slimes drain system is constructed above the synethic liner near the center of both disposal cells in the lowest topographic area of the tailings disposal cell base.

In contrast to Cells 2 and 3, tailings disposal Cell 4-A is composed of a clayey liner over lain by geotextile fabric and a synthetic liner. Leak detection laterals, located in the clayey material consist of a synthetic liner overlain by a leak detection pipe and gravel material. This drain system slopes to the southwest corner of the disposal cell. An over drain system is also present over the cell lining system in the southwest corner of the disposal cell.

Reclamation activities for all of the disposal cells include dewatering the tailings material by the slimes drain and placement of a cover to control long-term erosion, limit radon emanation rates and to minimize long-term infiltration. Schematic drawings of the top and side slope covers are shown in Figures 5.1.1-3 and 5.1.1-4, respectively. In general, the cover consists of a minimum of 4-feet of random fill material to aid in tailings dewatering and provide a stable working surface for construction of the upper part of the multi-layered cover. The multi-layered cover consists of clay liner over lain by a capillary layer of coarser material. These materials are inturn overlain by random fill and vegetative support material on the top of the cells and a rock protection layer on the 5(H): 1 (V) cell-side slopes. Total minimum cover thickness is 10 feet.

5.1.2 "Aquifer" Tests

All existing monitor wells and the new wells (where feasible) were tested to determine hydrogeological properties. The existing wells were pumped at extremely low rates to extend the test duration as long as possible. Methods developed by Strausberg (1982) (see Appendix C) were used to determine bedrock permeability values in the tight formations. Injection tests were performed in three wells because of the extremely low permeability of the bedrock resulting in the inability to sustain pumping for any length of time. The recent test results compare favorably with the work conducted by Hydro-Engineering in 1991. Field permeability tests by the Bureau of Reclamation method E-18 were performed both in the unsaturated and saturated zones to determine rock permeability in the new borings. Wells completed in these borings will be developed and pump-tested at a later date. Weather conditions prevented these activities in December, 1992.

The aquifer tests performed in each respective boring, and/or completed well are presented in Appendix C. The results are also summarized in Tables 5.1.2-1 and 5.1.2-2. For the pump tests, hydraulic conductivity values have been corrected for the portion of the plotted wells below the shales of the Brushy Basin member of the Morrison Formation.

The borehole permeability tests (Table 5.1.2-1) show the unsaturated zone to exhibit a wide range of permeability values both in the Dakota and Burro Canyon Formations. The average permeability of the Burro Canyon Formation (2.83×10^{-5} cm/sec) is approximately one order of magnitude lower than the average of permeability tests performed in the Dakota Formation (2.58×10^{-4} cm/sec).

Aquifer testing performed in the saturated zone of the Burro Canyon (Table 5.1.2-2) show a wide range of hydraulic conductivity values within this formation. The values range from 2.2×10^{-6} cm/sec for Well WMMW-2 to 1.4×10^{-3} cm/sec for Well WMMW-11. Monitor Well WMMW-14 shows a moderate permeability value of 7.5×10^{-4} cm/sec. Considerately, the pumping characteristics of WMMW-11 and WMMW-14, it is believed that flow into these two wells is controlled by joint flow; whereas, the other wells are dominated by primary porosity flow.

Considering the saturated thickness of the unit, the low average hydraulic conductivity and low recharge into the formation. The Burro Canyon is not considered to be an aquifer below the White Mesa facility. This is consistent with proposed EPA groundwater standards which states that the uppermost aquifer is the hydrostratigraphic unit that can sustain a yield of 150 gpd/yr. Investigators for U.S. DOE UMTRA projects also consider water in the Burro Canyon Formation at the Slick Rock and Naturita sites not to be an aquifer for the above reasons.

5.2 Groundwater Water Movement

The flow of liquids in the area of the disposal cells is governed by a number of interrelated factors. Factors influencing short-term, postulated leakage from the cells include tailings permeability, head on the liner, size of postulated liner failure, and type of underliner. Factors that control the movement of liquids in the subsurface materials include unsaturated flow permeability and water content of the Dakota /Burrow Canyon Sandstone and anisotropic conditions in this unit. These anisotopic conditions include low-permeability shale layers, and permeable joints and coarse-grained channel deposits. Flow within the saturated zone is governed by the permeability and gradient within the Burro Canyon Formation and the permeability of the underlying aquitard, the Brushy Basin shales. Long-term flow is dominated by the rate of deep percolation (infiltration) into the subsurface materials.

Diagrammatic cross sections through Cell 3 and Cell 4-A are shown in Figures 5.3-1 and 5.3-2, respectively. These cross sections depict the flow relationships for unsaturated and saturated flow conditions and quantify the flow in the vadose and saturated zones. In general, potential flow out the Cell 3 is governed by the permeability of the tailings material and size of synthetic liner failure. Major failure of the synthetic liner would be detected in the underdrain system and monitored in the drain pipe of Cell 3. Smaller, diffuse leaks from the liner system would not be captured by

the leak detection system. In contrast to Cell 3, Cell 4-A is underlain by a clayey liner, the permeability of this material governs flow from the cell if the synthetic liner fails with saturated tailings in the impoundment. If unsaturated materials are placed in the cell, the rate of fluid flow is governed by the long-term infiltration rate. Detailed discerssion of flow in the vadose and saturated zones beneath the cells are presented in the following sections.

5.2.1 Vadose Zone

Fluid movement in the vadose zone (Dakota Formation) occurs principally in the vertical direction from the driving forces of both capillary pressure gradients and gravity. When seepage occurs through a nearly dry foundation material, as is the case at White Mesa, the capillary gradients act in the same direction as gravity and the rate of downward flow is enhanced.

Capillary gradients, however, are most important in the vicinity of the "wetting front." As seepage proceeds, the driving force due to gravity becomes increasingly important relative to capillary pressure. In the horizontal direction, the gradient of capillary pressure is the only driving force. Just as in the vertical direction, the capillary gradients decrease as the seepage spreads laterally.

When the wetting front encounters a layer with smaller pore size and lower permeability, the invading fluid is readily absorbed. There is, however, a corresponding decrease in the capillary gradient as the tight layer "wets up" and gravity becomes the dominant driving force. The maximum flux that can be sustained by gravity alone is that which is equal to the permeability of the layer. If the seepage rate from the impoundment is greater than the permeability, water will perch on the tight layer.

The permeability of the strata relative to the seepage rate is of critical importance to the question of whether or not perched water will develop. Field measurements of permeability indicate that the permeability of the tightest layers (claystones) within the Dakota Formation is about 1.0×10^{-7} cm/s (0.1 ft/yr). Downward flow from net infiltration in the current natural state is estimated to be approximately 0.01 ft/yr per square foot. Therefore, it is to be expected that no water perched on the claystones would be encountered, as indeed, is the case. Assuming that natural, net infiltration is 0.01 ft/yr, a layer with permeability of 0.01 ft/yr, or less, would not be required to cause sustained perched water to occur. The fact that no perched water was encountered in drilling the four new borings suggests that the permeability of the claystone layers present in the formation have a permeability equal to or greater than 0.01 ft/yr. It is believed that the most reasonable value for permeability of the claystone layers is about 1×10^{-7} cm/s (0.1 ft/yr), but it may range downward to perhaps 5.0×10^{-8} cm/s (0.05 ft/yr).

Considering the above, travel times for partially saturated flow through the vadose zone to the Burro Canyon can be estimated based on estimated infiltration, rates of permeability, and water content of the formation. Using an average volumetric water content of 3 percent from Table 4.2-1, the velocity through the Dakota sandstone is estimated to range from 1.7 to 3.3 feet per year. Taking the depth to the saturated zone from 70 to 90 feet, it would take approximately

20 to 50 years for pond seepage to reach the perched water table in the Burro Canyon Formation. In the absence of shale layers, the McWhorter-Nelson model predicts a travel time of 15.0 years for (pond) seepage to reach the water table. This analysis is valid for parts of the site where the discontinuous lenticular claystones do not exist.

If pond leakage occurred, there is a possibility that seepage under positive pressure could be in direct contact with vertical joints at the base of the ponds. For this condition, seepage would occur as localized saturated flow through the joints within the Dakota into the Burro Canyon. For this case, the travel time to the saturated zone is difficult to estimate but could be on the order of a few weeks to months.

5.3.2 Saturated Zone

The groundwater in the Burro Canyon Formation exists as unconfined perched water on top of the Brushy Basin member. This perched water is thickest north of the site and pinches out south of the site in a down gradient direction (Figure 5.3.2-1) and hydraulic conductivity values determined from tests are low to extremely low (see Table 5.1.2-2). As previously stated because of the low average hydraulic conductivity of the unit, the extent of the saturated zone and low recharge potential, it is not considered to be a aquifer in the immediate project area.

Water movement within this zone is in a south-southwest direction, the same as the dip of the bedrock strata. Using an average hydraulic conductivity value of 0.7 feet per day, an effective porosity of 15 percent, and an average hydraulic gradient of 0.01 foot/foot, the average velocity of groundwater movement is 0.047 feet per day (1.7 feet per year). For a saturated thickness of 20 feet, flow within the saturated zone of the Burro Canyon is estimated to be 5 cubic feet per square foot per year in a down gradient direction. This water flow into the system is absorbed into the Brushy Basin Member of the Morrison Formation at a rate of approximately 0.01 cubic feet per square foot per year. Thus, as the water in the perched zone travels very slowly (1.7 ft/yr) in a southern direction from the disposal cells, the water is slowly absorbed into the underlying Brushy Basin aquitard. Vertical movement of the water through the Brushy Basin into the Salt Wash member will take approximately 600 years. This value is based on a unit hydraulic gradient, permeability value of 0.1 foot per year and an effective porosity value of 20 per cent.

5.4 Water Quality

Groundwater monitoring of the Burro Canyon saturated zone has been conducted at the White Mesa facility since 1979. Table 5.1-2 shows a list of wells that have been constructed for monitoring purposes at White Mesa. The water quality data obtained from these wells are shown both in tabular and graphical form in Appendix B.

Comparisons of the water chemistries from the various wells were analyzed by graphical techniques. The trilinear plot and the Stiff diagram were used in "fingerprinting" site groundwater and differentiating the groundwater from different sources or wells. The trilinear plot is a graphical technique (Figure 5.3-1A) in which the percentage composition of the major

anions and cations in a water sample is plotted onto triangular plotting fields. The resultant plotting positions are then projected into a central plotting diamond, defining the sample's composition. The plot is so designed that mixtures of water are shown by progression along a straight line connecting the plotted points of both waters in the central plotting diamond. Thus, the trilinear plot is extremely useful in determining the percentage mixtures, based on the major ion compositional profile of the two-end point solutions.

The Stiff diagram is an analysis of water chemistry and is a "signature" formed by plotting the concentration of major cations to the left of a central axis and the anions to the right of the central axis and connecting the plotted points. In the computer mapping program utilized, the cations are plotted in the order of sodium plus potassium, calcium, and magnesium to the left of the central axis. The anions are plotted in the order of chloride, carbonate plus bicarbonate, and sulfate to the right of the central axis. Such a graphical signature is useful in making visual comparisons of various water chemistries.

Figure 5.3-1 is a trilinear plot for the water sampled in wells in the immediate vicinity of the Mill site during the fall of 1992. Figures 5.3-2 through 5.3-4 are Stiff diagrams presenting the same data. It can be seen from these plots that the water from all wells is of the sulfate (anion type). The cation definition of the water type is extremely variable. Of the thirteen wells analyzed for water chemistry four fall in the calcium-sulfate type category, four fall in the (sodium plus potassium) - sulfate type, two samples classify in the magnesium-sulfate type. Five samples have no dominant cation type. These five samples tend, however, to classify close to the (sodium plus potassium) - sulfate and calcium-sulfate types. Variability of water within the Burro Canyon Formation is the result of slow moving to nearly stagnate ground water flow beneath the site and very limited recharge to the perched zone. These conditions are amenable to dissolution of minerals from the Brushy Basin Shale and the formation of sulfate dominated waters.

A time sequence change of water chemistries from four sampling periods for wells WMMW-1, WMMW-2 and WMMW-3 using the trilinear plotting technique is shown in Figures 5.3-5 through 5.3-7. These figures present the change in water chemistries from October, 1979 through February 1991. The change in water chemistry is attributed to initial incomplete cleaning of wells, groundwater variation, laboratory analytical errors or a combination. The data for 1979 appears to be suspect with respect to providing an accurate representation of the groundwater chemistry. This is probably due to incomplete cleaning of the well after drilling and prior to the first sample.

The spatial variability of water within the Burro Canyon Formation is shown on Figures 5.3-8 and 5.3-9. Up gradient monitoring wells MW-1, MW-18, and MW-19, varied in sulfate concentrations from 676 to 1736 mg/l. Likewise, chloride concentrations in these wells varied from 12 to 92 mg/l. Across the site, sulfate and chloride concentrations vary with no discernible pattern to the variations. Details regarding chemistry of the Burro Canyon water can be found in a Appendix D, including the results of 1993 sampling for wells MW-17, 18 and 19.

Because of the extremely variable groundwater chemistry in the Burro Canyon baseline data, comparison of well chemistries to a single background well (chemistry) will not provide correct information on the possible effects of cell seepage or groundwater contamination. Water quality baseline established on a well-by-well basis will provide a meaningful representation of changes in groundwater chemistry. Using this concept, the statistical "T" test was performed on samples from chloride populations within specific wells over time (see Appendix E). Because chlorides are a conservative species and are concentrated in the tailings solutions, analyses using this parameter offers the best method of detecting detrimental changes to the groundwater. In addition, information on Cell 2 leak detection system chemistry provides a useful picture of the water chemistry directly below Cell 2. The following is a discussion of the analyses.

Cell 2 Leak Detection System - The water found in Cell 2 leak detection system (LDS) contains the lowest total dissolved solids (TDS) content (756 mg/l) of any water sampled in the area (Figure 5.3-1). Excepting the Jones well, it also contains the highest percentage of carbonate and bicarbonate when compared to the other monitoring wells. The slimes drain contains a TDS value of 47,115 mg/l and no carbonates due to its extremely low pH (typically 1.5 to 3). Any significant leakage of tailings solution into the LDS would react with the carbonates and raise the TDS levels which has not occurred to date.

WMMW-1 (Installed September 1979) - This well was originally chosen as the background well for the site. It is believed that improper well completion and/or analytical errors gave erroneous chemistry values for this well in 1979 (see Figure 5.3-5). Chlorides in this well have been relatively low (varying from 11 to 53.2) since 1980.

A "T" test was performed on sample population from 1980-81 to a sample population from 1990-92. The test indicates that there is a significant difference in the mean of the populations at the 0.05 level of significance. Statistically, the chloride levels are shown to have decreased significantly. Tests performed on a sulfate population from the period 1980-81 to a population from 1990-92 show the sulfates in this well have increased significantly.

WMMW-3 (Installed September 1979) - This well was originally constructed to serve as the "point of compliance well", Statistical testing ("T" test) on a chloride population from 1980-81 compared to a chloride population from 1990-92 shows that there is no significant difference in the two chloride populations. Sulfate samples taken 1980-81 compared to samples taken 1988-91 show there is a significant increase in sulfates.

WMMW-5 (Installed May 1980) - The statistical test "T" test performed on a sample from the chloride population (1981-83) to a sample from a chloride population (1990-92) shows there is a significant difference in the means of the chloride populations and that the chloride content has decreased.

WMMW-12 (Installed December 1982) - The statistical "T" test performed on a sample from the chloride population from 1982-85 compared to the chloride population from 1990-91 shows there is a significant difference in the means of the chloride populations of these two sampling periods and that the chloride content has decreased.

WMMW-14 and 15 (Installed September 1989) - These monitor wells were installed in the south embankment of Tailings Cell No. 3 in 1989. Wells 14 and 15 have a similar water chemistry to monitor well 12 which was installed in 1980 (see Figures 5.3-1 and 5.3-3). A statistical "T" test performed on samples from a chloride population shows wells 14 and 15 to have different mean chloride values. The mean chloride value in Well 15 is significantly higher than Well 14. Statistical tests also show that the chloride values are decreasing in both wells. Similar testing on Well 12 likewise shows a decrease in chlorides. Any contamination from the tailings solution would probably show an increase in the chloride values in these wells over time, which has not happened.

5.4 Impact of Operations on Groundwater

Uranium recovery operations at White Mesa has produced tailings solutions with high concentrations of sulfates and chlorides. To date, testing and analysis show that operations at White Mesa have not impacted the saturated zone of the Burro Canyon Formation.

6.0 RECOMMENDATIONS

A water quality baseline should be established on a well-by-well basis. Leak detection and action levels should be based on statistical comparisons of chemistry in a single well over time. Because the present analysis shows that none of the water in any of the existing monitoring wells is contaminated, all of the wells can be considered to be at background levels. It is recommended that only a select number of existing wells be designated as "background" wells and the background concentrations for specific ionic species be determined by statistical methods.

The NRC has indicated that additional geotechnical studies be considered for the White Mesa Facility. These studies include the investigation of joints beneath the facility, the delineation of the zero saturated thickness line, and evaluation of liquid movement within the vadose zone. Additional studies proposed by Umetco to meet these needs are set forth in Appendix F, Proposed Technical Studies.

Table 5.1-1
White Mesa Monitor Wells
White Mesa Project
San Juan County, Utah

				Water Level			Measuring Point	
Well Name	DateInstalled	Total Depth	Perforations	Date	Depth (ft)	Elevation (ft-MSL)	Above LSD (ft)	Elev. (ft - MSL)
WMMW-1	Sep-79	117'	92'-112'	19/11/92	75.45	5572.77	2.0	5648.22
WMMW-2	Sep-79	128.8'	85'-125'	19/11/92	110.06	5503.43	1.8	5613.49
WMMW-3	Sep-79	98'	67'-87'	19/11/92	83.74	5471.58	2.0	5555.32
WMMW-4	Sep-79	123.6'	92'-112'	19/11/92	92.42	5530.15	1.6	5622.57
WMMW-5	May-80	136'	95.5'-133.5'	19/11/92	108.32		0.6	5609.33
WMMW-6	May-80	This well was destroyed in March 1993 during construction of Cell 3						
WMMW-7	May-80	This well was destroyed in March 1993 during construction of Cell 3						
WMMW-8	May-80	This well was destroyed in March 1993 during construction of Cell 3						
WMMW-11	Oct-82	135'	90.7'-130.4'	19/11/92	102.53	5508.55	2.4	5611.08
WMMW-12	Oct-82	130.3'	84'-124'	19/11/92	109.68	5499.77	0.9	5609.45
WMMW-13	Oct-82	116.5'	This well was destroyed in during construction of Cell 4A					
WMMW-14	Sep-89	129.1'	90'-120'	19/11/92	105.34	5491.05	0.0	5596.39
WMMW-15	Sep-89	138'	99'-129'	19/11/92	108.28	5490.34	0.8	5598.62
WMMW-16	Dec-92	91.5'	78.5'-88.5'	7/12/92	Dry		1.5	
WMMW-17	Dec-92	110'	90'-100'	11/30/92	87.46		1.5	
WMMW-18	Dec-92	148.5'	103.5'-133.5'	11/30/92	92.11		1.5	
WMMW-19	Dec-92	149'	101'-131'	10/12/92	85.00		1.5	
#9-1	May-80	33.5'	10'-30'	3/4/91	Dry		1.8	5622.83
#9-2	May-80	62.7'	39.7-59.7	3/4/91	Dry		2	5622.58
#10-2	May-80	33.5'	11.3-31.3	3/4/91	Dry		2	5633.58
#10-2	May-80	62.2'	39.2-59.2	3/4/91	Dry		2.1	5633.39

Table 5.1-2

Ground Water Occurrence
White Mesa Project
San Juan County, Utah

Well Name	Ground Elev.	Top Saturated Zone	Depth To Sat Zone	Thickness Sat Zone
WMMW-1	5646.22	5572.77	73.45	37
WMMW-2	5611.69	5503.43	108.26	12.5
WMMW-3	5553.32	5471.58	81.74	5.25
WMMW-4	5620.97	5530.15	90.82	17
WMMW-5	5608.73	5500.95	107.78	12
WMMW-11	5608.68	5508.55	100.13	25.75
WMMW-12	5608.55	5499.77	108.78	7
WMMW-14	5596.39	5491.05	105.34	15.25
WMMW-15	5597.82	5490.34	107.48	20
Max=	5646.22	5572.77	108.78	37
Min=	5553.32	5471.58	73.45	5.25
Average=	5605.82	5507.62	98.20	16.86
New Wells				
WMMW-16			Dry	0
WMMW-17			87.46	17.7
WMMW-18			92.11	46.6
WMMW-19			85	46.3
		Max=	92.11	46.6
		Min=	85	0
		Average=	88.19	27.65
		All Wells		
		Max=	108.78	46.6
		Min=	0	0
		Average=	89.97	21.67

Table 5.1.2-1

Borehole Permeability Test Results
White Mesa Project
San Juan County, Utah

Well No.	Interval(ft)	Type of Test	Formation	Hydraulic Conductivity gpd/ft^2	Hydraulic Conductivity cm/sec	Hydraulic Conductivity ft/d
WMMW-16	28.5-31.5	Constant Head	Dakota	19.3	9.10E-04	2.58
	45.5-51.5	Constant Head	Burro Canyon	1.1	5.10E-05	0.14
	65.5-71.5	Constant Head	Burro Canyon	1.7	7.80E-05	0.22
	85.5-91.5	Constant Head	Burro Canyon	0.6	2.90E-05	0.08
WMMW-17	45-50	Constant Head	Dakota	0.1	3.00E-06	0.01
	90-95	Constant Head	Burro Canyon	0.1	3.50E-06	0.01
	100-105	Constant Head	Burro Canyon	0.1	5.50E-06	0.02
WMMW-18	27-32	Constant Head	Dakota	2.3	1.10E-04	0.31
	85-90	Constant Head	Burro Canyon	0.5	2.50E-05	0.07
	115-120	Constant Head	Burro Canyon	0.1	4.50E-06	0.01
WMMW-19	55-60	Constant Head	Dakota	0.2	8.40E-06	0.02
	95-100	Constant Head	Burro Canyon	0.03	1.40E-06	0.004
		Average Dakota		5.5	2.58E-04	0.7
		Median Dakota		1.3	5.92E-05	0.2
		Average Burro Canyon		0.6	2.83E-05	0.08
		Median Burro Canyon		0.5	2.50E-05	0.07

Table 5.1.2-2

Aquifer Test Results, Existing Wells
White Mesa Project
San Juan County, Utah

			Hydro-Engine	Peel Enviromental		
Well No.	Interval(ft)	Type of Test	Interval Transmissivity gpd/ft	Interval Transmissivity gpd/ft	Hydraulic Conductivity gpd/ft^2	Hydraulic Conductivity cm/sec
WMMW-1	92-111	Slug		2.0	0.2	9.30E-06
WMMW-2	107-119	Pump		9.0	1.0	4.70E-05
WMMW-3	82.5-87.5	Slug		0.3	0.05	2.20E-06
WMMW-4	91-107.5	Pump		1.6	0.2	9.55E-06
WMMW-5	107.5-119.5	Slug	3.1	8.8	0.8	3.60E-05
WMMW-11	114-125	Pump	808	604.3	28.7	1.40E-03
WMMW-12	108.5-115.5	Pump	5.1	2.9	0.5	2.20E-05
WMMW-14	105.5-121	Pump	298	224.0	16.0	7.50E-04
WMMW-15	106.5-126.5	Pump	10.5	7.9	0.4	1.90E-05
		Average		95.6	5.3	2.6E-04
		Median		7.9	0.5	2.2E-05

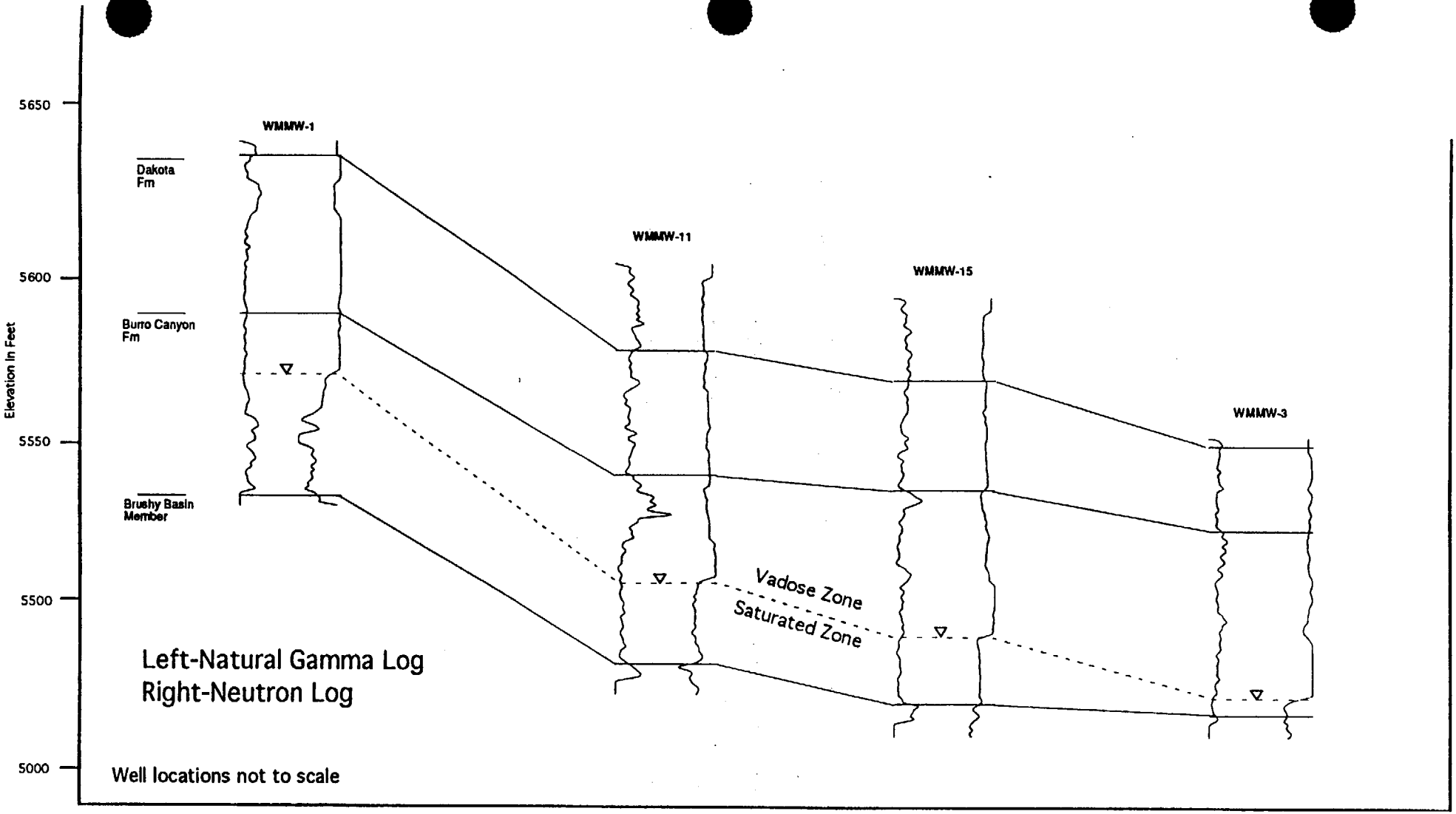


Figure 5.1-1 - North-South Stratigraphic Section Through The White Mesa Mill Site

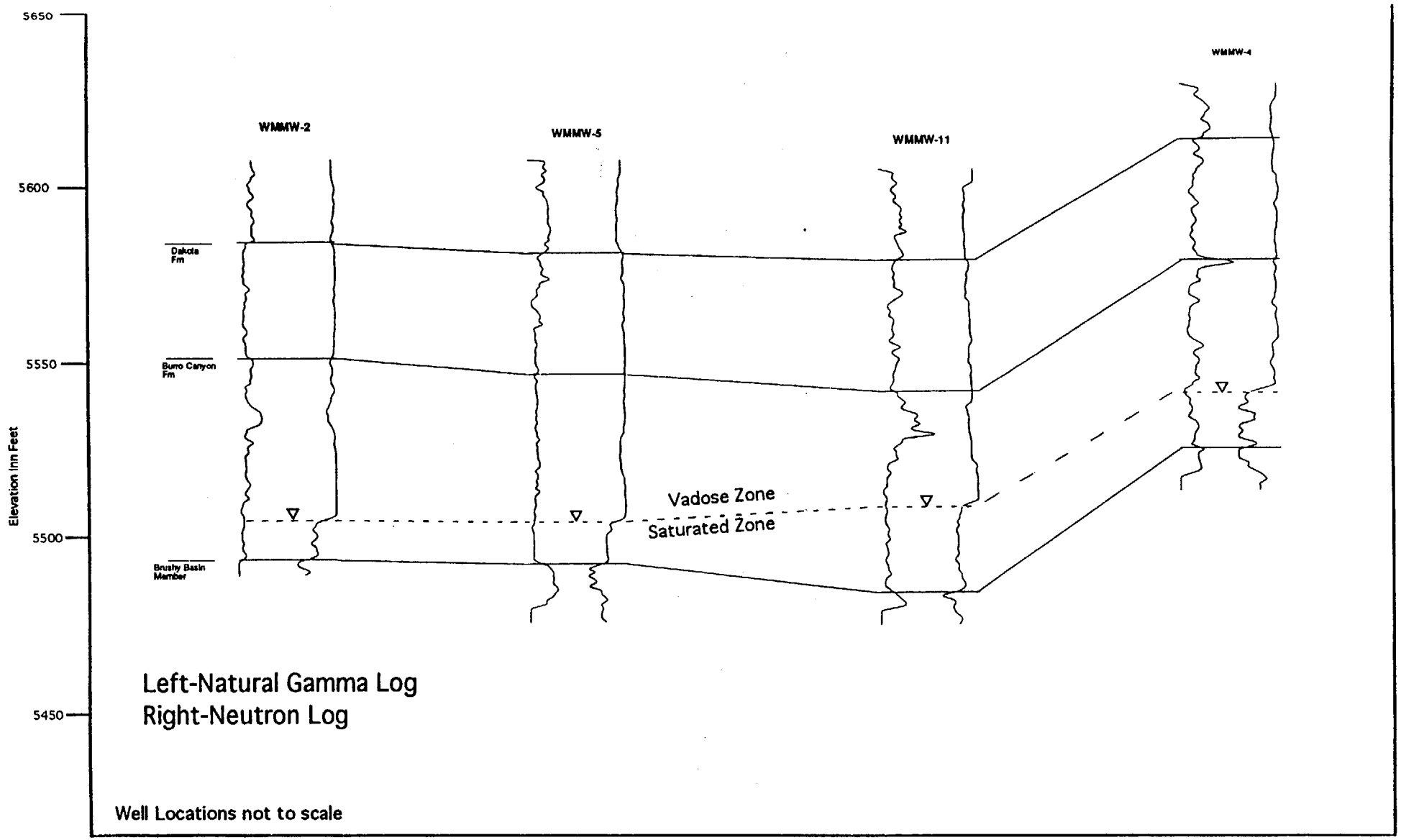
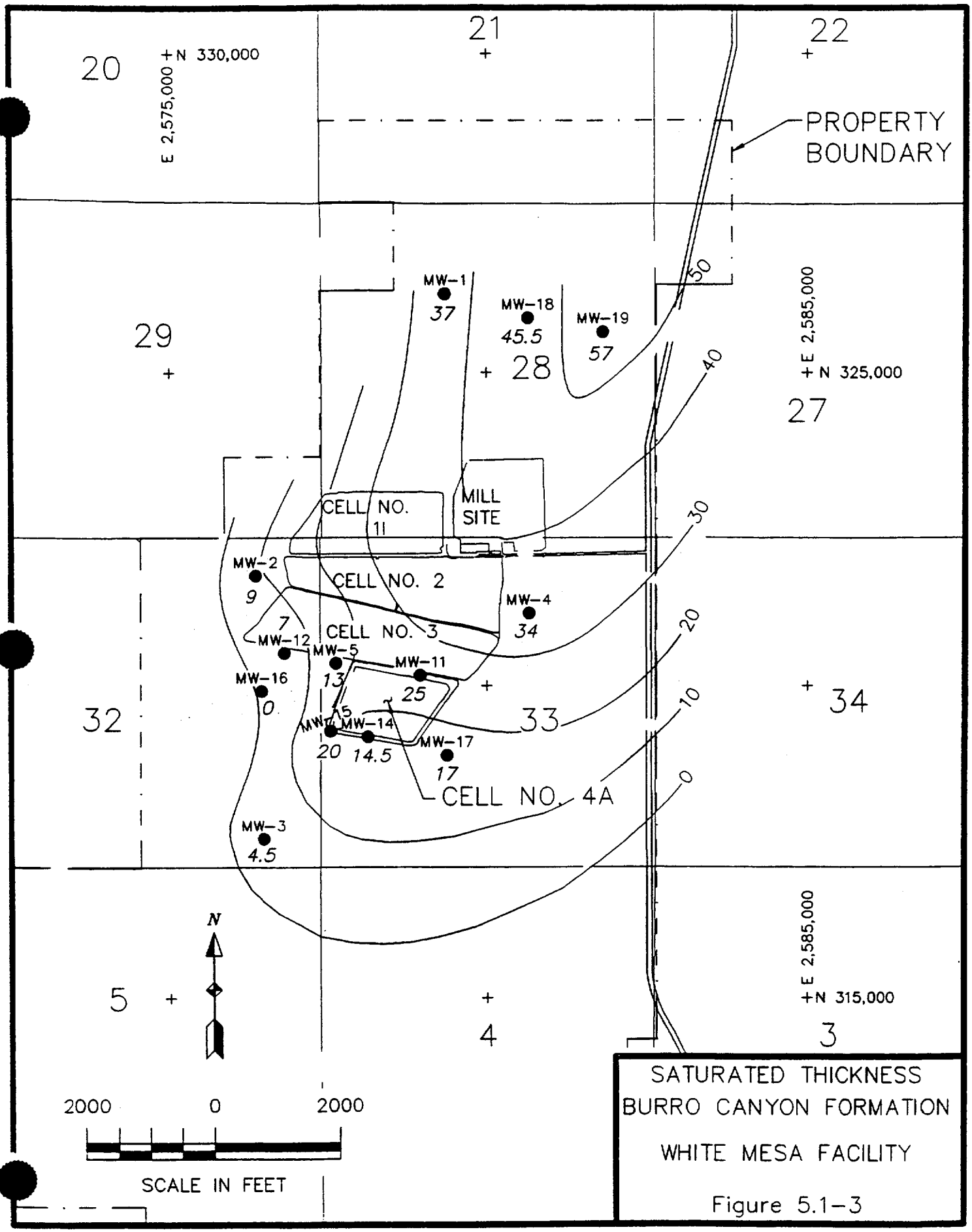
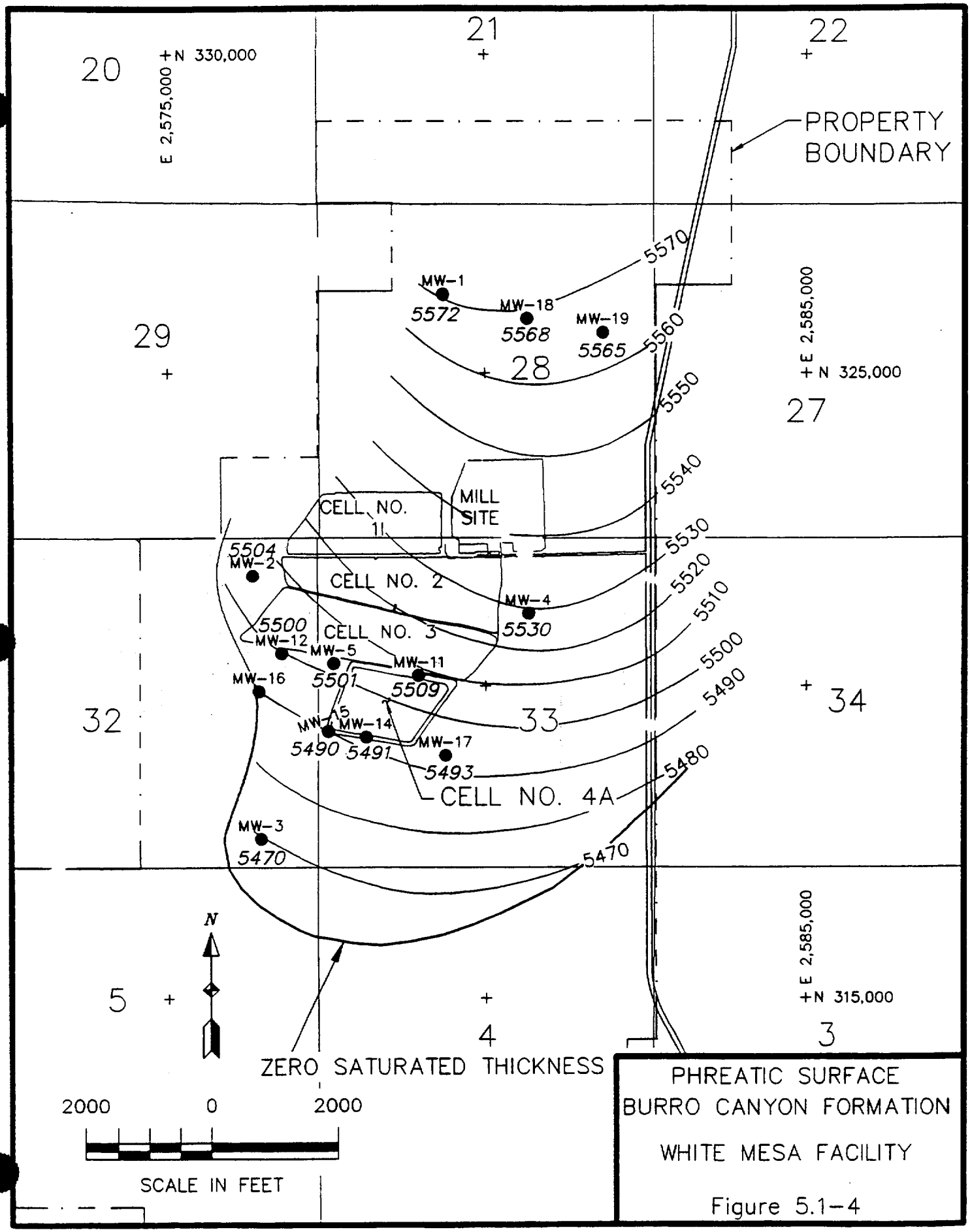


Figure 5.1-2 - East -West Stratigraphic Section Through The White Mesa Mill Site

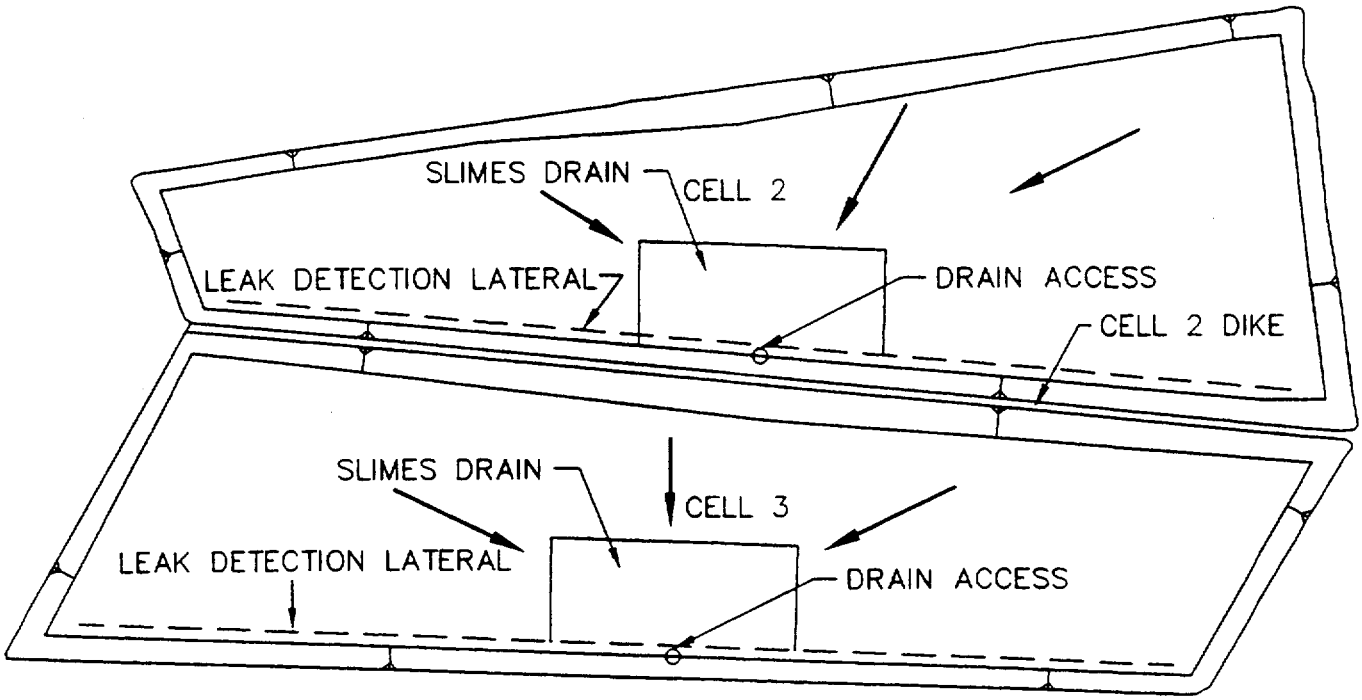


SATURATED THICKNESS
BURRO CANYON FORMATION
WHITE MESA FACILITY
Figure 5.1-3



PHREATIC SURFACE
BURRO CANYON FORMATION
WHITE MESA FACILITY

Figure 5.1-4



LEGEND

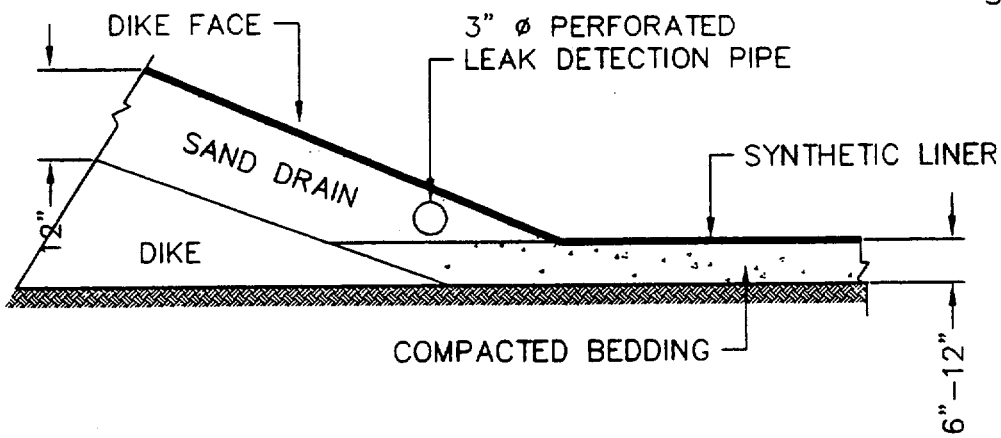
FLOW DIRECTION →

N

600 0 600

SCALE IN FEET

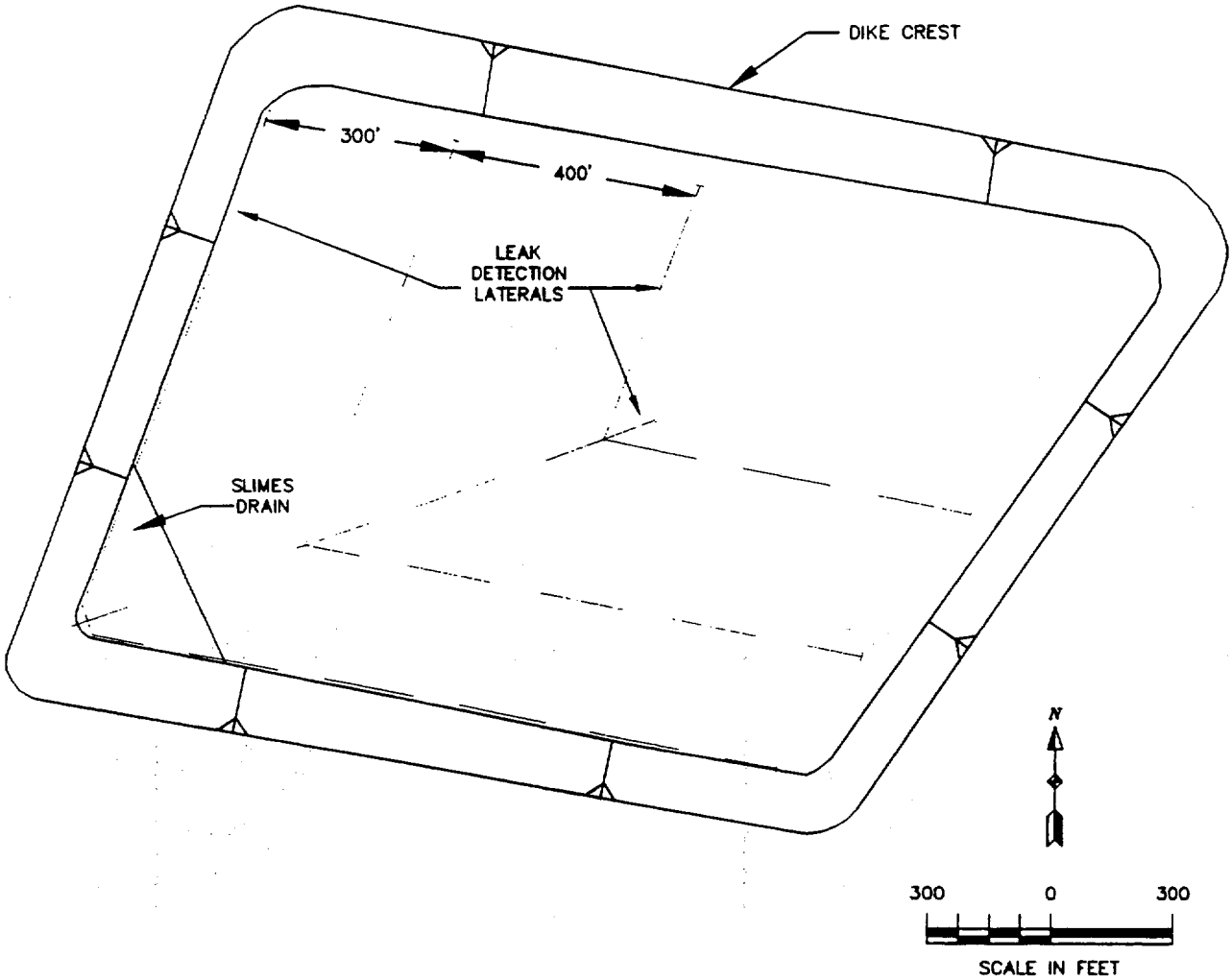
NTS



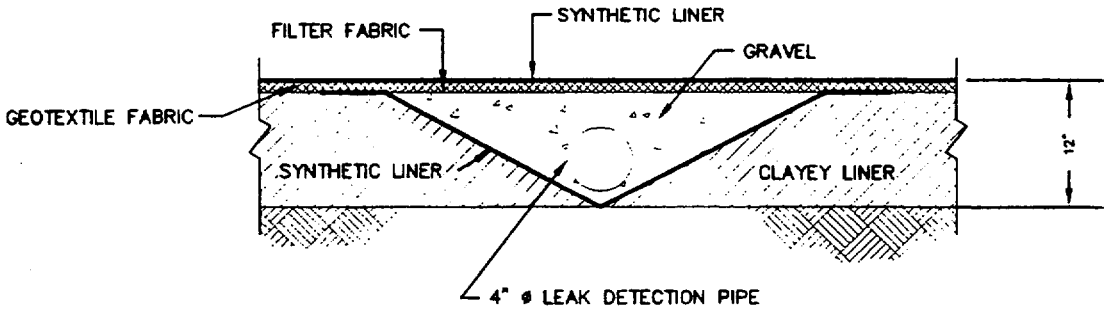
SCHEMATIC DRAWING
CELL 2 & 3 UNDERDRAIN

WHITE MESA FACILITY

Figure 5.1.1–1

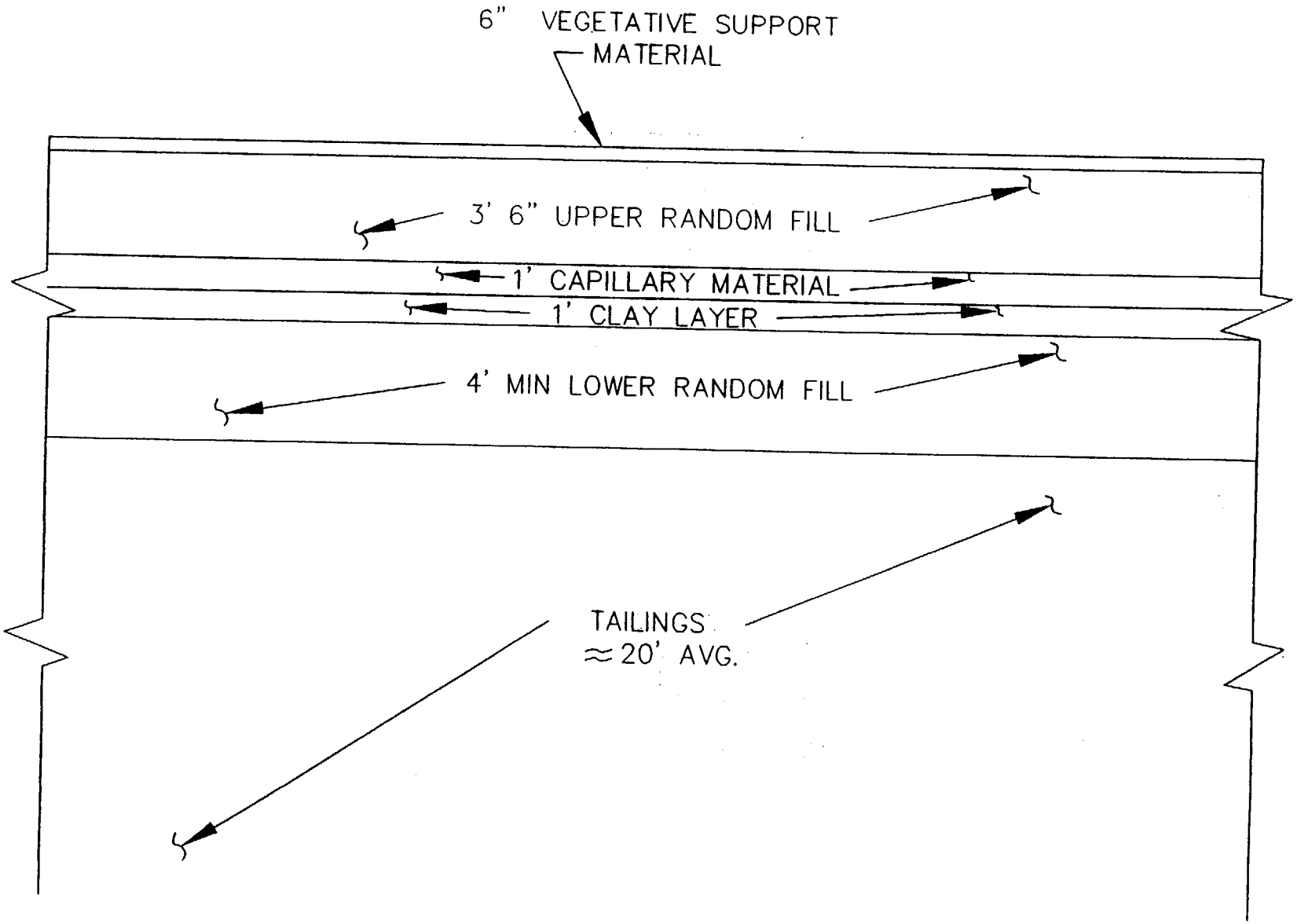


NTS



SCHEMATIC DRAWING
CELL 4A LEAK DETECTION SYSTEM
WHITE MESA FACILITY

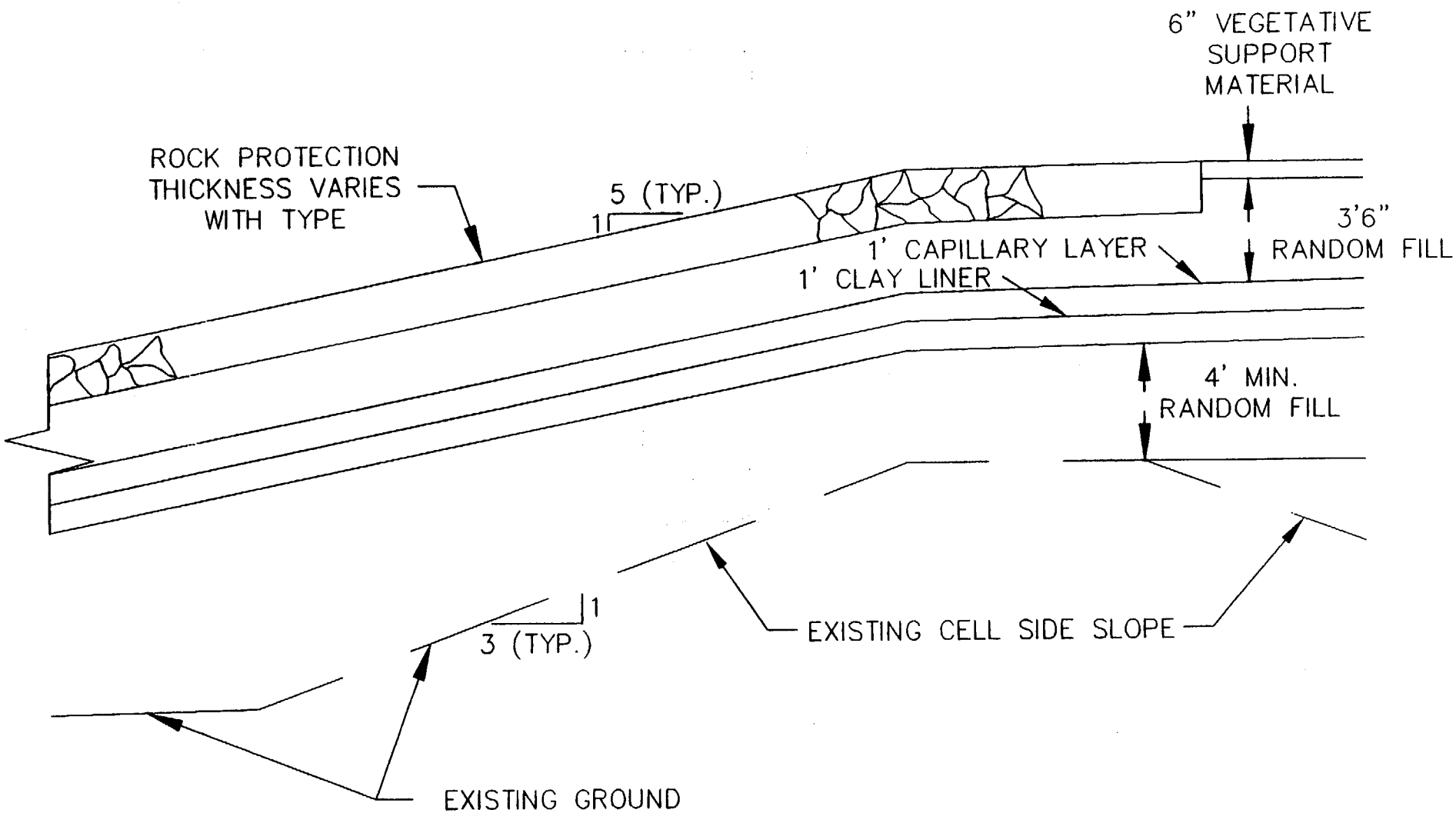
Figure 5.1.1-2



RECLAMATION COVER DETAILS

WHITE MESA FACILITY

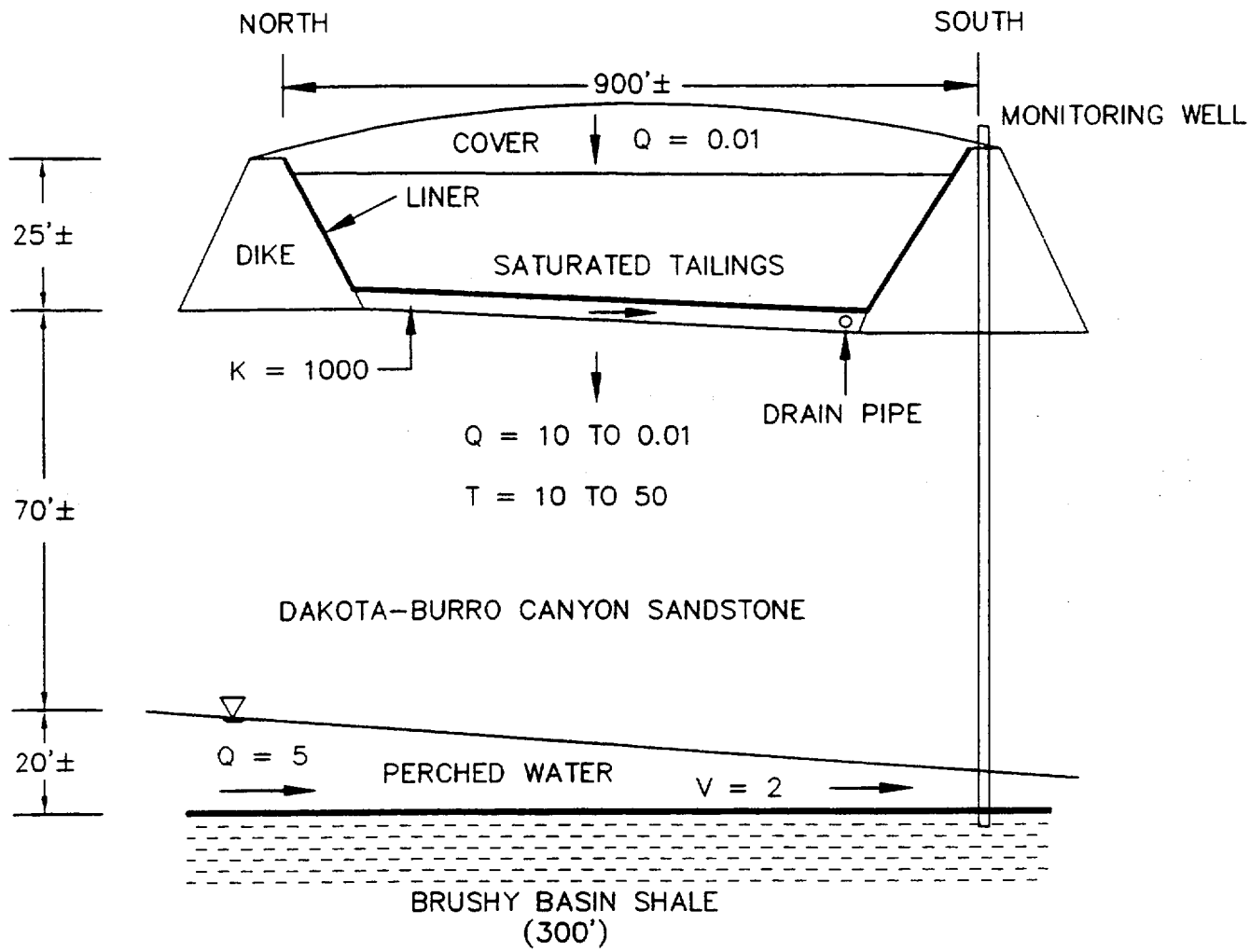
Figure 5.1.1-3



SIDE SLOPE RECLAMATION COVER DETAIL

WHITE MESA FACILITY

Figure 5.1.1-4

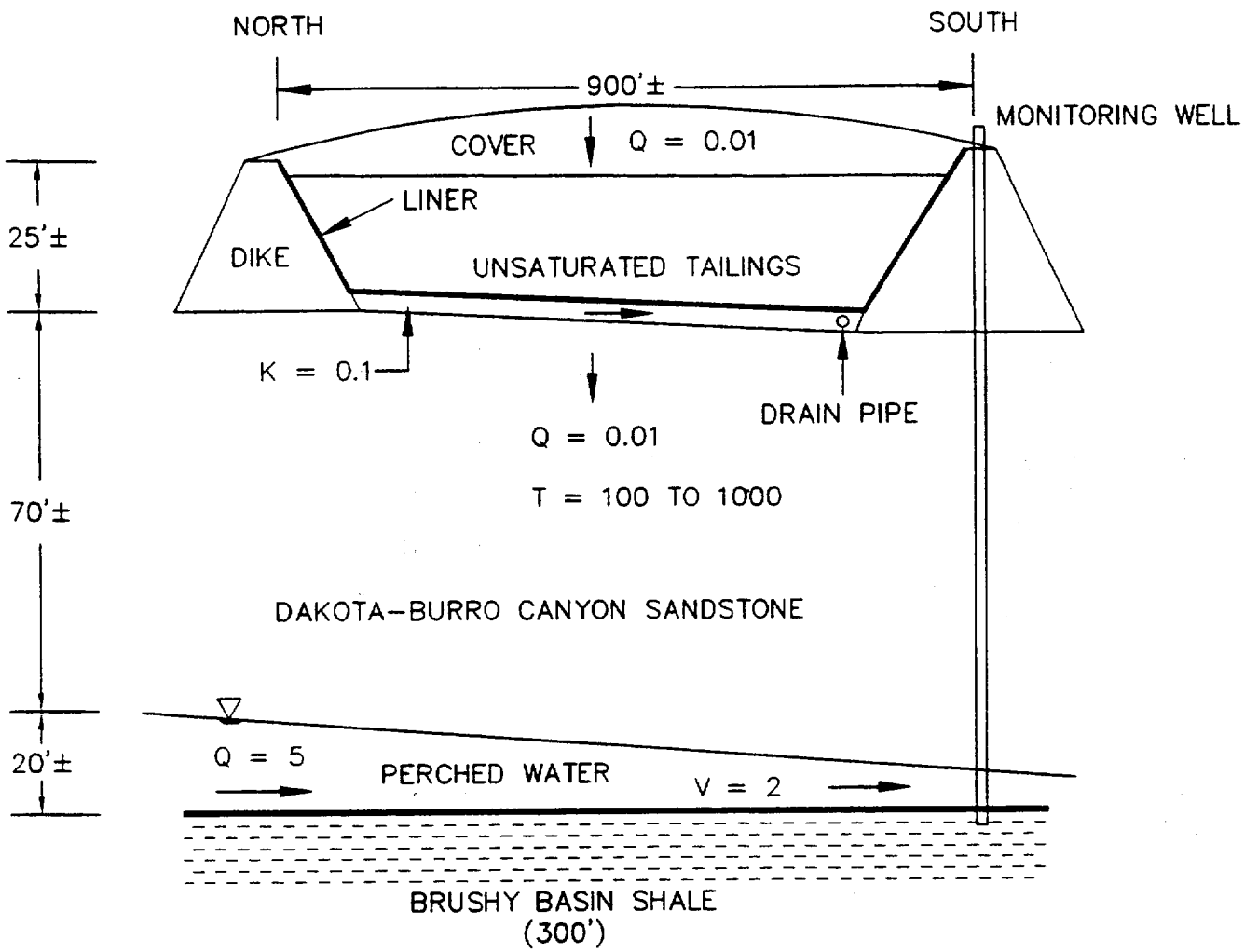


K = feet per year
Q = cubic feet per year per square foot
V = feet per year
T = years

CELL 4A SCHEMATIC DIAGRAM
FLUID FLOW

WHITE MESA FACILITY

Figure 5.2-1

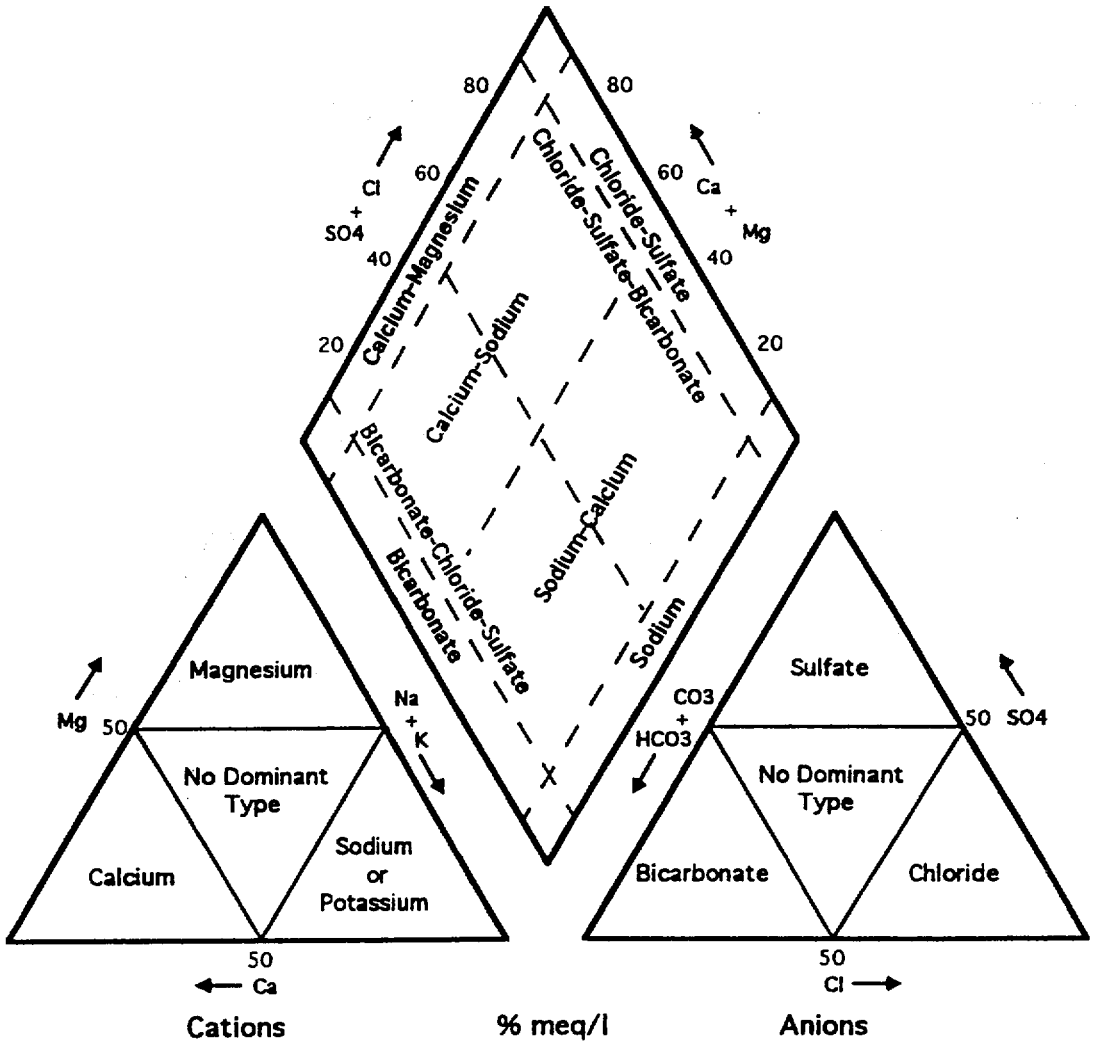


K = feet per year
Q = cubic feet per year per square foot
V = feet per year
T = years

CELL 3 SCHEMATIC DIAGRAM
FLUID FLOW

WHITE MESA FACILITY

Figure 5.2-2



CLASSIFICATION OF WATER TYPES USING THE TRILINEAR DIAGRAM

UMETCO MINERALS CORPORATION

DATE: 12/92 | FIG. NO. 5.3-1A

No.	TDS	Well Name
1	1329	MW-1
2	3132	MW-2
3	5056	MW-3
4	3284	MW-4
5	2063	MW-5
6	2679	MW-11
7	3798	MW-12
8	3523	MW-14
9	3849	MW-15
10	1217	Jones Well
11	2563	Anderson Well
12	1909	Windmill Well
13	3078	Jet Pump Well
14	1282	Fly Ash Pond
15	756	Cell 2 LDS
16	47115	Slimes Drain

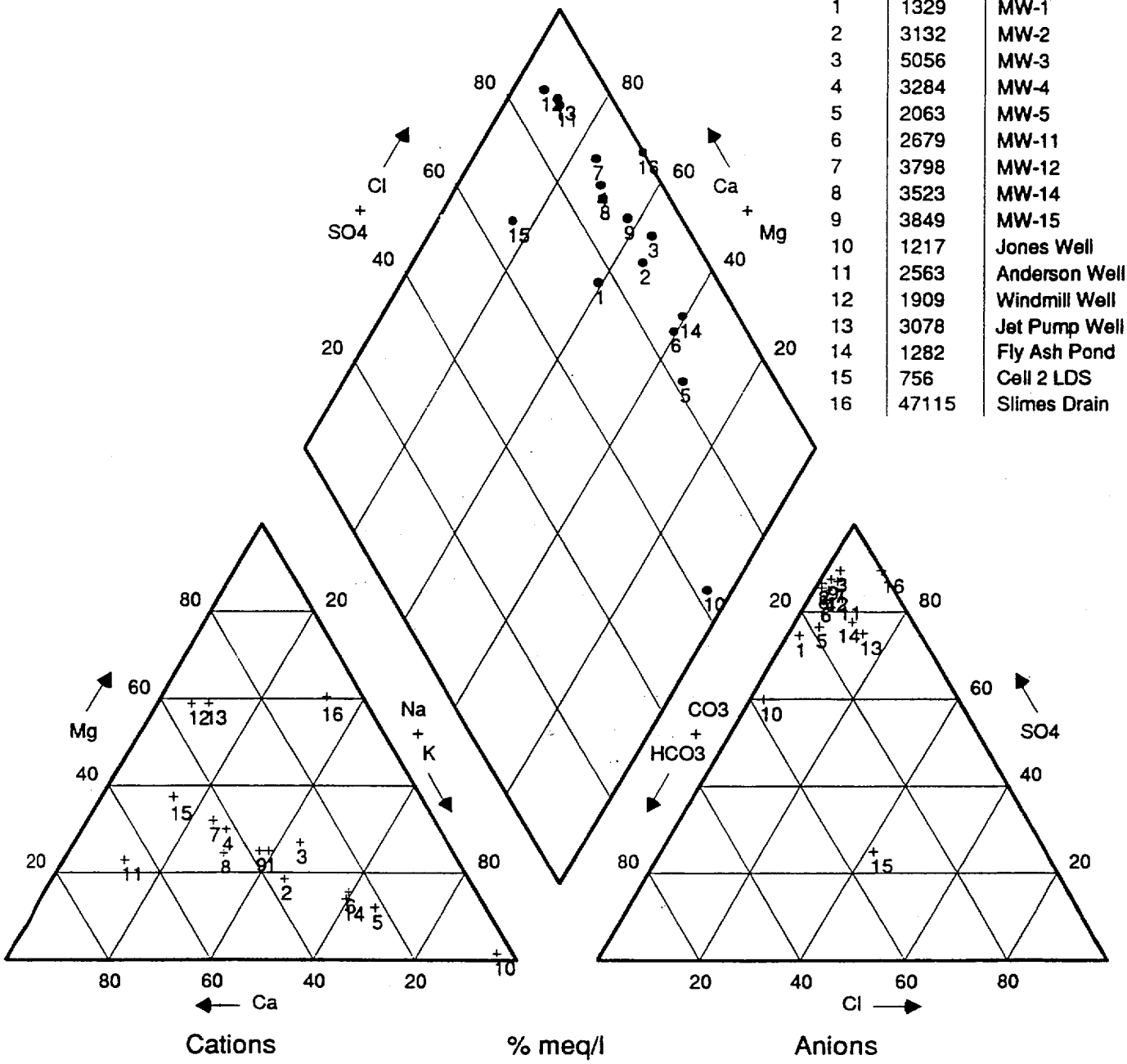


Figure 5.3 - 1 Trilinear Plot of Water From White Mesa Mill Monitor Wells, Fly Ash Pond and Slimes Drain, and Surrounding Stock Wells

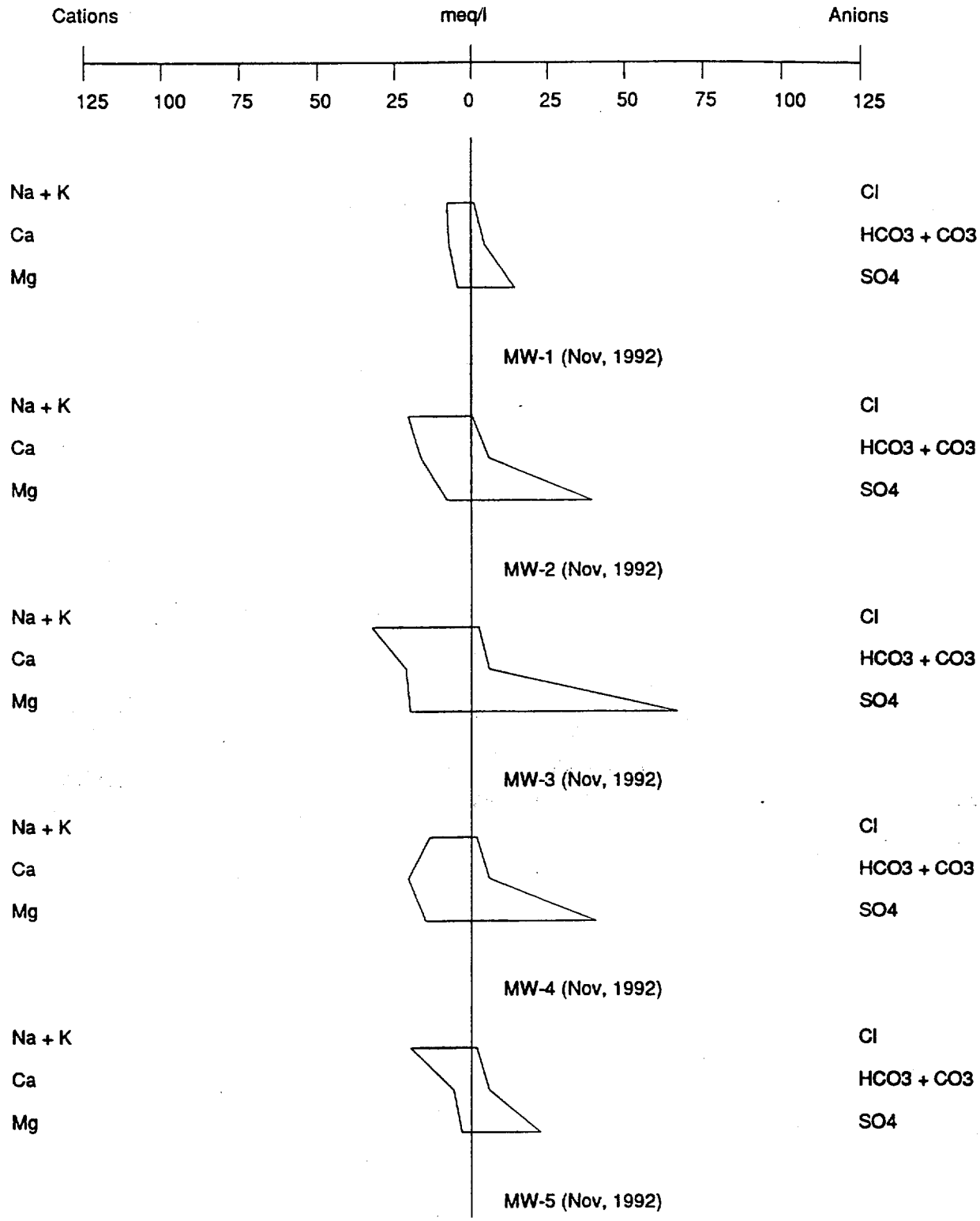


Figure 5.3 - 2 Stiff Diagrams Of Water From Monitor Wells

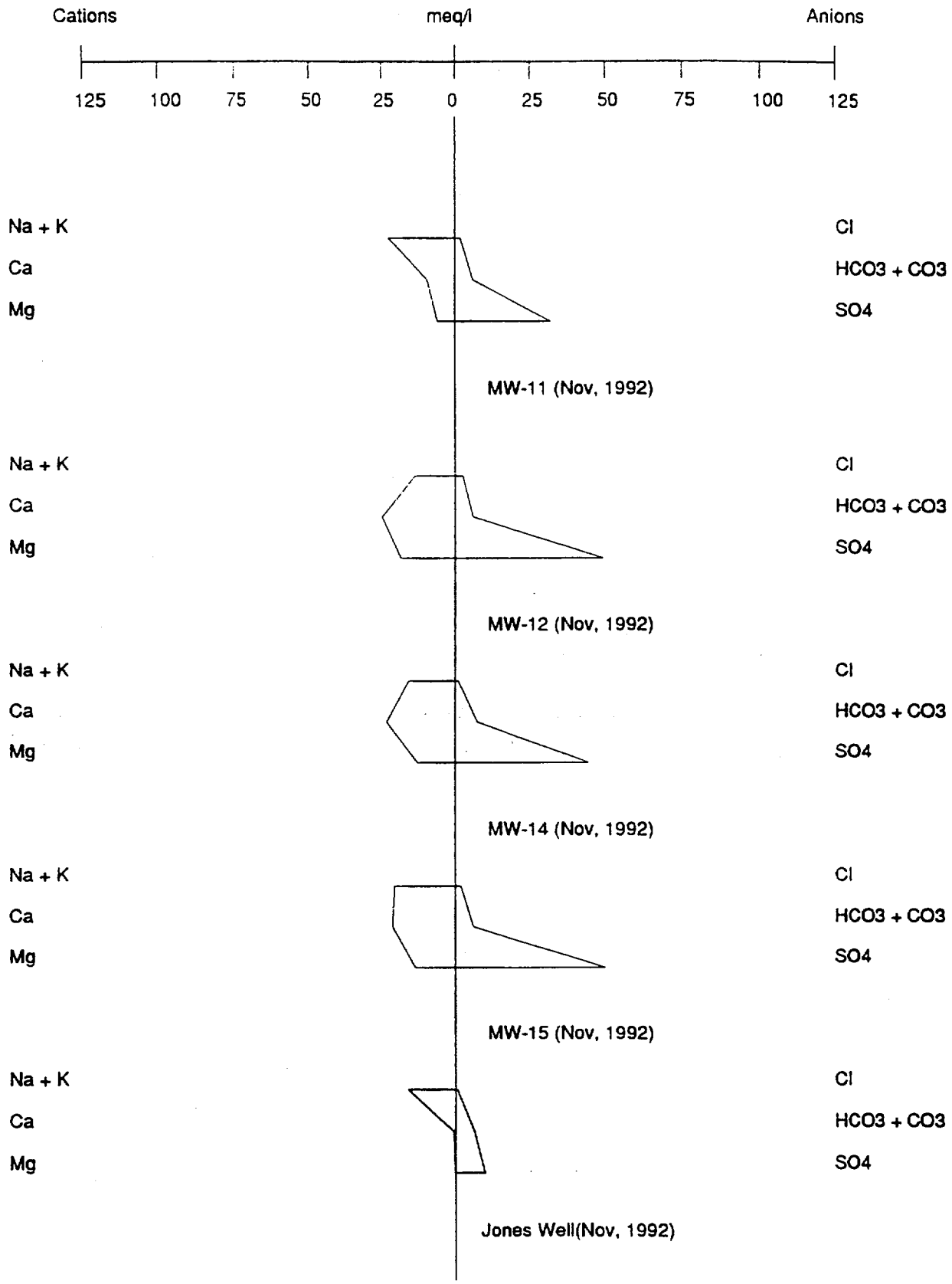


Figure 5.3 -3 Stiff Diagrams Of Water From Monitor Wells and Stock Well

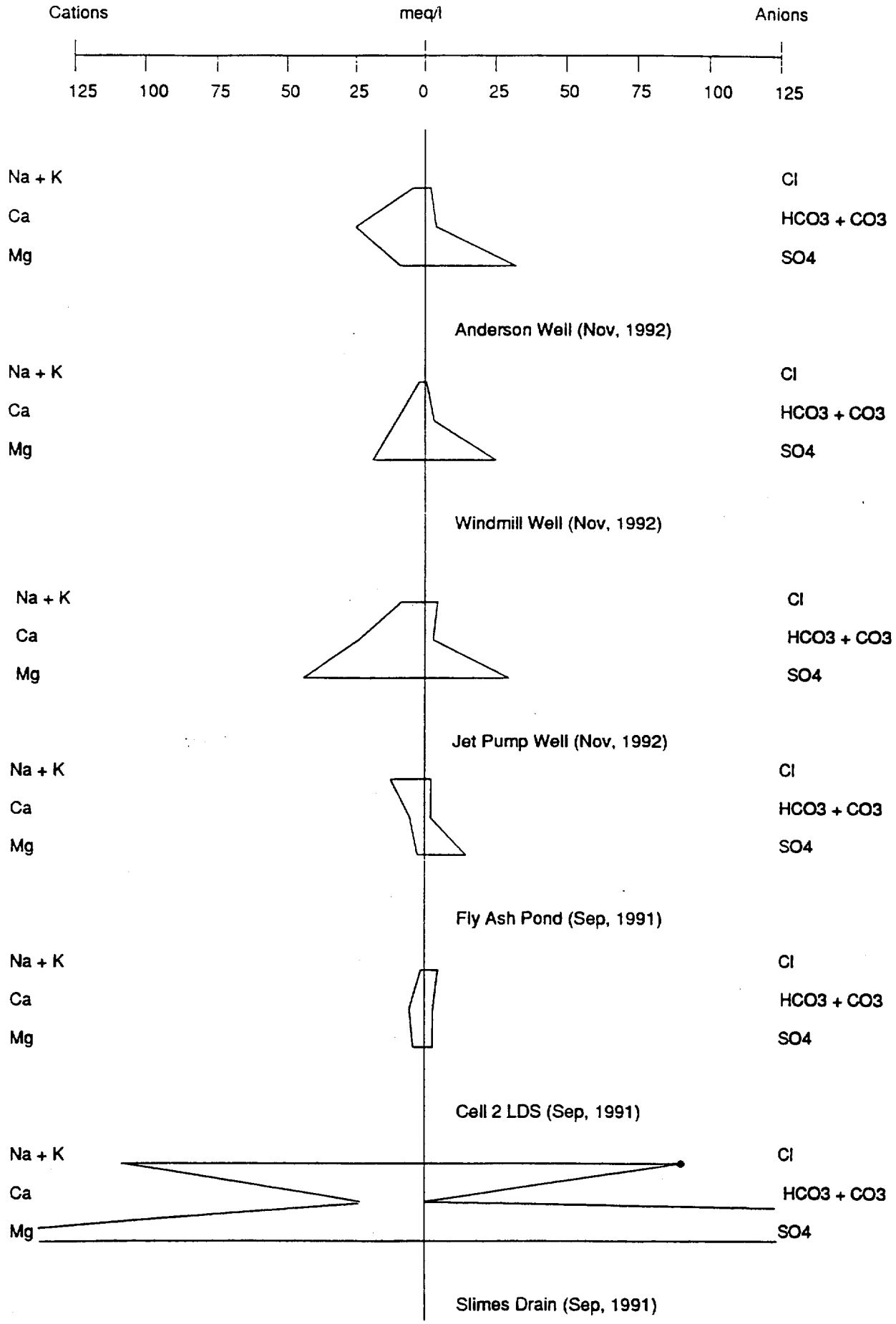


Figure 5.3-4 Stiff Diagrams Slimes Drain, Fly Ash Pond and Surrounding Stock Wells

No.	TDS	Sample Date
1	612	Oct-79
2	1103	Jan/80
3	1200	Apr/80
4	1297	Feb/91
5	1329	Nov/92

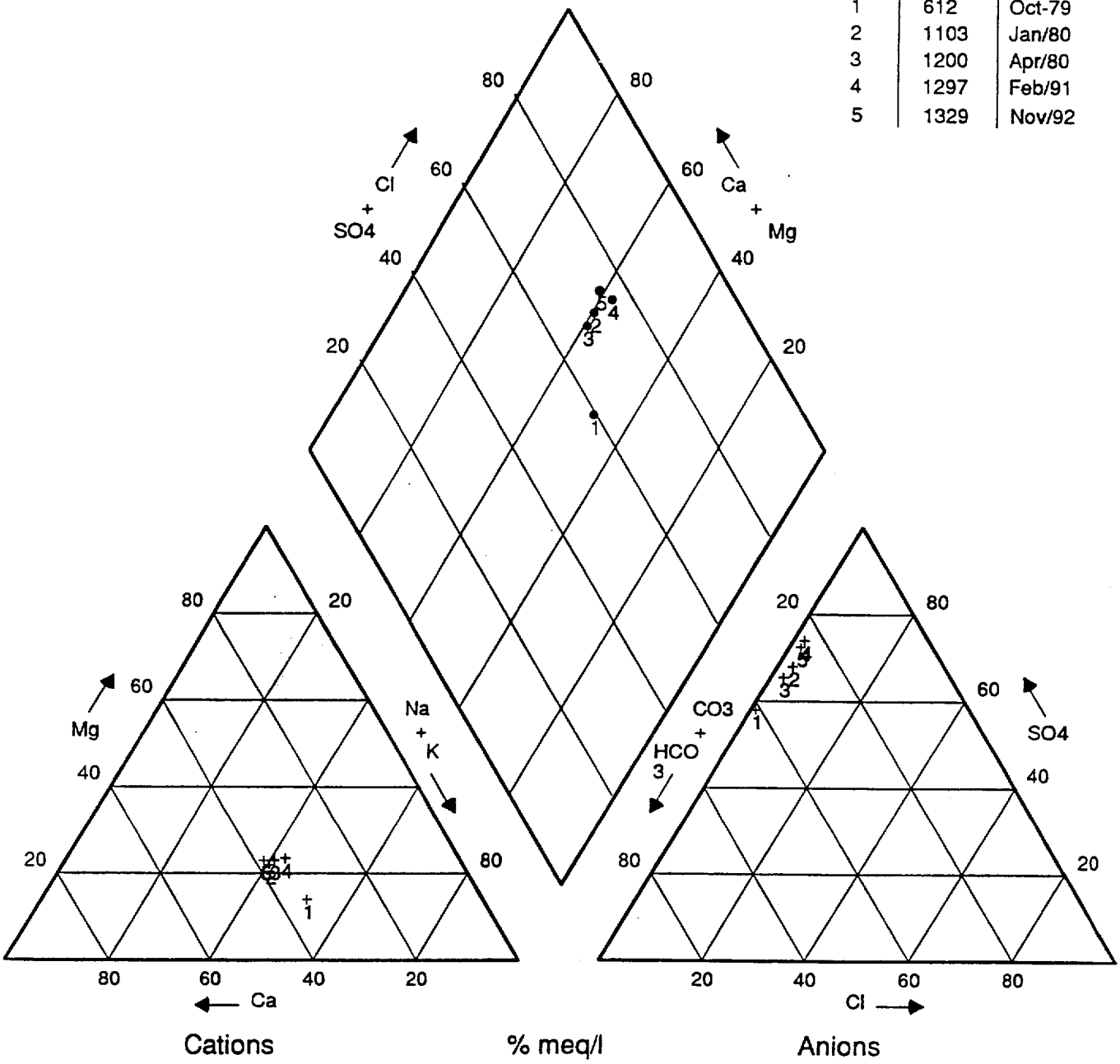


Figure 5.3 - 5 Time -Sequence Trilinear Plot of WMMW-1

No.	TDS	Sample Date
1	1837	Oct/79
2	3298	Jan/80
3	3288	Apr/80
4	4358	Feb/91
5	5056	Nov/92

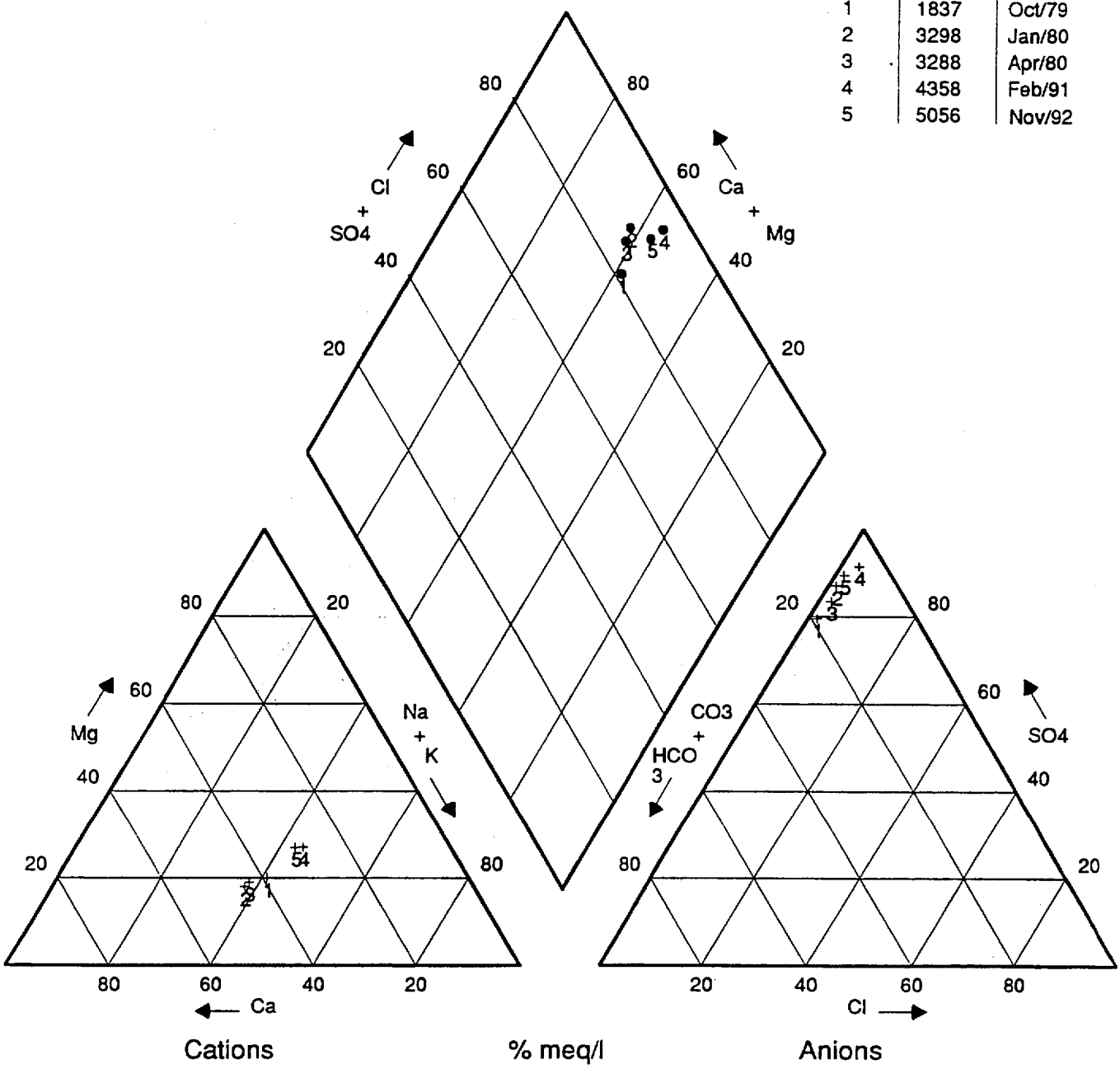


Figure 5.3 - 6 Time -Sequence Trilinear Plot of WMMW-3

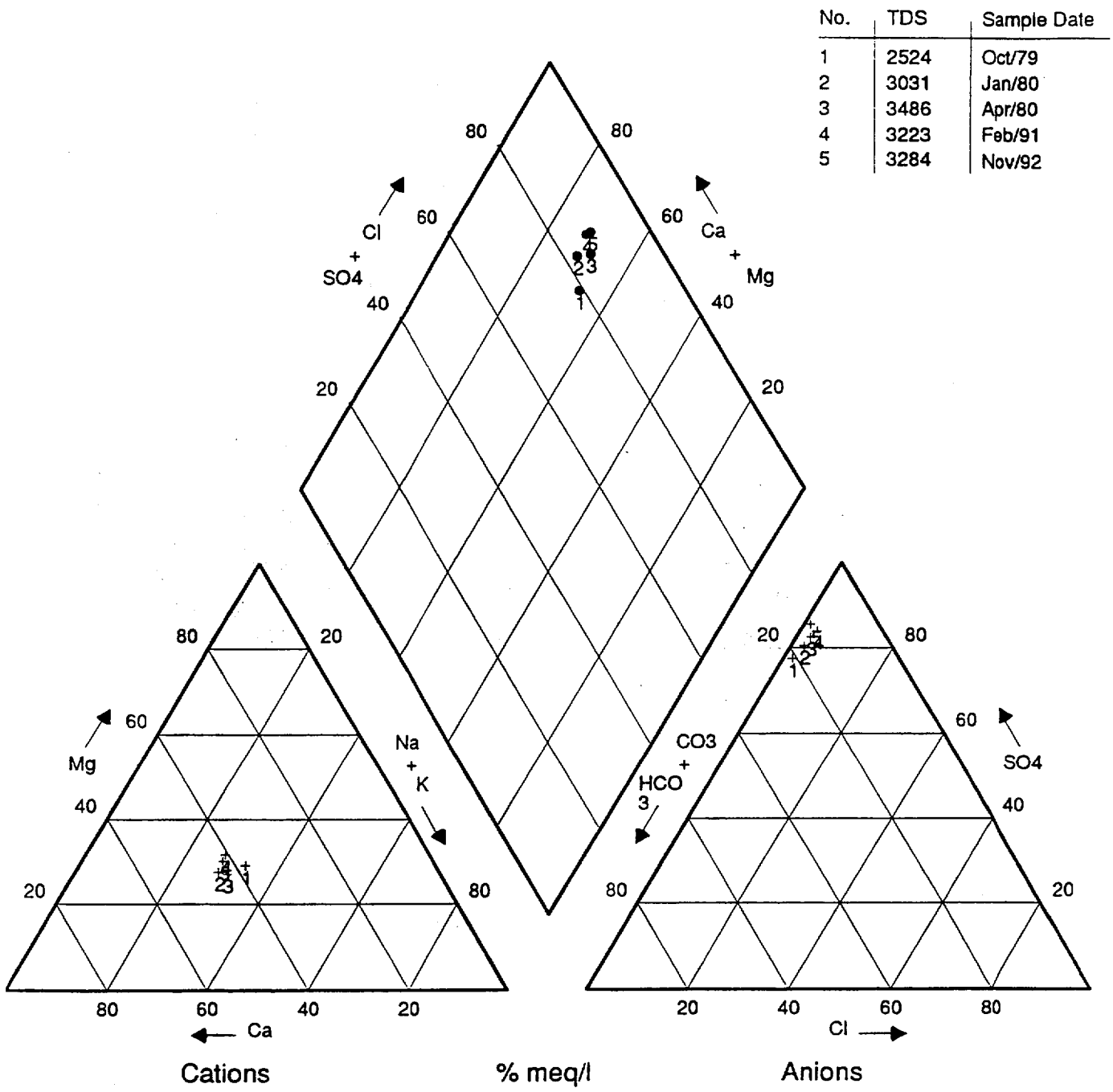


Figure 5.3 - 7 Time -Sequence Trilinear Plot of WMMW-4

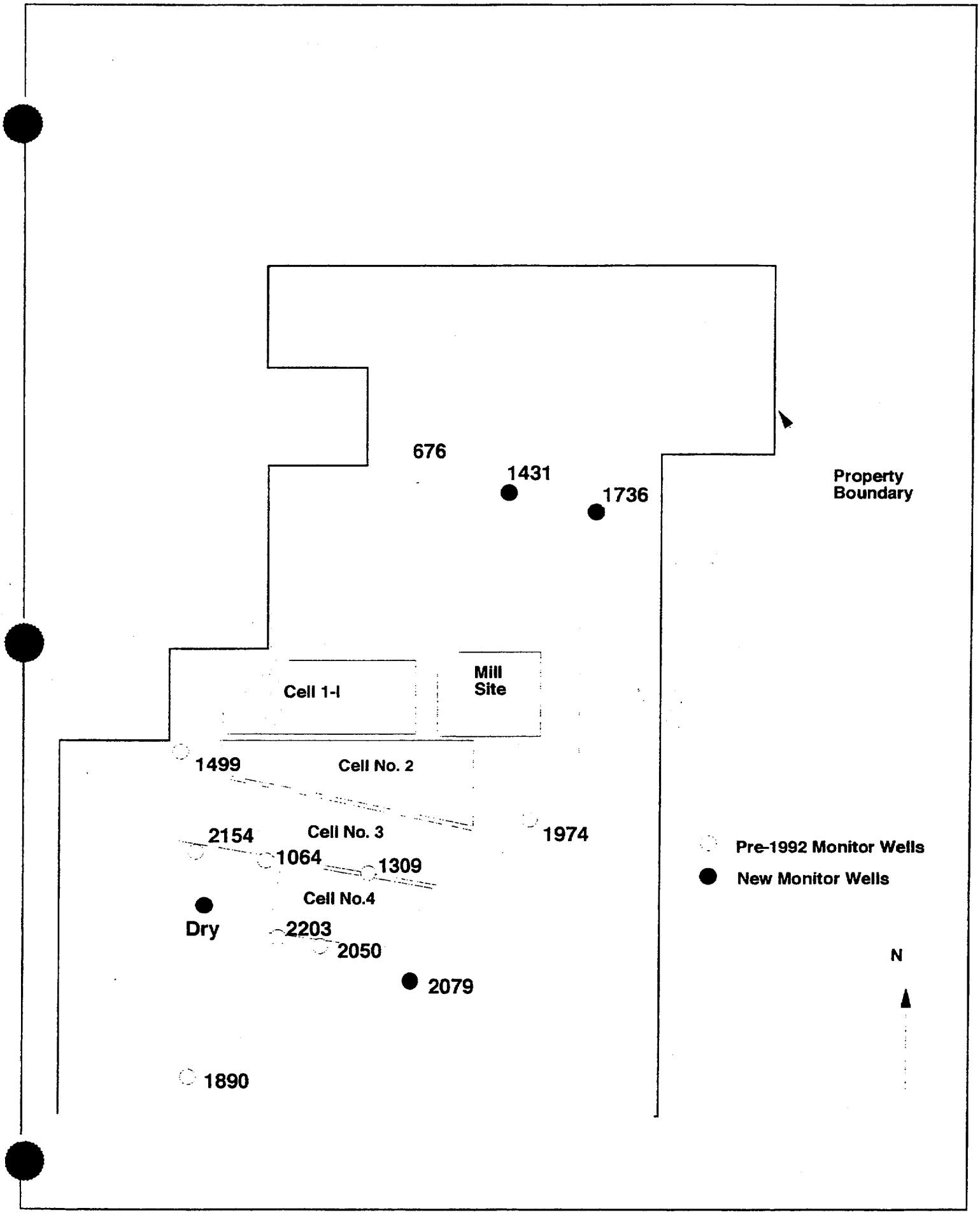


Figure 5.3-8 Sulfate Concentrations (mg/l) June, 1993

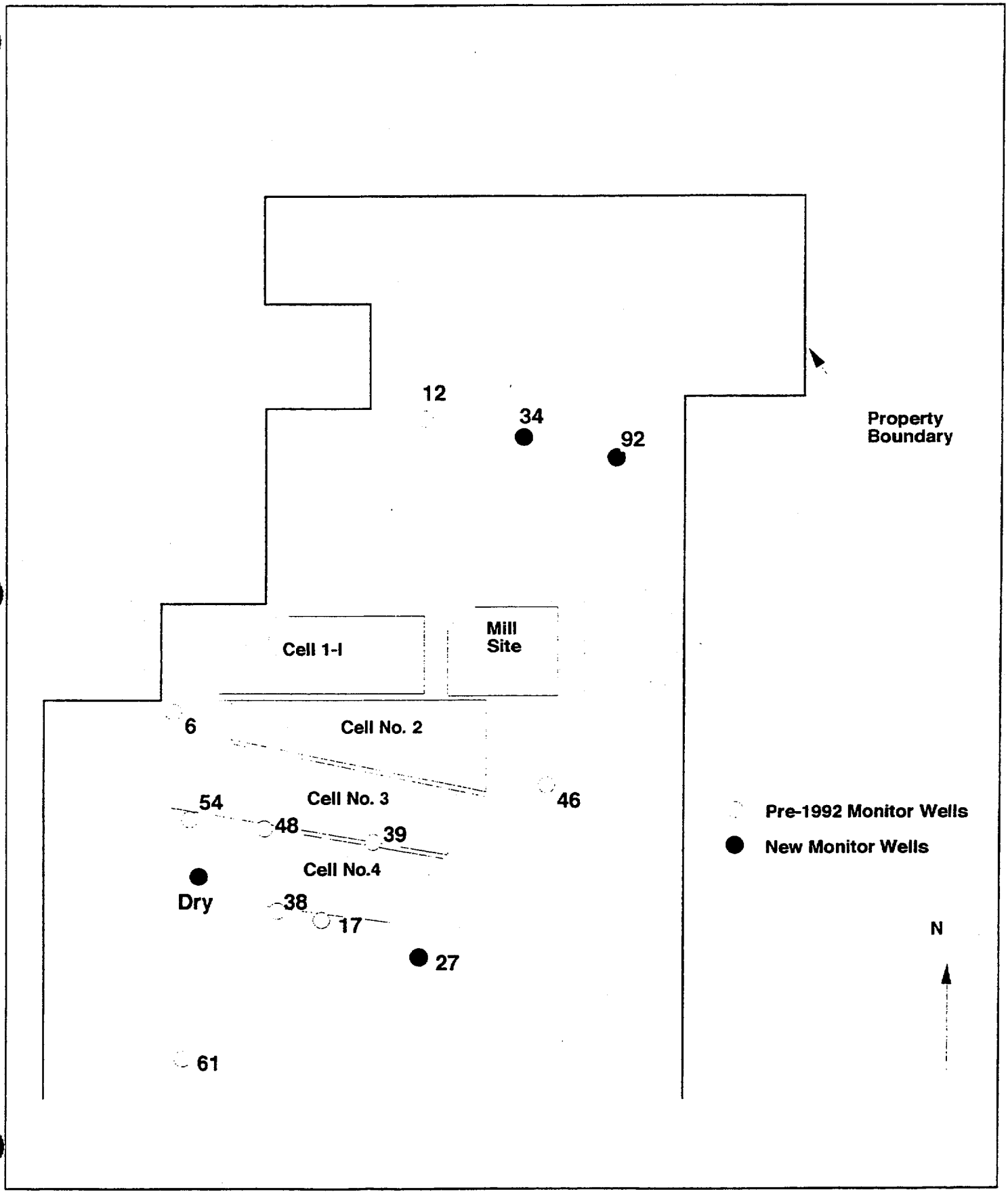


Figure 5.3-9 Chloride Concentrations (mg/l) June, 1993

7.0 REFERENCES

Chen and Associates, 1978, Soil Property Study, Earth-lined Tailings Retention Cells, White Mesa Uranium Project, Blanding, Utah, for Energy Fuels Nuclear, Inc.

Dames and Moore, 1978, Environmental Report, White Mesa Uranium Project, San Juan County, Utah for Energy Fuels Nuclear, Inc.

D'Appolonia, 1982, Environmental and Engineering Assessments, Section 16 Tailings Project, Blanding, Utah for Energy Fuels Nuclear, Inc.

Eardly, A. J., 1958, Physiography of southeastern Utah in Intermountain Association Petroleum Geologists Guidebook 9th Annual Field Conference, Geology of the Paradox Basin, p. 10-15.

Feltis, R. D., 1966, Water in Bedrock in the Colorado Plateau of Utah, Utah State Engineer Technical Publication No. 15.

Goode, H. D., 1958, The Geology and Distribution of Aquifers in the Southeastern Part of San Juan County, Utah, U.S.G.S. Open File Report.

Haynes, D. D., Vogel, D. G. and Wyant, D. G., 1972, Geology Structure and Uranium Deposits of the Cortez Quadrangle, Colorado and Utah, U.S.G.S. Miscellaneous Investigation Series, May I-629.

Hydro-Engineering, 1991, Ground-Water Hydrology at the White Mesa Tailings for Umetco Minerals Corporation.

Kelley, V. C., 1958, Tectonics of the Region of the Paradox Basin in Intermountain Association Petroleum Geologists Guidebook 9th Annual Field Convention, Geology of the Paradox Basin, p. 31-38.

McWhorter, D. B. and Nelson, J. D., Seepage in the Partially Saturated Zone Beneath Tailings Impoundments, Mining Engineering, April 1980.

Shoemaker, E. M., 1956, Structural Features of the Colorado Plateau and Their Relation to Uranium Deposits. U.S. Geological Survey Professional Paper 300, p. 155-168.

Strausberg, 1982, Permeability from "Mini-Rate" Pumping Tests, Groundwater Monitoring and Remediation, Summer, 1982.

United States Department of Energy (MK-Environmental Services) Albuquerque, New Mexico "Uranium Mill Tailings Remedial Action Project (UMTRAP), Naturita, Colorado, Preliminary Design for Review, Volume I", May 1990.

United States Department of Energy, UMTRA Project Office, Albuquerque, New Mexico "Environmental Assessment of Remedial Action at the Slick Rock Uranium Mill Tailings Sites, Slick Rock, Colorado, February, 1993.

APPENDIX A

Drilling, Geophysical Logging

and

Monitor Well Construction

DRILLING AND WELL CONSTRUCTION PROCEDURES

DRILLING

Four new observation wells were drilled and constructed at the White Mesa Mill site during November and December, 1992.

Twelve-inch borings were drilled to a depth of 19.5 feet for each of the new monitor wells. Steel surface casing 10-inch in diameter and 0.25-inch thick was set to this depth and cemented into place with a cement/bentonite grout and allowed to set up for 72 hours.

WMMW-16 was cored to total depth using an HQ diamond bit with an outer diameter of 4.25 inches. Once the total depth was achieved, the well was reamed using a 7 7/8-inch tricone bit. Ten-foot, 2.34-inch cores were obtained during each.

WMMW-17, -18 and -19 were drilled in a similar manner as WMMW-16 except these wells were not cored over the total depth of the hole. Once the surface casing was set, the borehole was drilled down to the first core point using a 7 7/8-inch tricone bit. (Drilling was conducted with air using small quantities of water from the White Mesa Culinary Well to keep the cuttings moist and reduce dust.) A 10-foot core was obtained using the equipment described for WMMW-16. Upon completion of the coring, the hole was then reamed with the tricone bit and drilled down to the next core point. It should be noted that core recoveries in WMMW-17, -18 and -19 are well below the 100 percent recoveries achieved in WMMW-16. The low core recovery rate in these boring is due to the following conditions:

- Each new core run was started in an 8-inch hole which allowed the barrel and pipe to wobble in the hole resulting in the core not being held firmly in the core catcher as it was cut.

- In order to recover an uncontaminated core, the driller was not allowed to use a "core-loss polymer" which would have enhanced recovery.

- The drill rig, bit and pipe were decontaminated upon completion of each hole, prior to moving to the next location.

WELL DEVELOPMENT

Once the borehole had been logged, the well was developed by jetting the groundwater and residual cuttings out of the borehole, then allowing the well to partially recover, then jetting once again. This was repeated until all the cuttings were removed and the water was clear.

WELL CONSTRUCTION

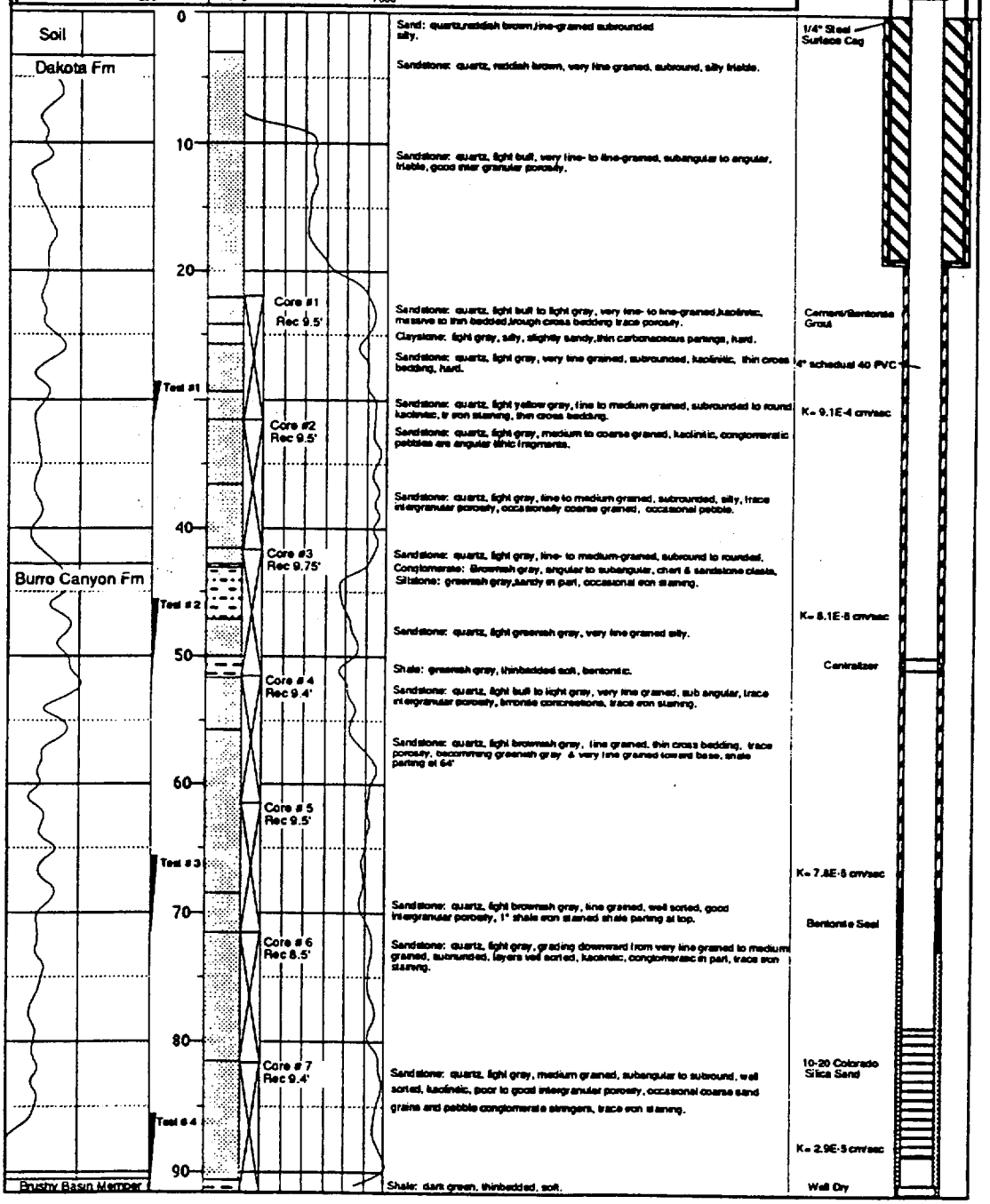
Each observation well was constructed using 4-inch flush-joint schedule 40 PVC pipe, 20-slot (0.02-inch) was used for the slotted section, 10 - 20 Colorado silica sand gravel pack, bentonite pellets, and cement/bentonite grout. A cap was placed on the bottom of the 4-inch PVC-riser pipe. This was followed by an interval of blank PVC pipe to act as a sump for the well. A screened interval was placed above of the sump, followed by blank PVC pipe to surface. A gravel pack was then placed between the 4-inch PVC pipe and the wall of the borehole from the bottom of the hole to a selected point above the slotted portion of the PVC pipe. Five feet of bentonite pellets were then placed above the gravel pack. Bentonite/cement grout was placed from the top of the bentonite pellet seal to surface. PVC caps were then placed on the pipe and a locking cap constructed on the steel casing. Completion diagrams for wells WMMW-16 through WMMW-19 are shown on the attached schematic diagram and on the associated boring log for each well. A schematic diagram for monitor wells WMMW-1 through WMMW-5 and WMMW-11 through WMMW-13 is also included in this appendix.

PEEL Environmental Services
Arvada, CO (303)422-6116

Bore Hole No. : WMMW-16

Project: White Mesa	Surface Elev. 5587 est	T. D. = 91.5	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: Dry	Geologist: F. A. Peel	

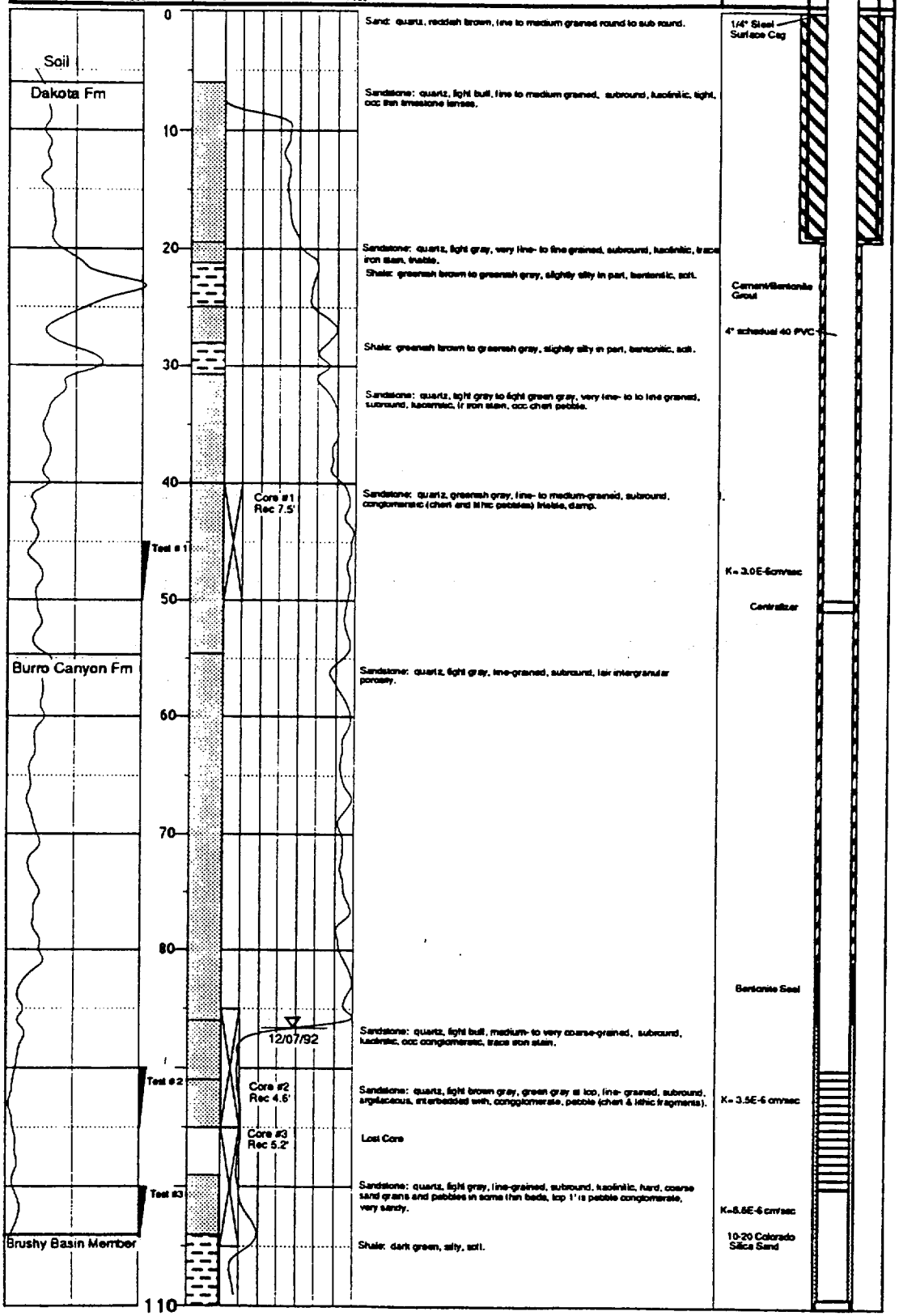
Gamma (Nat) 0–250 | Depth | Graphic Description | Neutron - API 0–7000 | Sample Description | Comments | Well Costruction



PEEL Environmental Services
Arvada, CO (303)423-6116

Bore Hole No. : WMMW-17

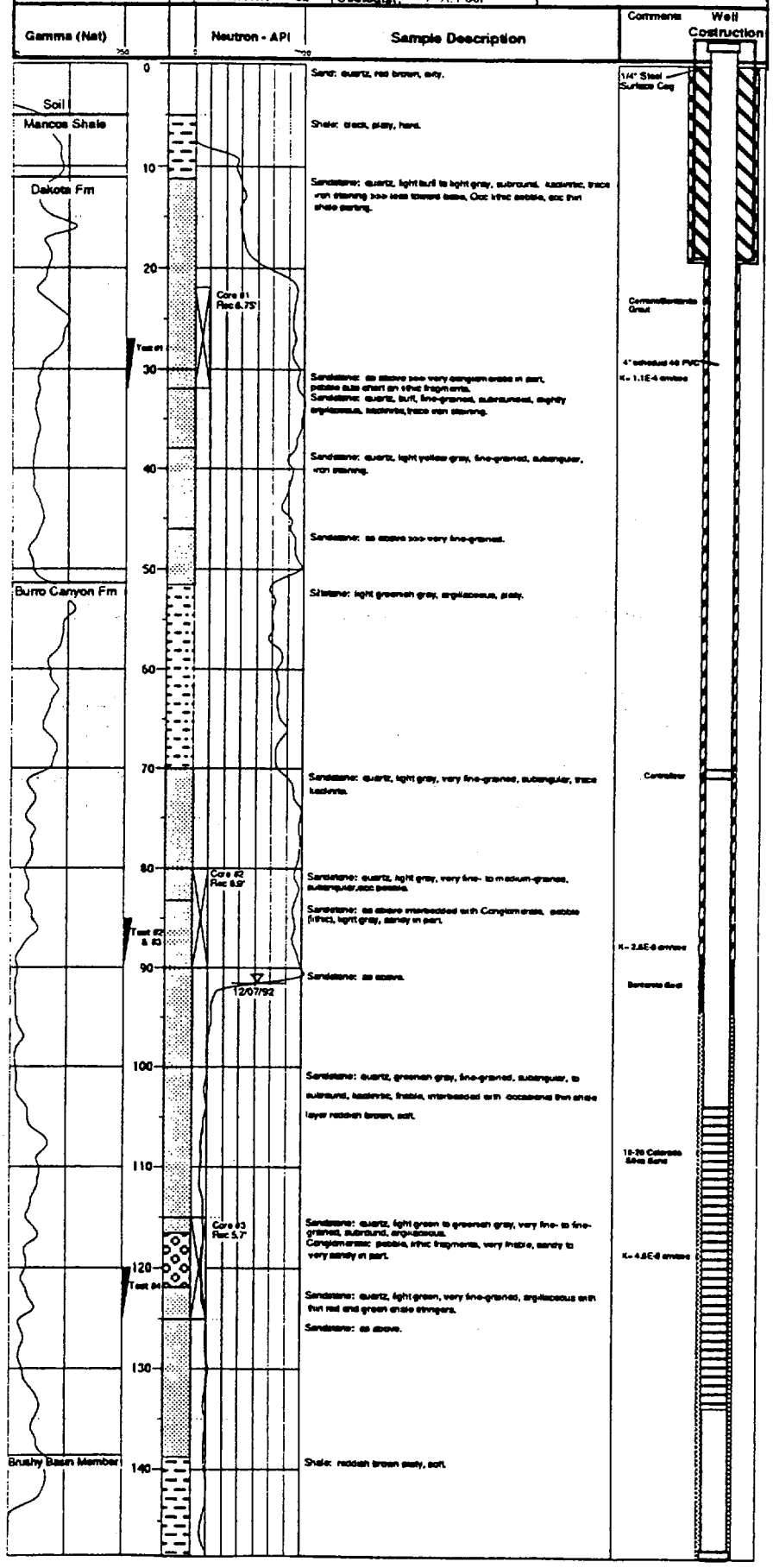
Project: White Mesa	**Surface Elev.** 5580 est	**T. D. =** 110'	**UMETCO Minerals Corporation**
Date: 12/07/92	**Depth to Water:** 86.5'	**Geologist:** F. A. Peel	



PEEL Environmental Services
Arvada, CO (303)425-6116

Bore Hole No. : WMMW-18

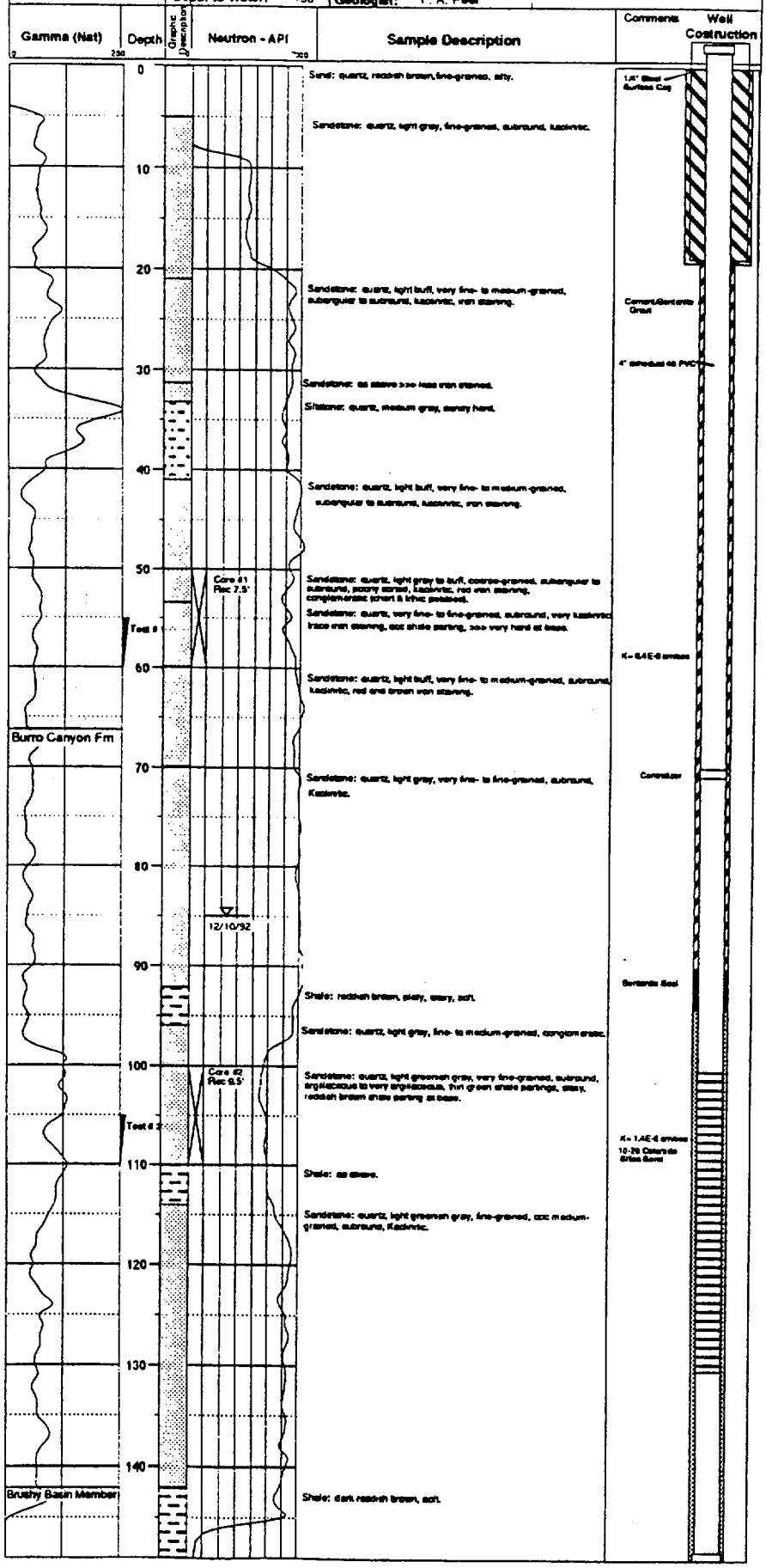
Project: White Mesa	Surface Elev. 5660	T. D. = 148.5'	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: 92'	Geologist: F. A. Peel	



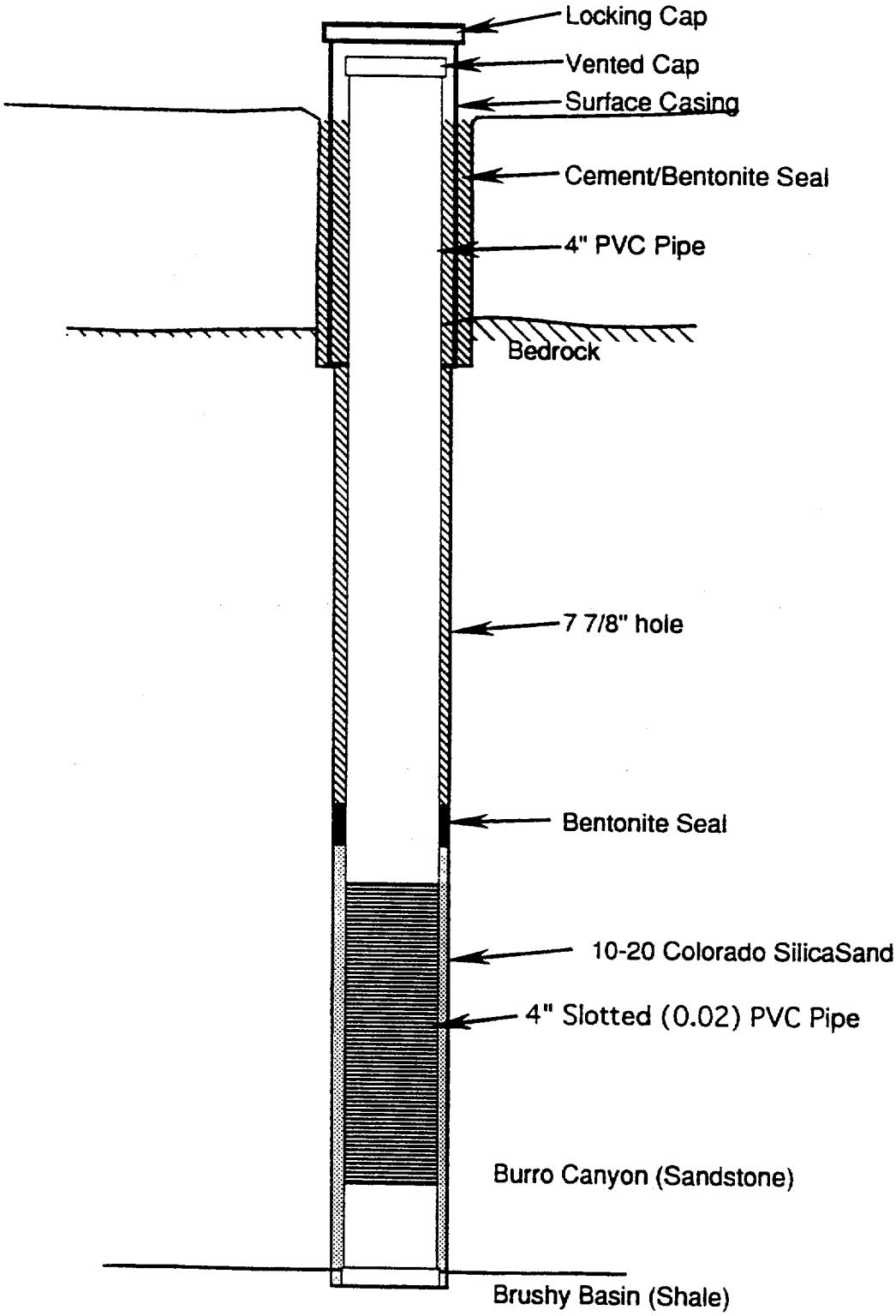
PEEL Environmental Services
Arvada, CO

Bore Hole No. : WMMW-19

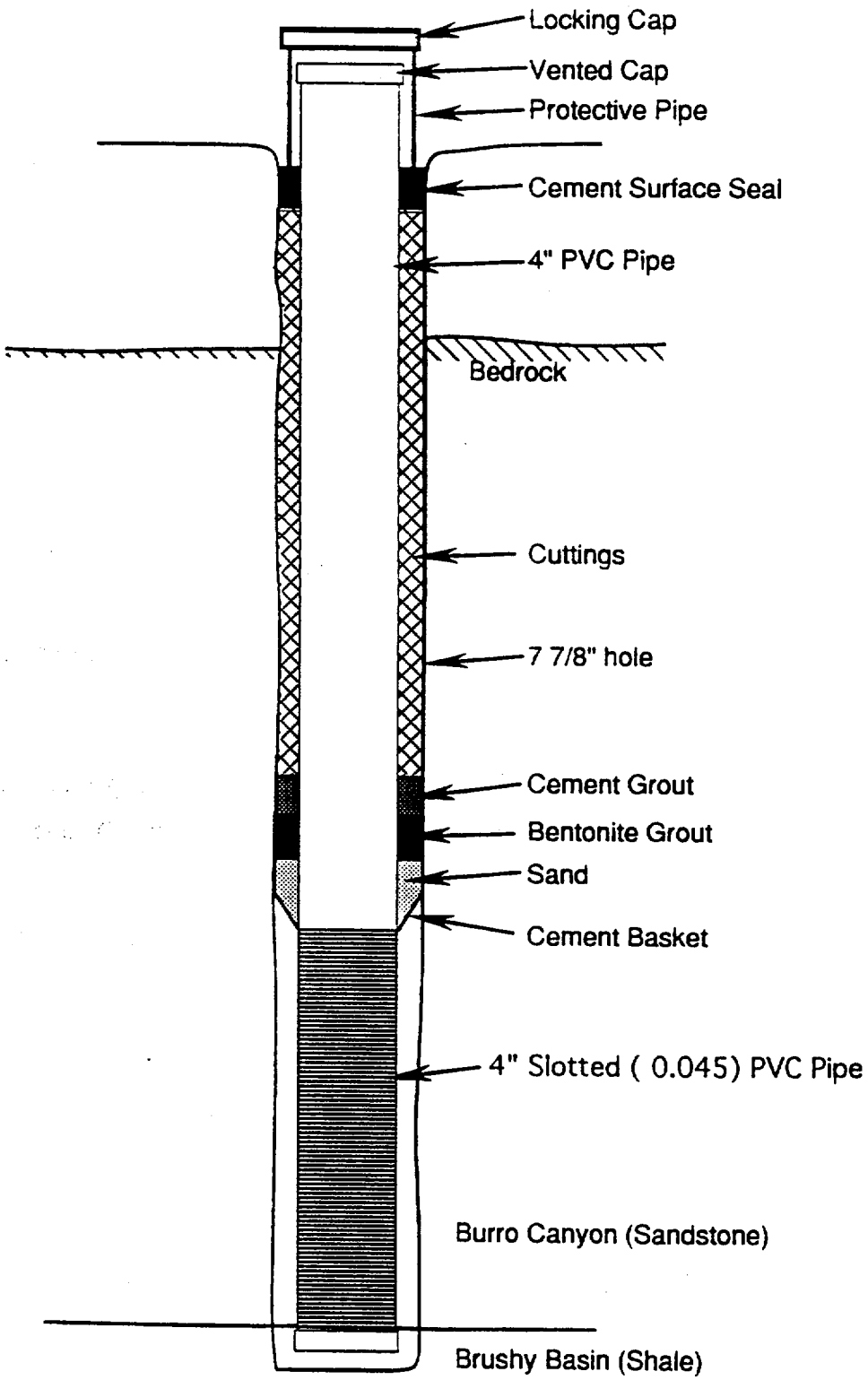
Project: White Mesa	Surface Elev. 5650	T. D. = 149	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: 150	Geologist: F. A. Peel	



*If w. well was topped before the well recharged



Schematic Of Well Completion - Monitor Wells WMMW-16 Through WMMW-19



Schematic Of Well Completion - Monitor Wells WMMW-1 Through WMMW-5 and WMMW-11 through WMMW-13

NOTICE OF INTENTION TO DRILL
(Start Card)

FILL THIS CARD OUT COMPLETELY

On or about 11/23/92, I will

DRILL NEW WELL ☑ REPLACE OLD WELL ☐ CLEAN/REPAIR ☐ DEEPEN ☐ PLUG ☐

8 Inch Well for UMETCO Minerals Corp
(Water User's Name)

PO Box 1029 Grand Junction CO 81502
(Water User's Address)

Under State Engineer's Authorization, RE: 92-09-03MW

Well Location Approx. *S 2100 ft. *W 950 ft. from NE Cor.,

of Sec. 32 Township 37 *S, Range 22 *E, SLM or USM.

#646 Andy R Smith
Well Driller No. Well Driller's Signature

*Strike out words not applicable.

NOTICE OF INTENTION TO DRILL
(Start Card)

FILL THIS CARD OUT COMPLETELY

On or about 11/23/92, I will

DRILL NEW WELL ☒ REPLACE OLD WELL ☐ CLEAN/REPAIR ☐ DEEPEN ☐ PLUG ☐

8 Inch Well for UMETCO Minerals Corp
(Water User's Name)

PO Box 1029 Grand Junction CO 81502
(Water User's Address)

Under State Engineer's Authorization, RE: 92-09-03MW

Well Location *N S 1610 ft. *E 2150 ft. from SW Cor.,

of Sec. 33 Township 37 *S, Range 22 *E, SLM or USM.

646 Andy R Smith
Well Driller No. Well Driller's Signature

*Strike out words not applicable.

Note: An accurate survey of the wells will be done when completed

NOTICE OF INTENTION TO DRILL
(Start Card)

FILL THIS CARD OUT COMPLETELY

On or about 11/23/92, I will

DRILL NEW WELL ☑ REPLACE OLD WELL ☐ CLEAN/REPAIR ☐ DEEPEN ☐ PLUG ☐

8 Inch Well for UMETCO Minerals Corp
(Water User's Name)

PO Box 1029 Grand Junction CO 81502
(Water User's Address)

Under State Engineer's Authorization, RE: 92-09-03 MW

Well Location *S 1660 ft. *W 1660 ft. from NE Cor.,

of Sec. 28 Township 37 *S, Range 22 *E, SLM or USM.

646 Andy R Smith
Well Driller No. Well Driller's Signature

*Strike out words not applicable.

NOTICE OF INTENTION TO DRILL
(Start Card)

FILL THIS CARD OUT COMPLETELY

On or about 11/23/92, I will

DRILL NEW WELL ☑ REPLACE OLD WELL ☐ CLEAN/REPAIR ☐ DEEPEN ☐ PLUG ☐

8 Inch Well for UMETCO Minerals Corp
(Water User's Name)

PO Box 1029 Grand Junction CO 81502
(Water User's Address)

Under State Engineer's Authorization, RE: 92-09-03MW

Well Location *S 2340 ft. *W 390 ft. from NE Cor.,

of Sec. 28 Township 37 *S, Range 22 *E, SLM or USM.

646 Andy R Smith
Well Driller No. Well Driller's Signature

*Strike out words not applicable.

APPENDIX B

Geophysical Logs

of

Monitor Wells

GEOPHYSICAL SURVEYS

Each hole was logged with the gamma (natural)/neutron geophysical probe. For the new wells, these geophysical logs have been incorporated with the lithological log (see Appendix A). Geophysical logs of previously installed wells are shown on the following pages.

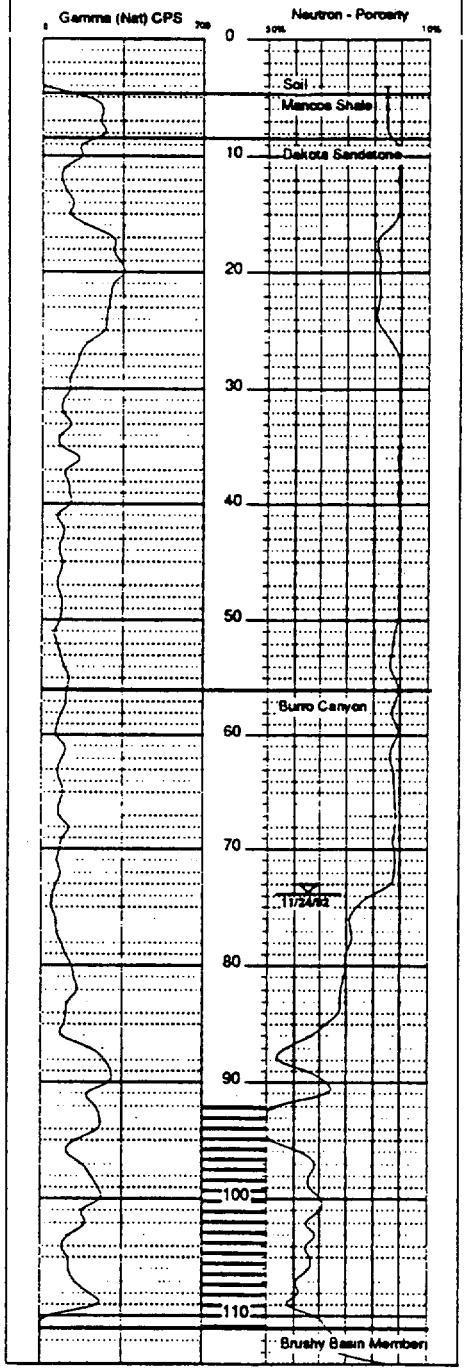
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/24/92

Gamma (Nat) - Neutron Porosity

Gd. Bev. 5642.2
T.D. 114

WMMW-1



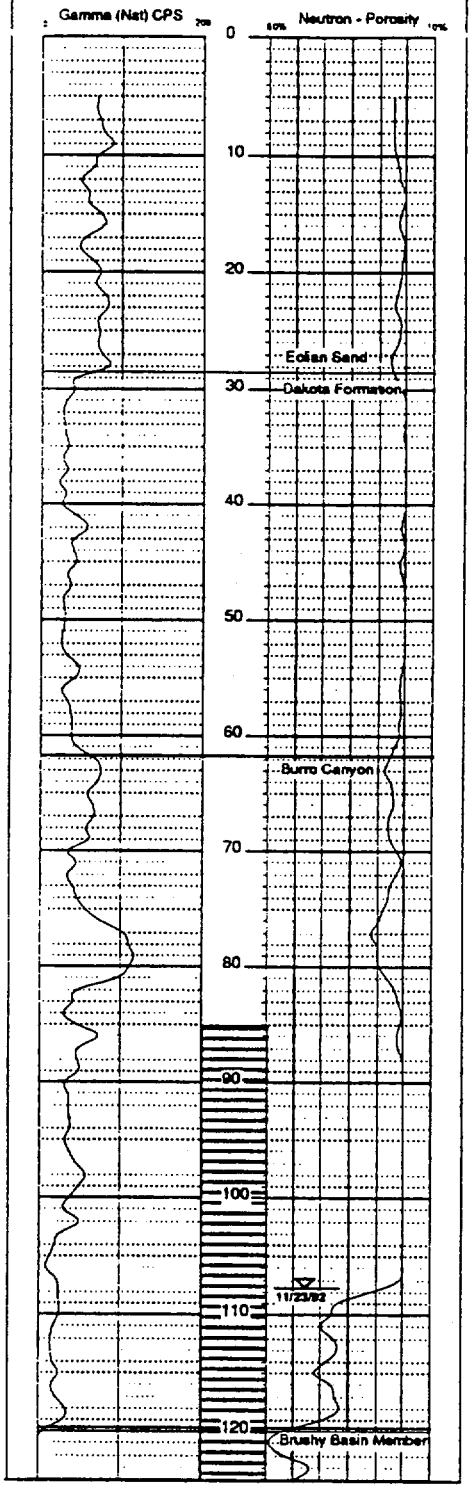
Umetco Minerals Corporation

Location: Montrose County Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5611.8
T.D. 124

WMMW-2



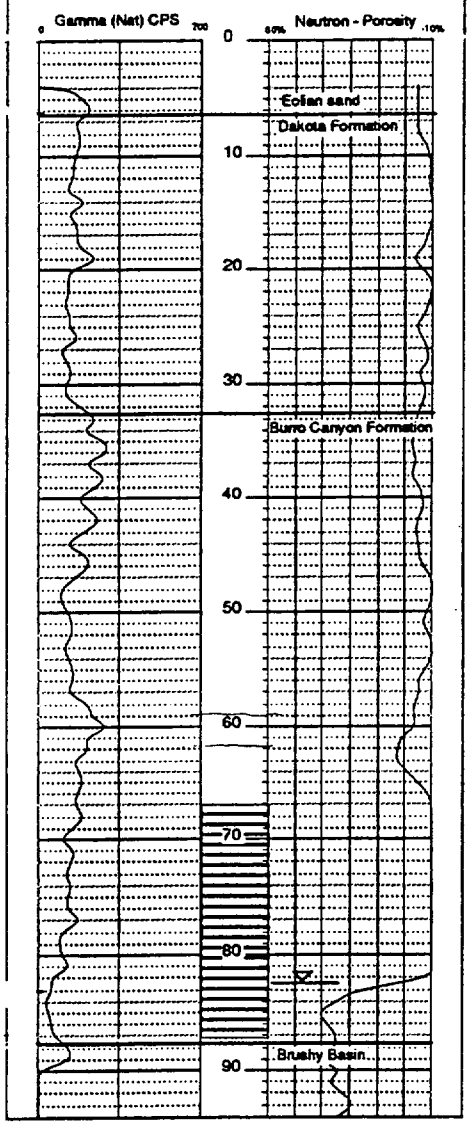
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/24/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5553.3
T.D. 96

WMMW-3



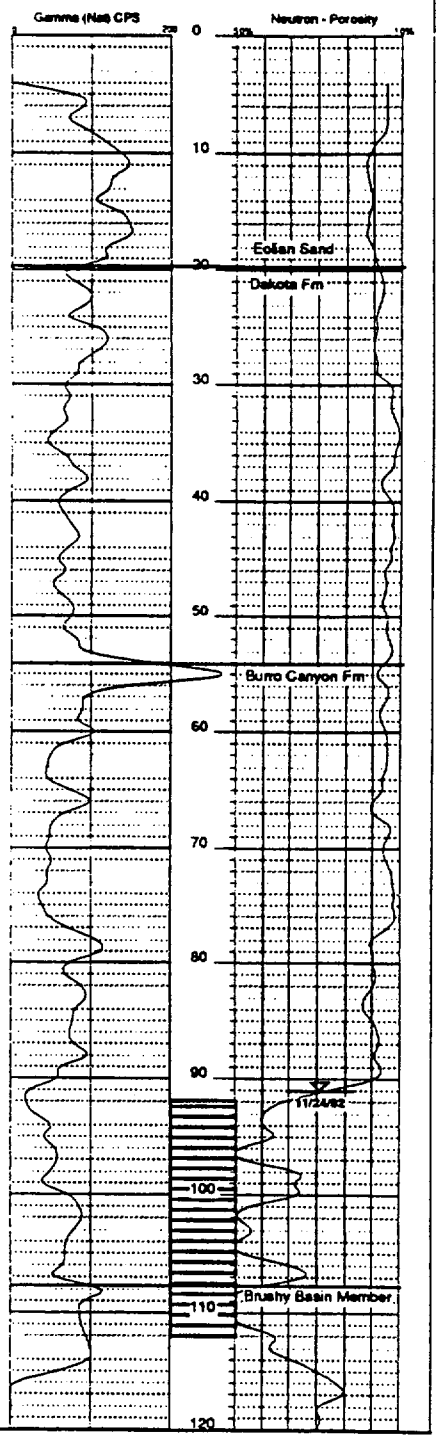
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/24/82

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5421
T.D. 120

WMMW-4



Umetco Minerals Corporation

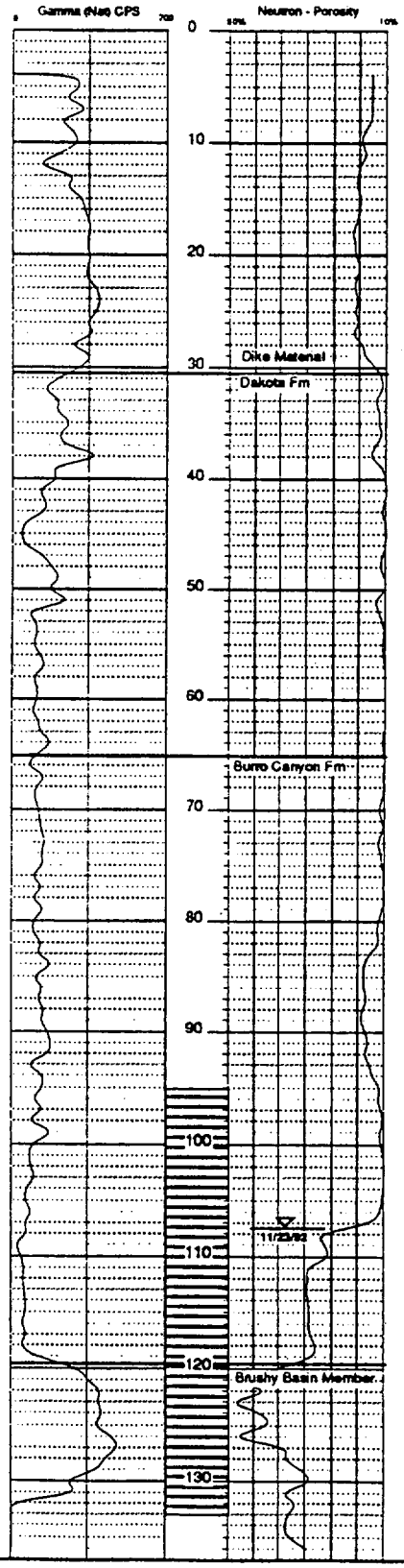
Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5608.9

T.D. 138

WMMW-5



Umetco Minerals Corporation

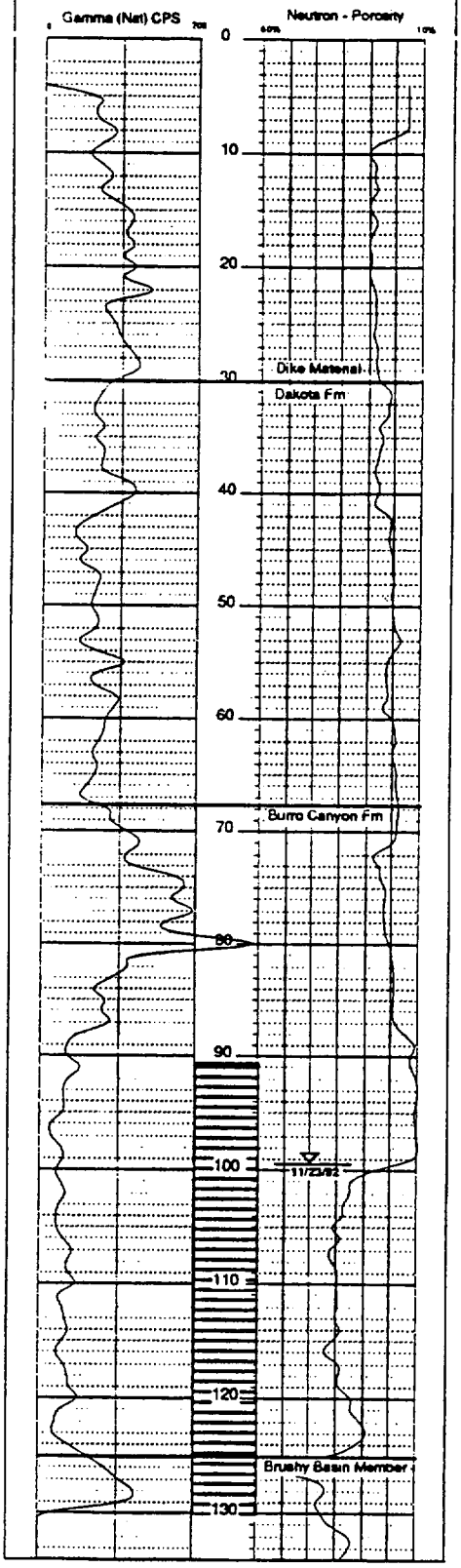
Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5608.6

T.D. 134

WMMW-11



Umetco Minerals Corporation

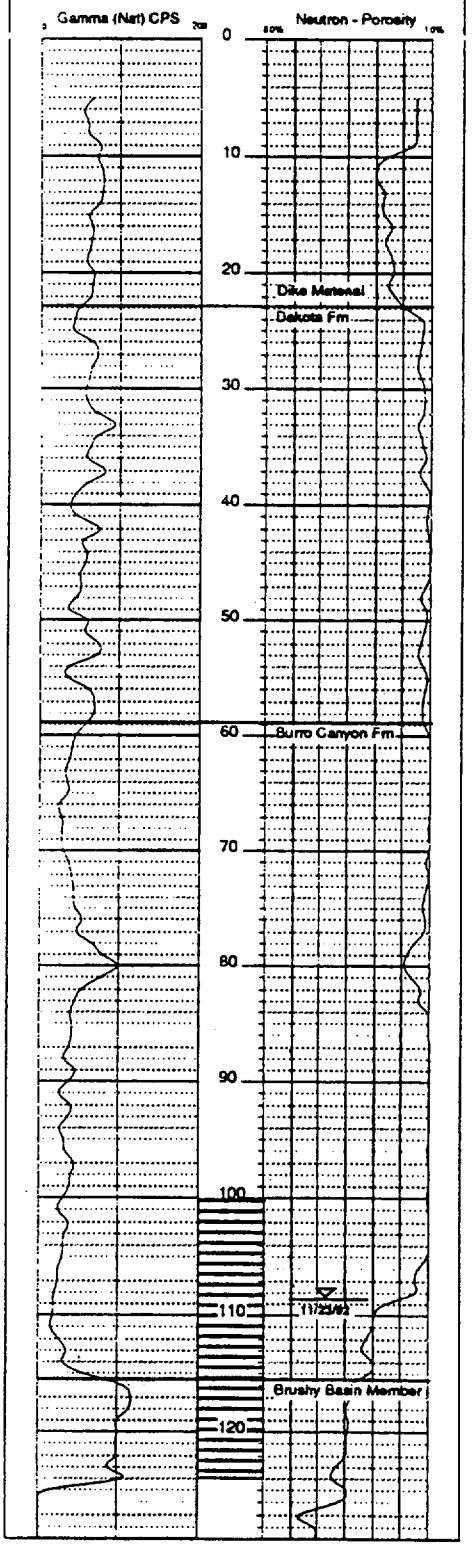
Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5608.5

T.D. 129

WMMW-12



Umetco Minerals Corporation

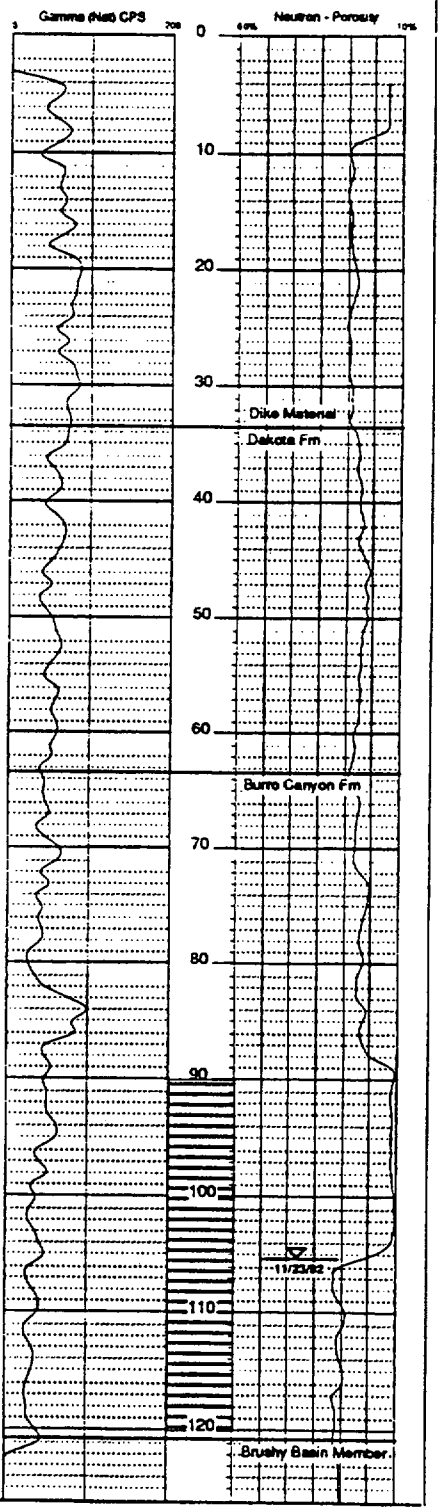
Location: San Juan County, Utah Date: 11/23/82

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5596

T.D. 127

WMMW-14



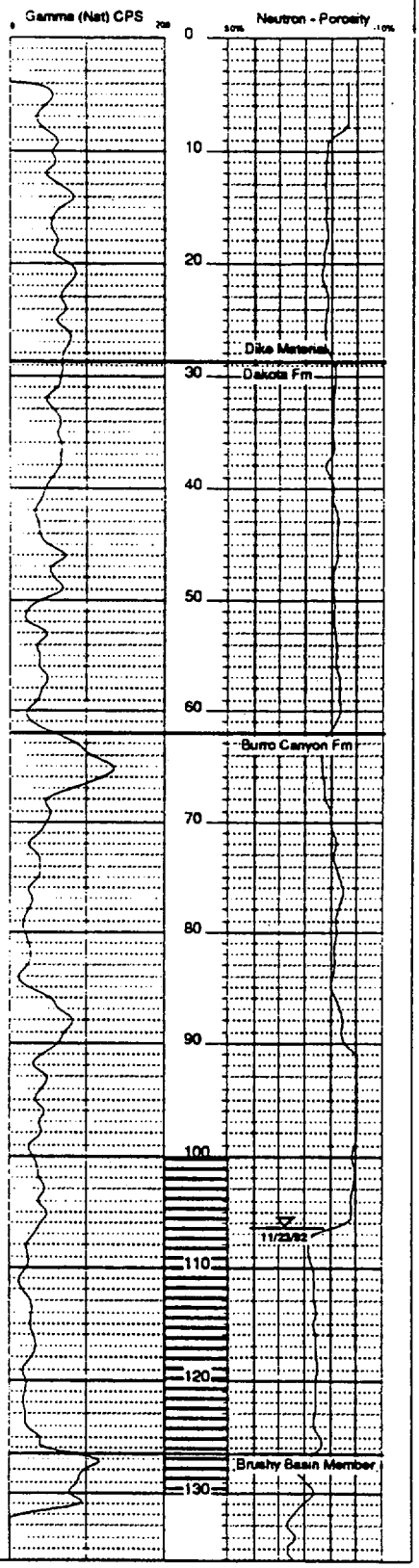
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

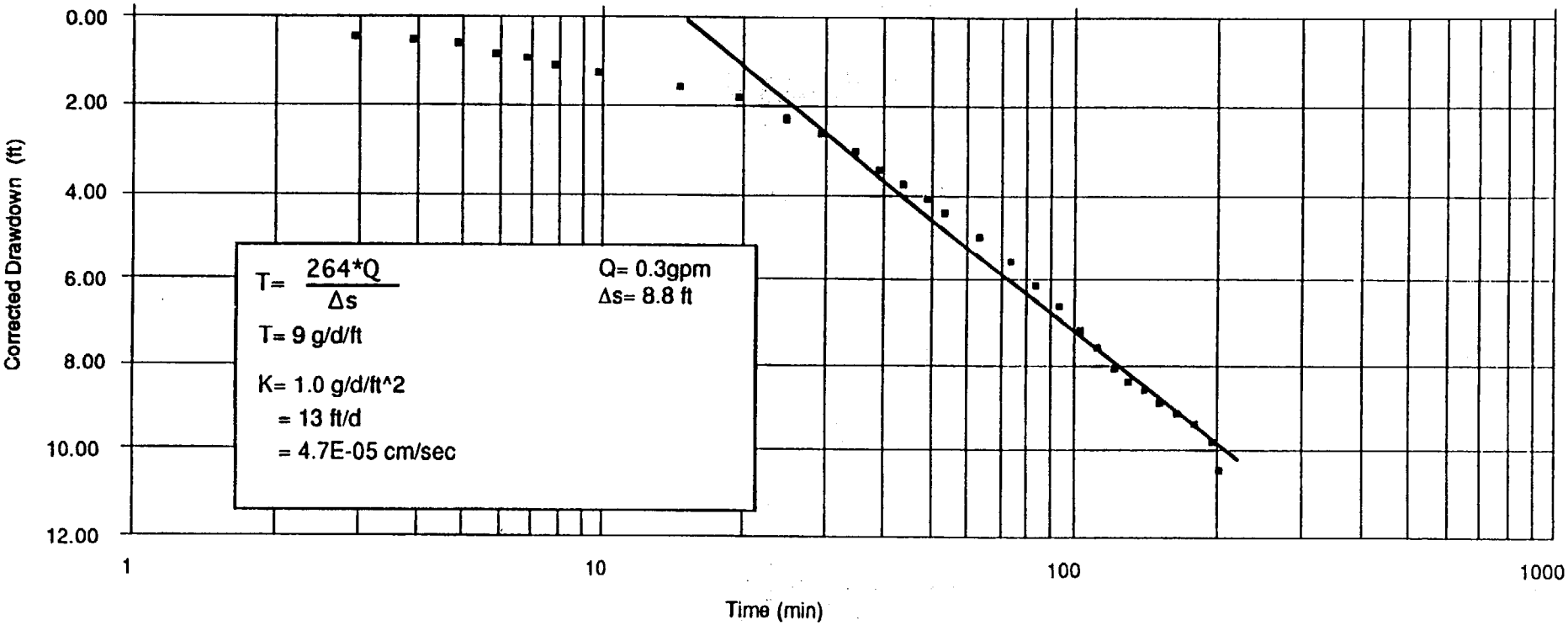
Gd. Elev. 5596.8
T.D. 136

WMMW-15



APPENDIX C

Aquifer Tests

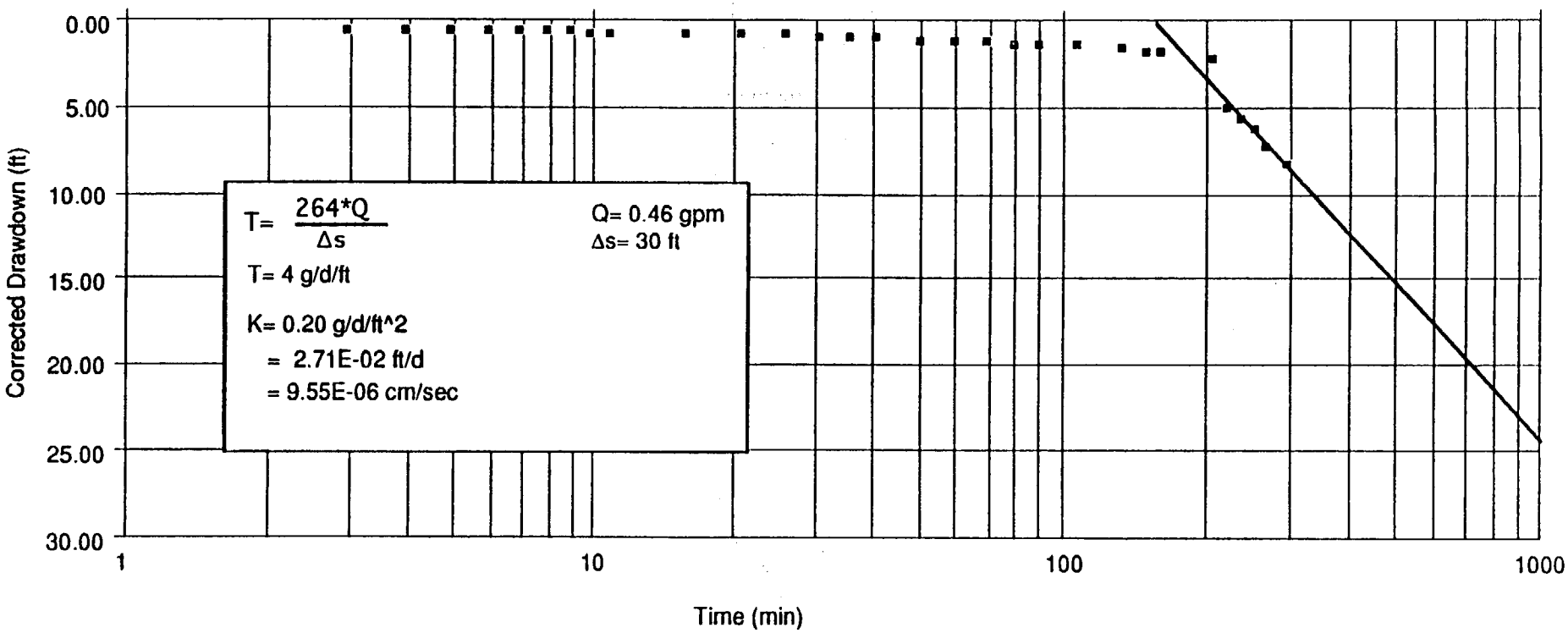


WMMW-2 Semi-Log Plot Of Time vs Drawdown (Corrected For Dewatering)

Aquifer Test Data For WMMW-2

Facility	Whit Mesa Mill
Monitor Well	WMMW-2
Date Pump	11/19/92

	Time (min)	Depth to Water(ft)	Drawdown(ft)	Drawdown Corrected(ft)
Pump Started	0.1	110.03	0	
	1	110.24	0.21	0.21
	3	110.57	0.54	0.53
	4	110.63	0.6	0.59
	5	110.79	0.76	0.75
	6	111	0.97	0.95
	7	111.11	1.08	1.05
	8	111.22	1.19	1.16
	10	111.39	1.36	1.32
	15	111.79	1.76	1.69
	20	112.08	2.05	1.96
	25	112.63	2.6	2.45
	30	113	2.97	2.78
	35	113.45	3.42	3.17
	40	113.89	3.86	3.54
	45	114.27	4.24	3.85
	50	114.68	4.65	4.18
	55	115.15	5.12	4.55
	65	115.87	5.84	5.10
	75	116.68	6.65	5.69
	85	117.45	7.42	6.22
	95	118.23	8.2	6.74
	105	119.05	9.02	7.25
	115	119.83	9.8	7.71
	125	120.62	10.59	8.15
	135	121.3	11.27	8.51
	145	121.8	11.77	8.76
	155	122.27	12.24	8.98
	170	122.85	12.82	9.25
	185	123.47	13.44	9.51
	200	124.47	14.44	9.91
Well out of Water	206	126.35	16.32	10.53
	208	125.9	15.87	
	209	125.77	15.74	
	210	125.69	15.66	
	211	125.6	15.57	
	212	125.56	15.53	
	213	125.54	15.51	
	214	125.53	15.5	
	215	125.49	15.46	
	225	125.37	15.34	
	235	125.3	15.27	
	245	125.25	15.22	
	255	125.18	15.15	
	265	125.11	15.08	
	275	125.07	15.04	
	290	125.09	15.06	
	305	125.01	14.98	
	375	124.77	14.74	
	435	124.49	14.46	

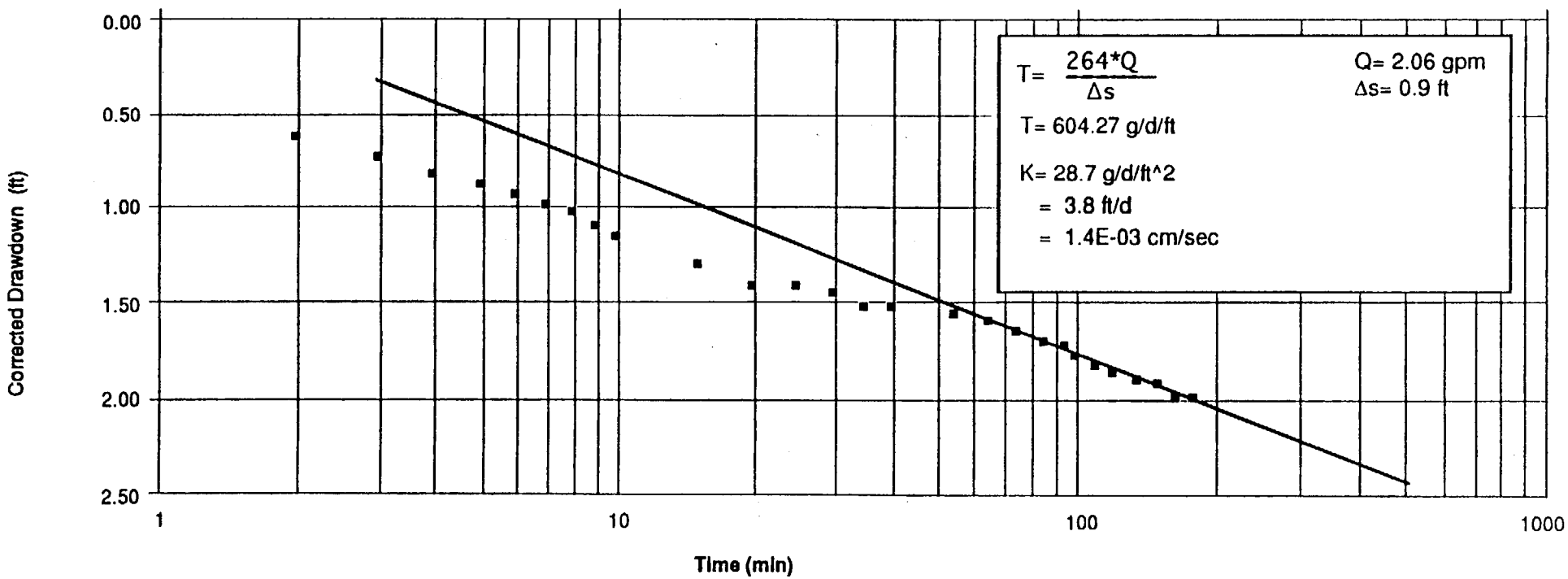


WMMW-4 Semi-Log Plot Of Time vs Drawdown (Corrected For Dewatering)

Aquifer Test Data For WMMW-4

Facility Whit Mesa Mill
Monitor Well WMMW-4
Date Pump 11/17/92

	Time (min)	Depth to Water(ft)	Drawdown(ft)	Drawdown Corrected(ft)
Pump Started	0.1	92.41	0	
	1	92.69	0.28	0.28
	2	92.88	0.47	0.47
	3	93.03	0.62	0.61
	4	93.03	0.62	0.61
	5	93.07	0.66	0.65
	6	93.05	0.64	0.63
	7	93.02	0.61	0.60
	8	93.06	0.65	0.64
	9	93.09	0.68	0.67
	10	93.11	0.7	0.69
	11	93.15	0.74	0.73
	16	93.21	0.8	0.79
	21	93.28	0.87	0.86
	26	93.38	0.97	0.95
	31	93.45	1.04	1.02
	36	93.49	1.08	1.06
	41	93.53	1.12	1.10
	51	93.67	1.26	1.23
	61	93.66	1.25	1.22
	71	93.73	1.32	1.29
	81	93.85	1.44	1.40
	91	93.9	1.49	1.45
	109	94.1	1.69	1.64
	137	94.17	1.76	1.70
	152	94.26	1.85	1.79
	165	94.62	2.21	2.12
	212	97.98	5.57	5.02
	227	98.84	6.43	5.69
	242	99.69	7.28	6.33
	257	101.03	8.62	7.29
	272	102.35	9.94	8.18
	302	104.11	11.7	9.26
	332	105.45	13.04	10.00
Well out of Water	333	105.49	13.08	10.02

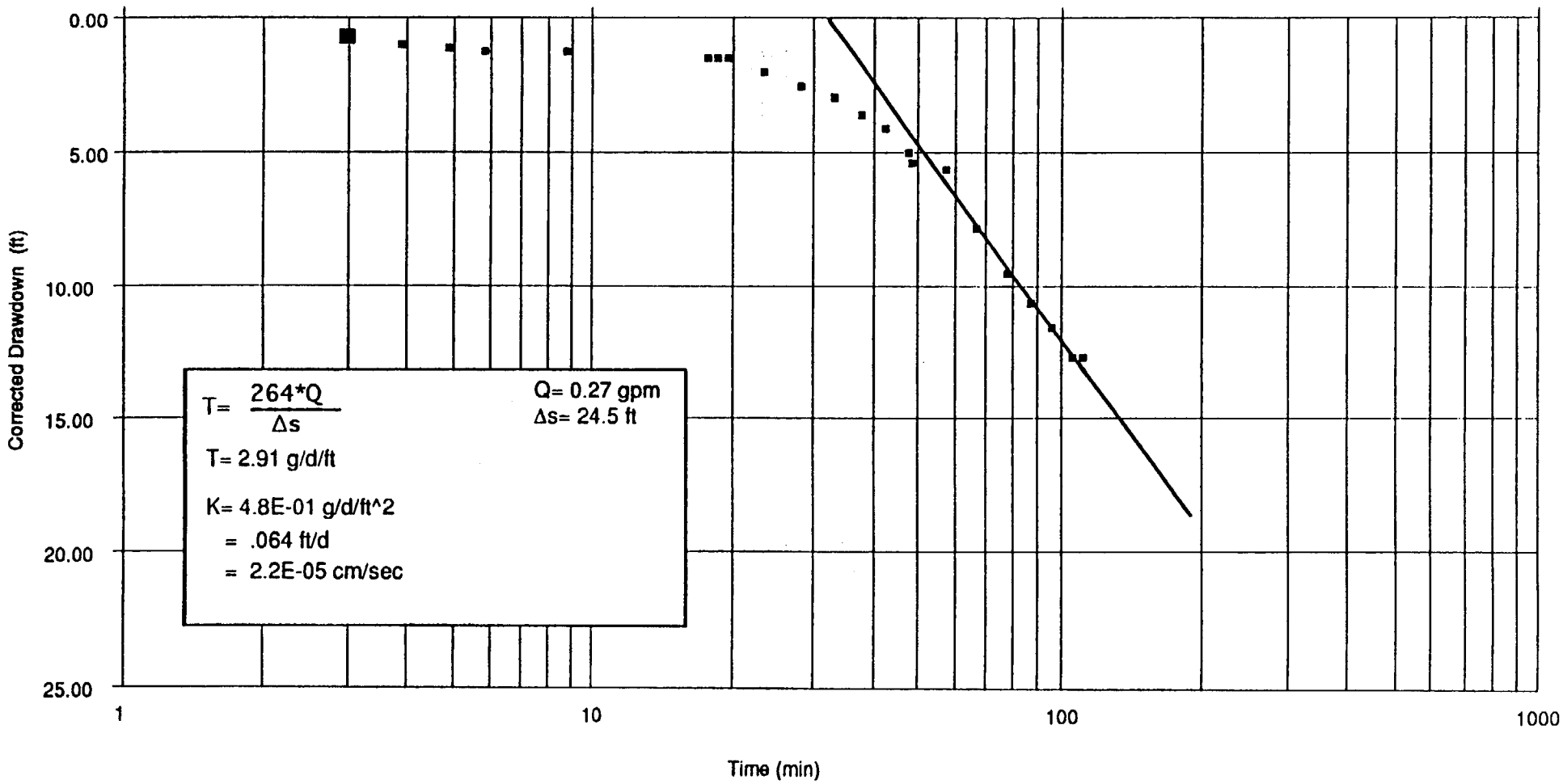


WMMW-11 Semi-Log Plot Of Time vs Drawdown (Corrected For Dewatering)

Aquifer Test Data For WMMW-11

Facility Whit Mesa Mill
Monitor Well WMMW-11
Date Pump 11/12/92

	Time (min)	Depth to Water(ft)	Drawdown(ft)	Drawdown Corrected(ft)
Pump Started	0.1	102.27	0	
	1	102.71	0.44	0.44
	2	102.92	0.65	0.64
	3	103.02	0.75	0.74
	4	103.12	0.85	0.84
	5	103.18	0.91	0.90
	6	103.24	0.97	0.95
	7	103.29	1.02	1.00
	8	103.33	1.06	1.04
	9	103.4	1.13	1.11
	10	103.47	1.2	1.17
	15	103.61	1.34	1.31
	20	103.72	1.45	1.41
	25	103.72	1.45	1.41
	30	103.76	1.49	1.45
	35	103.85	1.58	1.54
	40	103.85	1.58	1.54
	55	103.88	1.61	1.56
	65	103.93	1.66	1.61
	75	103.98	1.71	1.66
	85	104.03	1.76	1.70
	95	104.05	1.78	1.72
	100	104.12	1.85	1.79
	110	104.18	1.91	1.84
	120	104.22	1.95	1.88
	135	104.25	1.98	1.91
	150	104.27	2	1.93
	165	104.35	2.08	2.00
	180	104.35	2.08	2.00
Pump off	200	104.38	2.11	2.03
	205	104.38	2.11	2.03
	206	104.03	0.35	
	207	103.8	0.58	
	208	103.66	0.72	
	209	103.58	0.8	
	210	103.5	0.88	
	211	103.44	0.94	
	212	103.41	0.97	
	213	103.33	1.05	
	214	103.35	1.03	
	215	103.34	1.04	
	220	103.18	1.2	
	225	103.09	1.29	
	235	103.03	1.35	
	250	102.92	1.46	
	270	102.88	1.5	
	290	102.78	1.6	
	310	102.78	1.6	

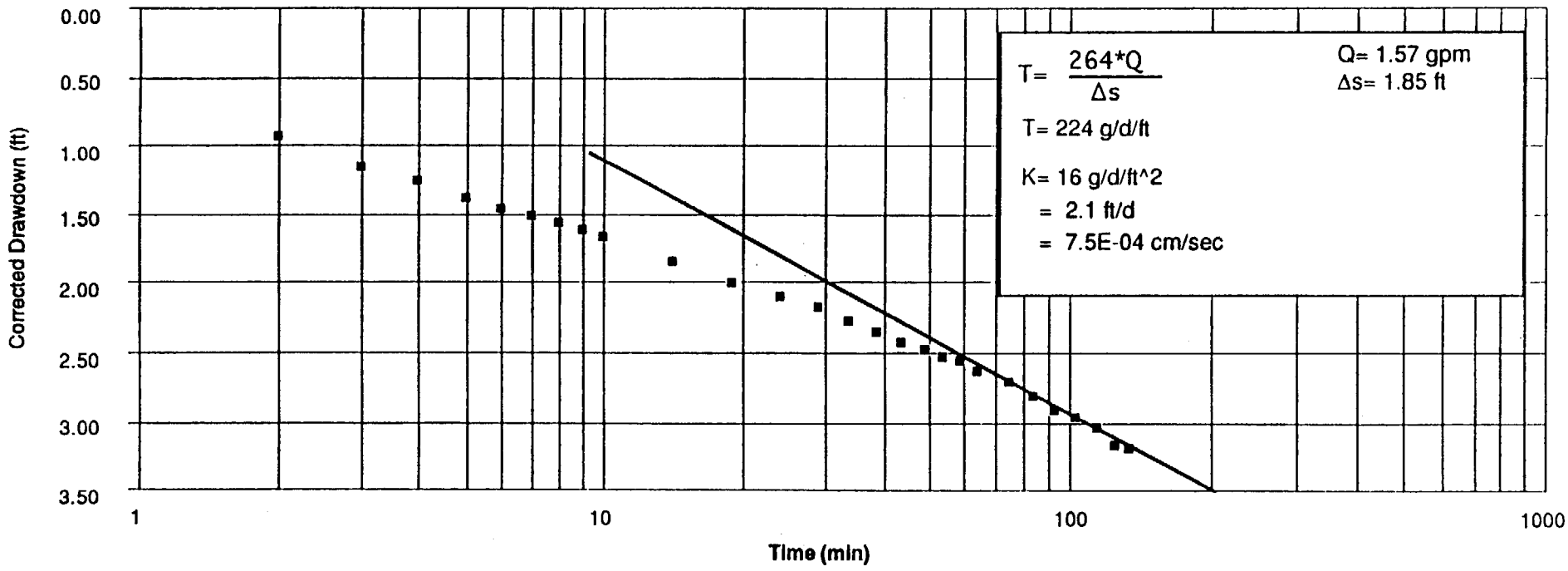


WMMW-12 Semi-Log Plot Of Time vs Drawdown (Corrected For Dewatering)

Aquifer Test Data For WMMW-12

Facility	Whit Mesa Mill
Monitor Well	WMMW-12
Date Pump	11/19/92

	Time (min)	Depth to Water(ft)	Drawdown(ft)	Drawdown Corrected(ft)
Pump Started	0.1	109.45	0	
	2	110	0.55	0.54
	3	110.24	0.79	0.78
	4	110.47	1.02	1.00
	5	110.63	1.18	1.16
	6	110.68	1.23	1.20
	9	110.79	1.34	1.31
	18	110.95	1.5	1.46
	19	111	1.55	1.51
	20	111.07	1.62	1.57
	24	111.61	2.16	2.08
	29	112.08	2.63	2.51
	34	112.6	3.15	2.97
	39	113.3	3.85	3.59
	44	113.83	4.38	4.04
	49	114.93	5.48	4.94
	50	115.52	6.07	5.41
	59	115.84	6.39	5.66
	69	118.77	9.32	7.77
	79	121.47	12.02	9.44
	89	123.64	14.19	10.59
	99	125.66	16.21	11.52
Well dry	109	128.92	19.47	12.70
	114	128.91	19.46	12.70
	115	128.83	19.38	12.67
	117	128.65	19.2	12.62
	118	128.49	19.04	12.57
	119	128.48	19.03	12.56
	120	128.44	18.99	12.55
	121	128.37	18.92	12.53
	122	128.35	18.9	12.52
	123	128.34	18.89	12.52
	124	128.29	18.84	12.50
	129	128.15	18.7	12.46
	139	128	18.55	12.41
	149	127.8	18.35	12.34
	164	127.97	18.52	12.40
	179	127.75	18.3	12.32
	209	127.35	17.9	12.18
	339	125.84	16.39	11.59
	399	125.18	15.73	11.31
	464	124.48	15.03	11.00
	1414	116.12	6.67	5.88

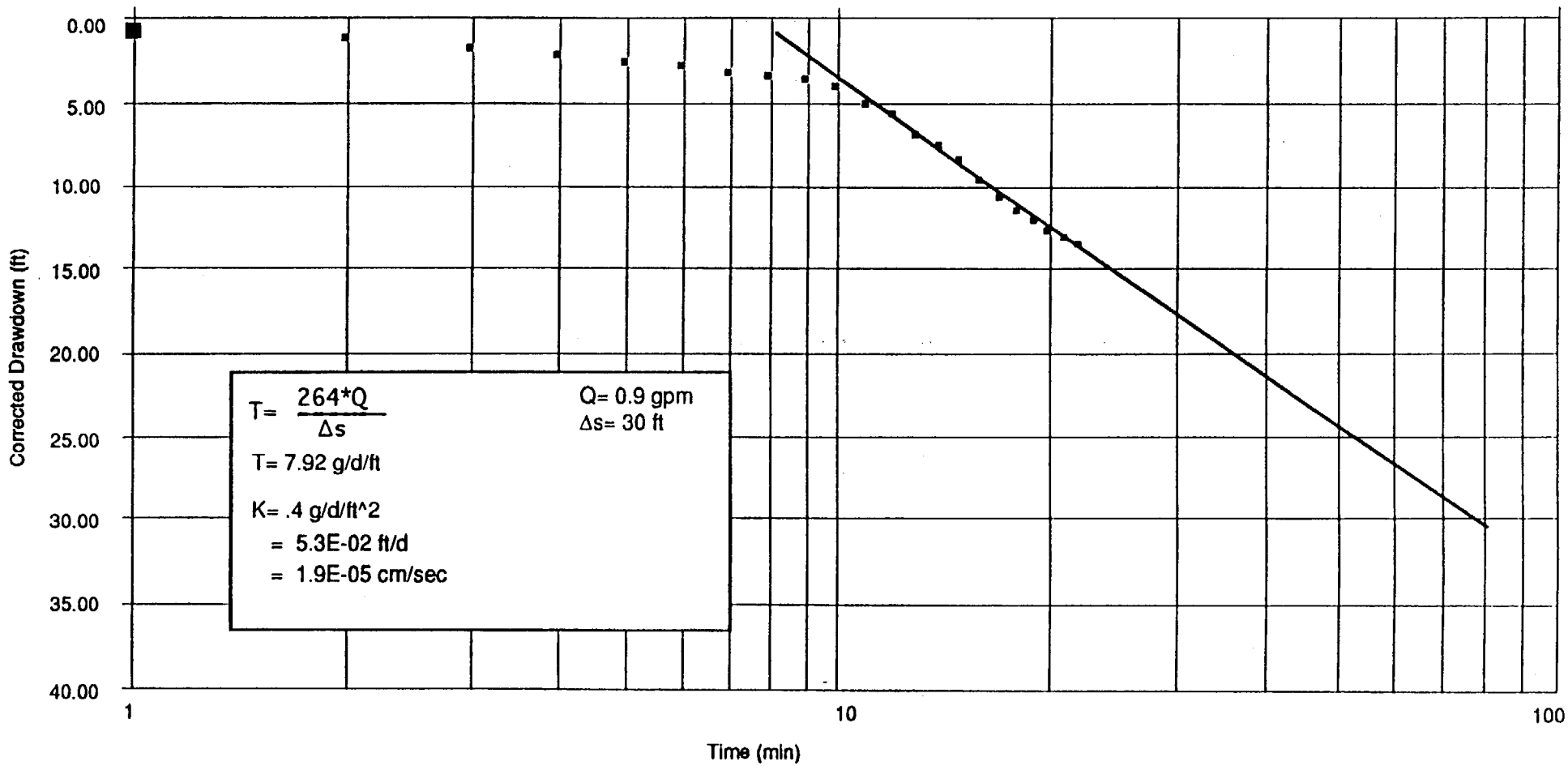


WMMW-14 Semi-Log Plot Of Time vs Drawdown (Corrected For Dewatering)

Aquifer Test Data For WMMW-14

Facility	Whit Mesa Mill
Monitor Well	WMMW-14
Date Pump	11/13/92

	Time (min)	Depth to Water (ft)	Drawdown (ft)	Drawdown Corrected (ft)
Pump Started	0.1	105.43	0	
	1	106.21	0.78	0.77
	2	106.4	0.97	0.95
	3	106.62	1.19	1.16
	4	106.74	1.31	1.28
	5	106.88	1.45	1.41
	6	106.94	1.51	1.47
	7	107.01	1.58	1.54
	8	107.07	1.64	1.59
	9	107.12	1.69	1.64
	10	107.17	1.74	1.69
	14	107.36	1.93	1.86
	19	107.51	2.08	2.00
	24	107.64	2.21	2.12
	29	107.72	2.29	2.20
	34	107.83	2.4	2.30
	39	107.91	2.48	2.37
	44	107.99	2.56	2.44
	49	108.04	2.61	2.49
	54	108.11	2.68	2.55
	59	108.13	2.7	2.57
	64	108.22	2.79	2.65
	74	108.32	2.89	2.74
	84	108.41	2.98	2.82
	94	108.53	3.1	2.93
	104	108.6	3.17	2.99
	114	108.69	3.26	3.07
	124	108.81	3.38	3.18
	134	108.85	3.42	3.21
	149	108.99	3.56	3.33
	164	109.14	3.71	3.46
	179	109.18	3.75	3.50
	194	109.28	3.85	3.59
	211	109.39	3.96	3.68
Pump Shut Down	224	109.53	4.1	3.80
	226	109.48	4.05	
	227	108.86	3.43	
	228	108.56	3.13	
	229	108.32	2.89	
	230	108.2	2.77	
	231	108.08	2.65	
	232	108	2.57	
	233	107.91	2.48	
	234	107.84	2.41	
	239	107.67	2.24	
	244	107.5	2.07	
	254	107.33	1.9	
	269	107.15	1.72	
	284	107.02	1.59	
	299	106.96	1.53	
	314	106.92	1.49	
	329	106.86	1.43	

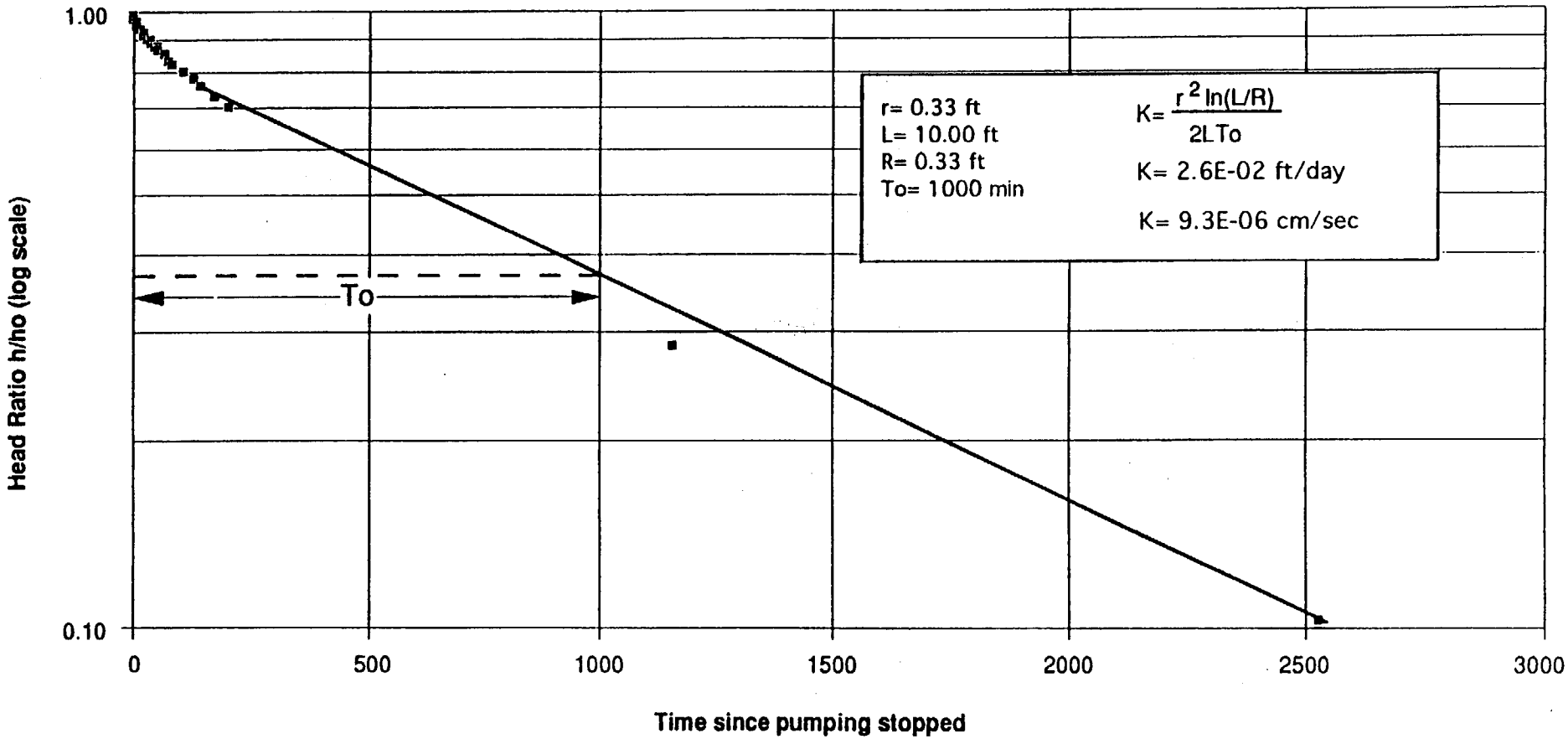


WMMW-15 Semi-Log Plot Of Time vs Drawdown (Corrected For Dewatering)

Aquifer Test Data For WMMW-15

Facility	Whit Mesa Mill
Monitor Well	WMMW-15
Date Pump	11/13/92

	Time (min)	Depth to Water(ft)	Drawdown(ft)	Drawdown Corrected(ft)
Pump Started	0.1	107.25	0	
	1	108	0.75	0.74
	2	108.53	1.28	1.25
	3	109.02	1.77	1.71
	4	109.53	2.28	2.19
	5	110	2.75	2.61
	6	110.35	3.1	2.93
	7	110.67	3.42	3.21
	8	111	3.75	3.50
	9	111.25	4	3.71
	10	111.55	4.3	3.97
	15	112.85	5.6	5.04
	20	113.8	6.55	5.78
	25	115.23	7.98	6.84
	30	116.37	9.12	7.63
	35	117.46	10.21	8.35
	45	119.48	12.23	9.56
	55	121.43	14.18	10.59
	65	123.28	16.03	11.44
	75	124.94	17.69	12.10
	85	126.45	19.2	12.62
	95	128.44	21.19	13.17
Out of water	108	130.2	22.95	13.54
	110	129.79	22.54	13.47
	111	129.5	22.25	13.41
	112	129.19	21.94	13.34
	113	128.91	21.66	13.28
	114	128.66	21.41	13.22
	115	128.4	21.15	13.16
	120	127.06	19.81	12.80
	125	125.66	18.41	12.36
	130	124.19	16.94	11.82
	135	123.06	15.81	11.35
	140	121.99	14.74	10.86
	146	120.21	12.96	9.96
	150	118.15	10.9	8.78
	160	116.1	8.85	7.45
	170	114.35	7.1	6.20
	180	112.83	5.58	5.02
	195	111.31	4.06	3.77
	210	110.18	2.93	2.78
	225	109.9	2.65	2.52
	320	108.41	1.16	1.14
	420	107.94	0.69	0.68

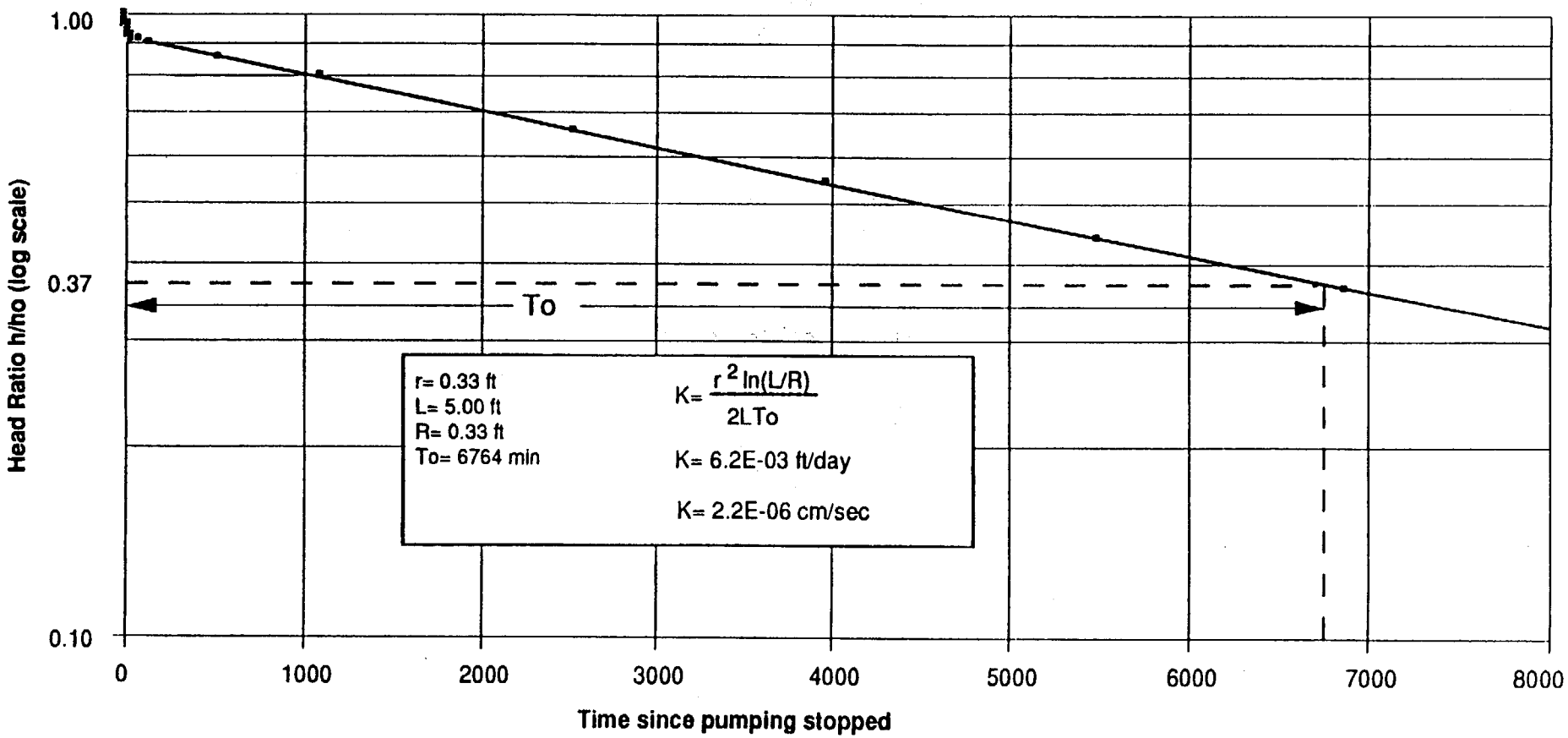


WMMW-1 Semi log Plot of Head Ratio vs Time

Aquifer Test Data For WMMW-1

Facility	Whit Mesa Mill
Monitor Well	WMMW-1
Date Pump	11/19/92

Time(min)	Depth to Water(ft)	Drawdown(ft)	t/t'	h/ho
0.1	75.67	0		
Well out of Water				
3	89.1	13.43	0.03	1.00
4	89.04	13.37	1.00	1.00
5	88.88	13.21	1.33	0.98
6	88.74	13.07	1.67	0.97
7	88.67	13	2.00	0.97
8	88.64	12.97	2.33	0.97
9	88.63	12.96	2.67	0.97
10	88.6	12.93	3.00	0.96
11	88.59	12.92	3.33	0.96
12	88.55	12.88	3.67	0.96
17	88.38	12.71	4.00	0.95
22	88.23	12.56	5.67	0.94
27	88.11	12.44	7.33	0.93
32	88.01	12.34	9.00	0.92
37	87.89	12.22	10.67	0.91
42	87.75	12.08	12.33	0.90
47	87.67	12	14.00	0.89
52	87.58	11.91	15.67	0.89
57	87.47	11.8	17.33	0.88
67	87.27	11.6	19.00	0.86
77	87.07	11.4	22.33	0.85
87	86.91	11.24	25.67	0.84
107	86.54	10.87	29.00	0.81
127	86.26	10.59	35.67	0.79
147	86	10.33	42.33	0.77
172	85.58	9.91	49.00	0.74
207	85.17	9.5	57.33	0.71
1152	79.51	3.84	69.00	0.29
2530	77.08	1.41	384.00	0.10

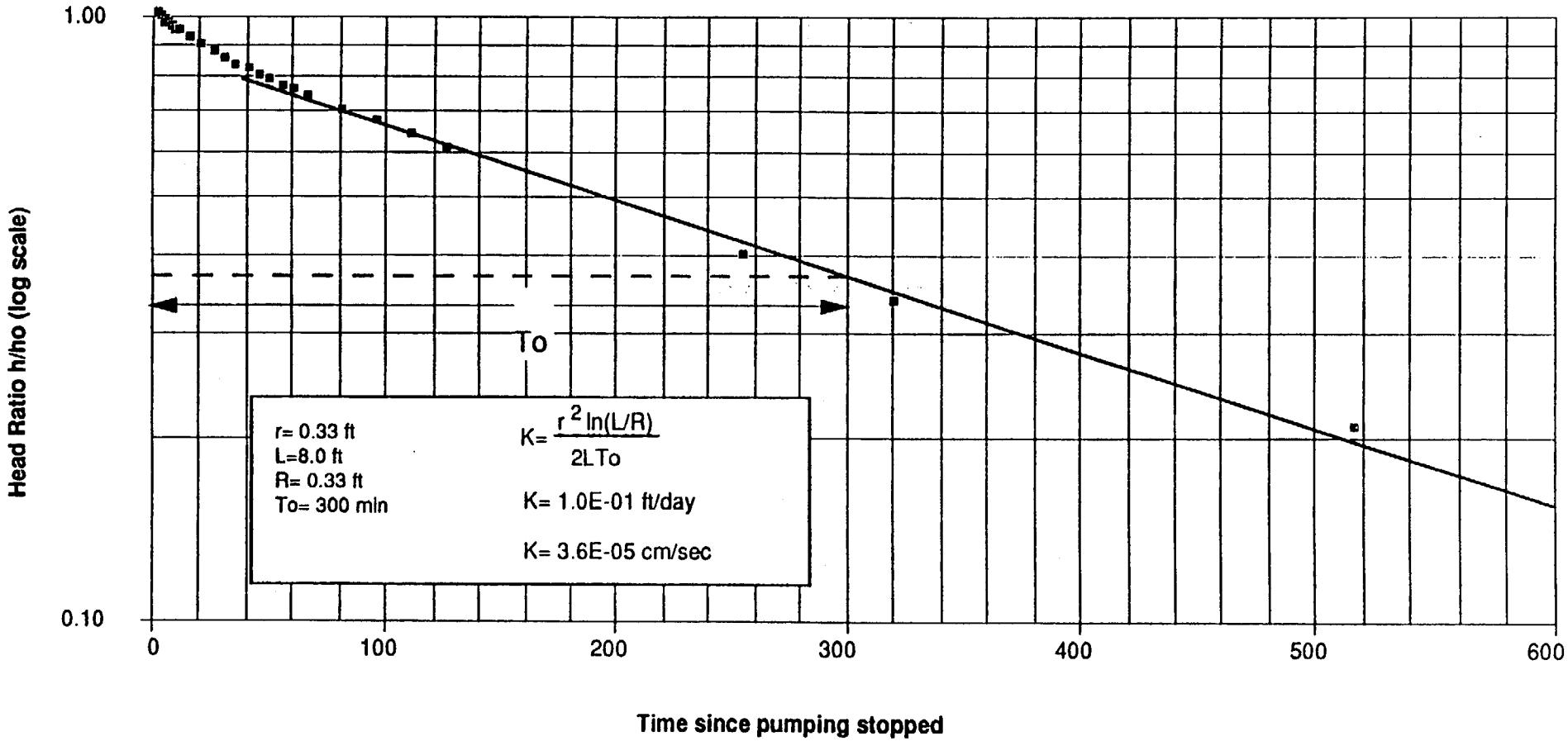


WMMW-3 Semi log Plot of Head Ratio vs Time

Aquifer Test Data For WMMW-3

Facility	Whit Mesa Mill
Monitor Well	WMMW-3
Date Pump	11/16/92

	Time(min)	Depth to Water(ft)	Drawdown(ft)	t/t'	h/ho
	0.1	83.81	0		
Well dry	7	88.99	5.18	0.01	1.00
	8	88.92	5.11	1.00	0.99
	9	88.89	5.08	1.14	0.98
	10	88.86	5.05	1.29	0.97
	11	88.85	5.04	1.43	0.97
	12	88.83	5.02	1.57	0.97
	14	88.8	4.99	1.71	0.96
	19	88.78	4.97	2.00	0.96
	24	88.68	4.87	2.71	0.94
	29	88.61	4.8	3.43	0.93
	34	88.59	4.78	4.14	0.92
	39	88.58	4.77	4.86	0.92
	49	88.57	4.76	5.57	0.92
	74	88.55	4.74	7.00	0.92
	134	88.5	4.69	10.57	0.91
	514	88.24	4.43	19.14	0.86
	1094	87.96	4.15	73.43	0.80
	2534	87.2	3.39	156.29	0.65
	3974	86.64	2.83	362.00	0.55
	5489	86.08	2.27	567.71	0.44
	6884	85.7	1.89	784.14	0.36

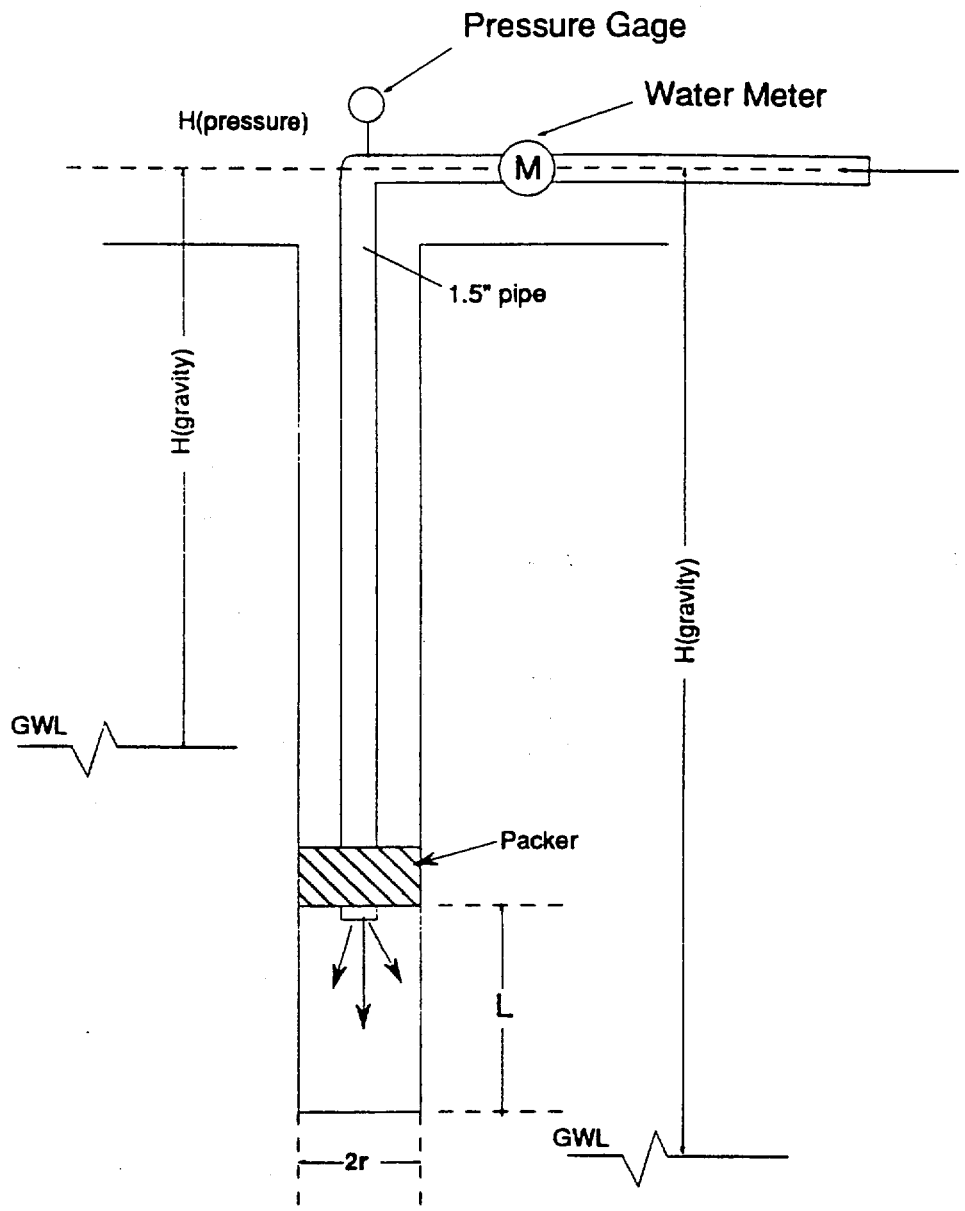


WMMW-5 Semi log Plot of Head Ratio vs Time

Aquifer Test Data For WMMW-5

Facility	Whit Mesa Mill
Monitor Well	WMMW-5
Date Pump	11/17/92

Time(min)	Depth to Water(ft)	Drawdown(ft)	t/t'	h/ho
0.1	108.39	0		
5	113.53	5.14	0.02	1.00
6	113.47	5.08	1.00	0.99
7	113.38	4.99	1.20	0.97
8	113.35	4.96	1.40	0.96
9	113.32	4.93	1.60	0.96
10	113.3	4.91	1.80	0.96
11	113.25	4.86	2.00	0.95
12	113.2	4.81	2.20	0.94
13	113.18	4.79	2.40	0.93
18	113.06	4.67	2.60	0.91
23	112.96	4.57	3.60	0.89
28	112.82	4.43	4.60	0.86
33	112.72	4.33	5.60	0.84
38	112.6	4.21	6.60	0.82
43	112.55	4.16	7.60	0.81
48	112.45	4.06	8.60	0.79
53	112.4	4.01	9.60	0.78
58	112.3	3.91	10.60	0.76
63	112.22	3.83	11.60	0.75
68	112.13	3.74	12.60	0.73
83	111.96	3.57	13.60	0.69
98	111.78	3.39	16.60	0.66
113	111.62	3.23	19.60	0.63
128	111.45	3.06	22.60	0.60
258	110.42	2.03	25.60	0.39
323	110.09	1.7	51.60	0.33
518	109.45	1.06	64.60	0.21



Single-Packer Permeability Test, Equipment Set-Up

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	11/30/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-16

Test #	1	
Depth to Bottom of Borehole	31.5	ft
Depth to Top of Test Section	28.5	ft
Depth to Base of Test Section	31.5	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	9.5	ft
Pressure (static conditions)	12	psi
Pump Rate (static conditions)	6	gal/min

Q= 6 gal/min
L= 3 ft
H= 67.22 ft
r= 0.18 ft

Permeability (k) = **1.3E-02** gal/min/ft^2
9.1E-04 cm/sec

Test #	2	
Depth to Bottom of Borehole	51.5	ft
Depth to Top of Test Section	45.5	ft
Depth to Base of Test Section	51.5	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	7.92	ft
Pressure (static conditions)	120	psi
Pump Rate (static conditions)	2.7	gal/min

Q= 2.7 gal/min
L= 6 ft
H= 333.62 ft
r= 0.18 ft

Permeability (k) = **7.6E-04** gal/min/ft^2
5.1E-05 cm/sec

$$K = \frac{Q}{2\pi \times L \times H} \times \ln\left(\frac{L}{R}\right)$$

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	1/1/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-16

Test #	3	
Depth to Bottom of Borehole	71.5	ft
Depth to Top of Test Section	65.5	ft
Depth to Base of Test Section	71.5	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	8.6	ft
Pressure (static conditions)	65	psi
Pump Rate (static conditions)	2.8	gal/min

Q = 2.8 gal/min
L = 6 ft
H = 227.25 ft
r = 0.18 ft

Permeability (k) = **1.2E-03** gal/min/ft^2
7.8E-05 cm/sec

Test #	4	
Depth to Bottom of Borehole	91.5	ft
Depth to Top of Test Section	85.5	ft
Depth to Base of Test Section	91.5	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	9.75	ft
Pressure (static conditions)	91.5	psi
Pump Rate (static conditions)	1.4	gal/min

Q = 1.4 gal/min
L = 6 ft
H = 309.615 ft
r = 0.18 ft

Permeability (k) = **4.2E-04** gal/min/ft^2
2.9E-05 cm/sec

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	1/1/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-17

Test #	1	
Depth to Bottom of Borehole	50	ft
Depth to Top of Test Section	45	ft
Depth to Base of Test Section	50	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	8.8	ft
Pressure (static conditions)	99	psi
Pump Rate (static conditions)	0.12	gal/min

Q = 0.12 gal/min
L = 5 ft
H = 284.99 ft
r = 0.18 ft

Permeability (k) = **4.5E-05** gal/min/ft^2
3.0E-06 cm/sec

Test #	2	
Depth to Bottom of Borehole	95	ft
Depth to Top of Test Section	90	ft
Depth to Base of Test Section	95	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	89	ft
Height of Press Gage Above G.L.	6.1	ft
Pressure (static conditions)	135	psi
Pump Rate (static conditions)	0.2	gal/min

Q = 0.2 gal/min
L = 5 ft
H = 406.95 ft
r = 0.18 ft

Permeability (k) = **5.2E-05** gal/min/ft^2
3.5E-06 cm/sec

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	1/1/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-17

Test #	3	
Depth to Bottom of Borehole	105	ft
Depth to Top of Test Section	100	ft
Depth to Base of Test Section	105	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	89	ft
Height of Press Gage Above G.L.	10.5	ft
Pressure (static conditions)	300	psi
Pump Rate (static conditions)	0.6	gal/min

Q =	0.6	gal/min
L =	5	ft
H =	792.5	ft
r =	0.18	ft

Permeability (k) =	**8.0E-05**	gal/min/ft^2
	5.5E-06	cm/sec

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	1/3/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-18

Test #	1	
Depth to Bottom of Borehole	32	ft
Depth to Top of Test Section	27	ft
Depth to Base of Test Section	32	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	7.1	ft
Pressure (static conditions)	30	psi
Pump Rate (static conditions)	1.6	gal/min

Q =	1.6	gal/min
L =	5	ft
H =	105.9	ft
r =	0.18	ft

Permeability (k) = **1.6E-03** gal/min/ft^2
1.1E-04 cm/sec

Test #	2	
Depth to Bottom of Borehole	90	ft
Depth to Top of Test Section	85	ft
Depth to Base of Test Section	90	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	6.7	ft
Pressure (static conditions)	40	psi
Pump Rate (static conditions)	0.65	gal/min

Q =	0.65	gal/min
L =	5	ft
H =	186.6	ft
r =	0.18	ft

Permeability (k) = **3.7E-04** gal/min/ft^2
2.5E-05 cm/sec

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	1/3/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-18

Test #	3*	
Depth to Bottom of Borehole	90	ft
Depth to Top of Test Section	85	ft
Depth to Base of Test Section	90	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	ft
Height of Press Gage Above G.L.	6.7	ft
Pressure (static conditions)	80	psi
Pump Rate (static conditions)	1	gal/min

Q = 1 gal/min
L = 5 ft
H = 279 ft
r = 0.18 ft

Permeability (k) = **3.8E-04** gal/min/ft^2
2.6E-05 cm/sec

Test #	4	
Depth to Bottom of Borehole	125	ft
Depth to Top of Test Section	120	ft
Depth to Base of Test Section	125	ft
Diameter of Borehole	4.25	in
Depth to Ground Water	91	
Height of Press Gage Above G.L.	12.1	ft
Pressure (static conditions)	115	psi
Pump Rate (static conditions)	0.231	gal/min

Q = 0.231 gal/min
L = 5 ft
H = 368.75 ft
r = 0.18 ft

Permeability (k) = **6.7E-05** gal/min/ft^2
4.5E-06 cm/sec

* This test covers the same interval that was tested in Test #2. The constant head pressure, however, was changed.

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested

CONSTANT HEAD TESTS

Location	White Mesa Mill, Utah
Date	1/7/92
Geohydrologist	F. A. Peel
Borehole Tested	MW-19

Test #	1	
Depth to Bottom of Borehole	60	
Depth to Top of Test Section	55	
Depth to Base of Test Section	60	
Diameter of Borehole	4.25	in
Depth to Ground Water	NA	
Height of Press Gage Above G.L.	5.4	ft
Pressure (static conditions)	55	psi
Pump Rate (static conditions)	0.22	gal/min

Q = 0.22 gal/min
L = 5 ft
H = 189.95 ft
r = 0.18 ft

Permeability (k) = **1.2E-04** gal/min/ft^2
8.4E-06 cm/sec

Test #	2	
Depth to Bottom of Borehole	100	
Depth to Top of Test Section	95	
Depth to Base of Test Section	100	
Diameter of Borehole	4.25	in
Depth to Ground Water	97	
Height of Press Gage Above G.L.	7.0	ft
Pressure (static conditions)	180	psi
Pump Rate (static conditions)	0.1	gal/min

Q = 0.1 gal/min
L = 5 ft
H = 519.8 ft
r = 0.18 ft

Permeability (k) = **2.0E-05** gal/min/ft^2
1.4E-06 cm/sec

Q = Pump rate under static conditions
L = Length of test section
H = Differential head under static conditions
r = radius of hole tested